임상 현장에서 EIT의 적용 사례

(Cases of EIT Applications in Real-World Practice)

울산대학교 의과대학 서울아산병원

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Disclosure statement

- **There are no conflicts of interest to declare**

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KATRD
INTERNATIONAL CONFERENCE 2024
The 138th Congress of the Korean Academy of Tuberculosis and Respiratory Diseases
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Deputy Editors

Laurent Brochard, M.D.

Laurent Brochard, M.D., is the Interdepartmental Division Director for Critical Care Medicine in the Faculty of Medicine, University of Toronto and the Keenan Chair for Critical Care and Respiratory Medicine. He is Full Professor, Clinician scientist at the Keenan Research Centre, St. Michael's Hospital, in Toronto. He spent most of his previous career in Paris and three years in Geneva. He has been chair of the critical care program committee of the ATS and was editor-in-chief of the journal Intensive Care Medicine from 2001 to 2007. He has published more than 350 papers in peer-reviewed journals, mostly in the field of invasive and noninvasive mechanical ventilation, ARDS, and COPD.

Disclosures

Setting positive end-expiratory pressure: does the 'best compliance' concept really work?

Luca S. Menga[a,b,c,d], *Carles Subirà*[a,b,e,f,g], *Alfred Wong*[a,b], *Mayson Sousa*[a,b] *and Laurent J. Brochard*[a,b]

Table 1. Summary of the advantages and disadvantages of the different techniques to assess recruitment and overdistention in ARDS patients

Technique	Advantages	Disadvantages
Pressure–volume loops	- Yields insights into quasi-static lung mechanics at different pressure-volume stages - Helps establish the pressure range to maintain recruitment without causing overdistention	- Necessitates off-line analysis unless equipped with specific software or ventilators - Interpretation can be challenging
Recruitment-to-inflation ratio	- Allows for a comparative analysis of recruitment and inflation (therefore also overdistention) between two PEEP levels - No special equipment required - Simple to execute at the bedside - Compatible with any ventilator	- Generally, provides data at the extremes of a 10 cmH_2O range, lacking detailed information - Results can be influenced by airway closure, if present
Nitrogen wash-in/wash-out technique	- Accurately determines actual lung volume - Enables examination of lung volumes at varying PEEP levels - Convenient to carry out at the bedside	- Needs to be associated with another calculation to understand recruitment vs. inflation - Precision may diminish with small PEEP steps - Susceptible to inaccuracies due to leaks, especially at high pressures - Specific ventilator required for the procedure
Electrical impedance tomography (EIT)	- Gives insights into recruitment and overdistention during a PEEP trial - Provides collapse and distension curves in a few minutes - Can offer pixel-level data, potentially - Easily conducted at the bedside	- Information is relative to the extreme PEEP values of the trial - Some detailed pixel-level analysis necessitates offline processing - EIT machines are not available in all ICUs

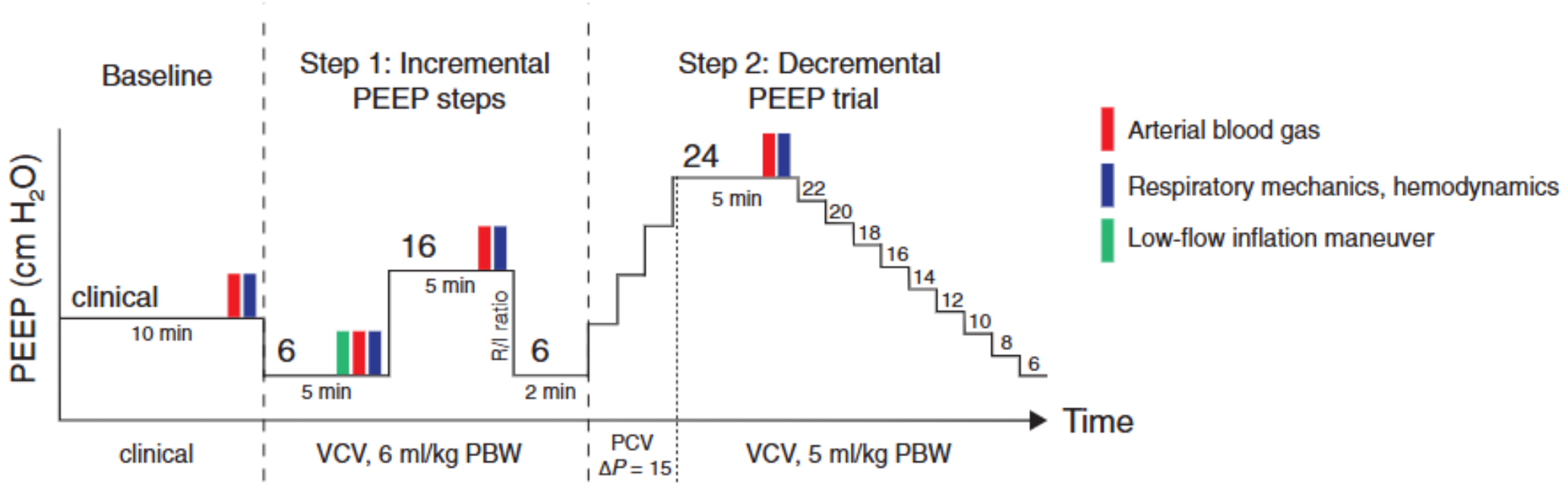
ARDS, acute respiratory distress syndrome; *P–V* loops, pressure–volume loops; PEEP, positive end-expiratory pressure.

Curr Opin Crit Care. 2024 Feb 1;30(1):20-27.

Lung Recruitment Assessed by Electrical Impedance Tomography (RECRUIT)

A Multicenter Study of COVID-19 Acute Respiratory Distress Syndrome

Annemijn H. Jonkman[1,2,3*], Glasiele C. Alcala[4*], Bertrand Pavlovsky[5,6], Oriol Roca[7,8], Savino Spadaro[9,10], Gaetano Scaramuzzo[9,10], Lu Chen[1,2], Jose Dianti[2,11], Mayson L. de A. Sousa[1,2,4], Michael C. Sklar[1,2], Thomas Piraino[1,2], Huiqing Ge[12], Guang-Qiang Chen[13], Jian-Xin Zhou[13], Jie Li[14], Ewan C. Goligher[2,11,15], Eduardo Costa[4], Jordi Mancebo[16†], Tommaso Mauri[17‡], Marcelo Amato[4‡], and Laurent J. Brochard[1,2‡]; for the Pleural Pressure Working Group (PLUG)



Am J Respir Crit Care Med. 2023 Jul 1;208(1):25-38.

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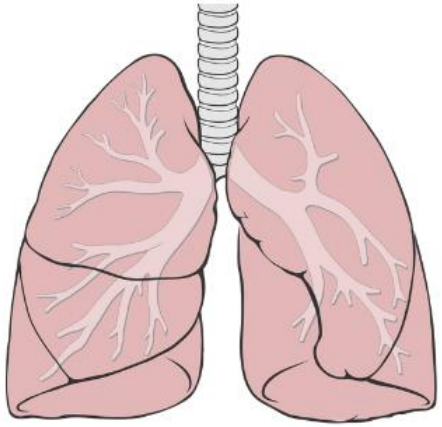

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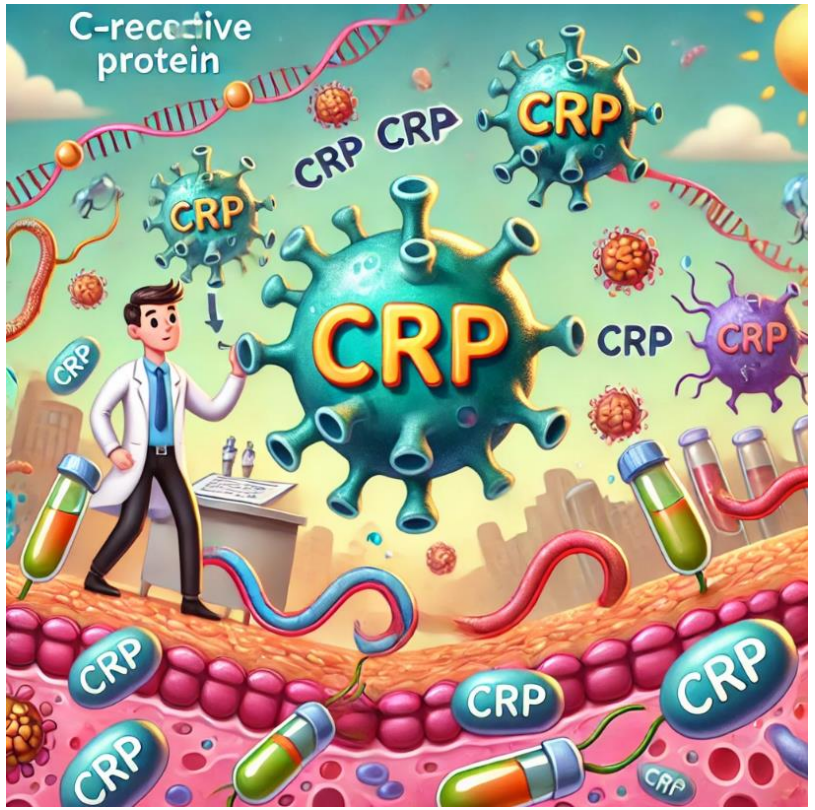
This calculator is ideal for education and simulation purposes. It DOES NOT replace clinical or professional judgement. Use at your own discretion.

Created by Thomas Piraino RRT in collaboaration with Lu Chen MD, Michele Bertoni MD and Ewan Goligher MD PhD


좋아
하세요?
EIT


저는,
중환자
의사
니까요.
네,
아ㅡ주
좋아합니다



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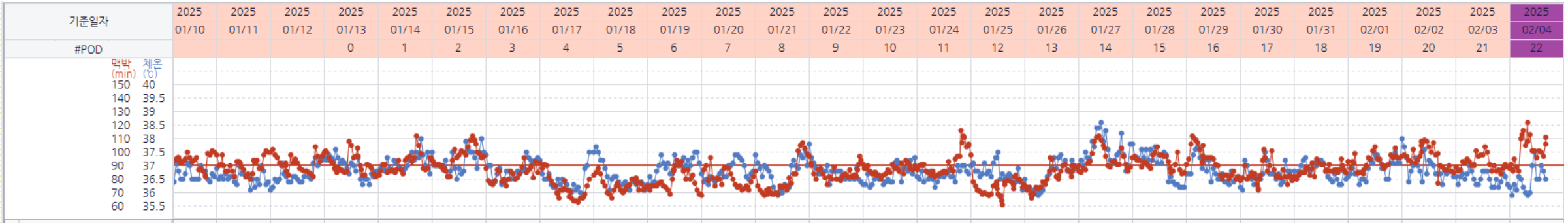

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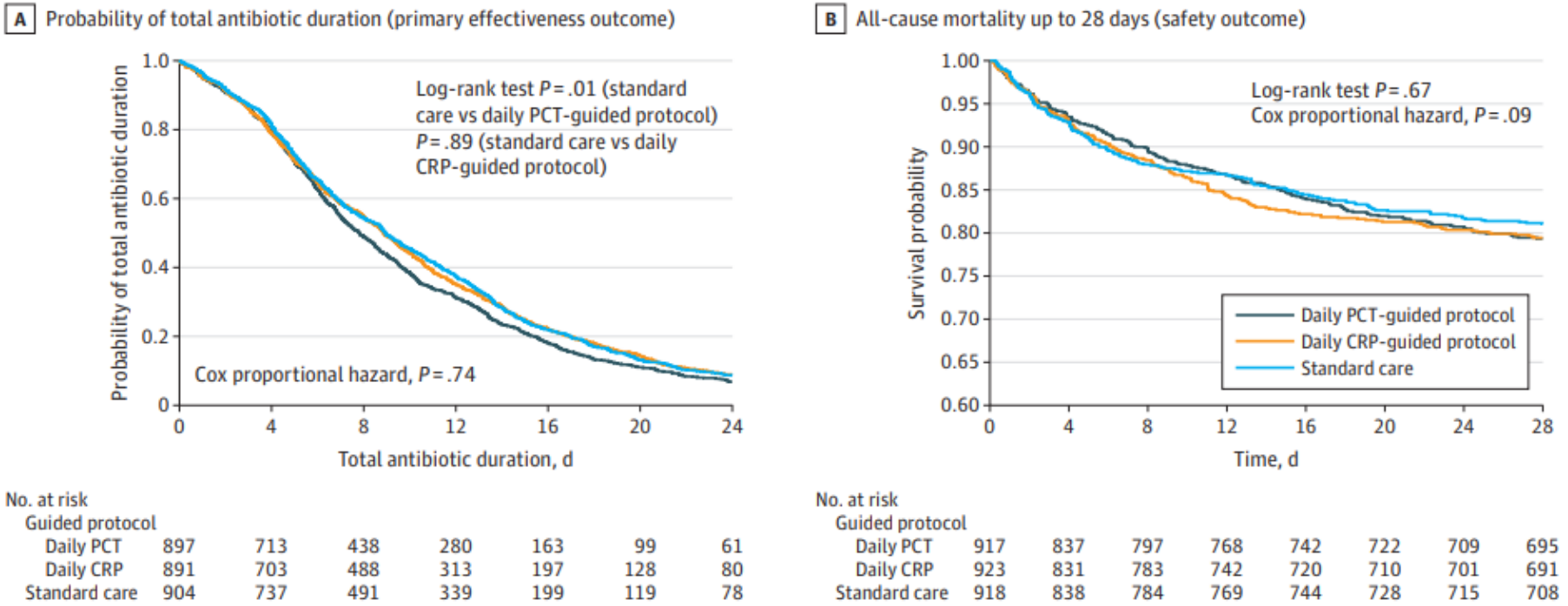
#POD				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
항목명	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	A34	A35	A36	A37	A38	A39
Protein																	5.6	6.0	5.5	5.9	5.6	5.7	6.1	6.3	6.2	6.2
Albumin	2.0	2.3	2.4	2.4	2.3	2.1	2.3	2.2	2.2	2.0	2.1	1.8	2.5	2.3	2.2	2.1	2.1	2.1	1.8	2.1	2.0	2.1	2.5	2.4	2.5	2.4
AST	39	53	56	54	73	61	64	96	47	36	37	43	67	48	52	39	30	28	33	43	24	23	24	24	28	31
ALT	63	62	60	53	63	56	62	113	92	79	76	72	101	92	98	75	62	57	49	60	45	37	35	31	28	32
ALP																	99	101	116	124	127	143	162	173	154	134
T-Bil																										
CRP(quant)	1.50	1.10	0.84	1.51	1.78	3.95	6.23	6.49	5.01	2.98	2.65	1.35	1.68	3.39	4.35	7.73	8.41	5.70	12.43	11.78	14.35	8.62	5.93	8.31	11.15	6.40
Procalcitonin						0.12												0.19								
Na	142	141	142	139	138	137	136	138	137	140	139	139	140	143	141	139	141	138	136	136	134	134	132	131	132	131
K	4.0	3.9	4.7	5.1	5.3	4.8	4.6	5.9	5.1	4.4	5.1	4.7	4.3	4.8	4.0	4.6	3.7	3.4	3.7	4.6	4.7	5.3	5.0	4.9	4.0	4.5
Cl	109	103	105	103	104	103	108	107	104	109	107	110	107	110	111	108	111	106	106	104	102	100	95	94	94	96
Mg	2.51	2.40	2.52	2.54	2.55	2.24	2.25	2.29	2.14	2.02	2.18	2.03	2.05	2.13	2.11	2.01	2.02	1.71	1.94	1.83	1.80	1.84	1.99	2.03	1.92	2.07
LD	210	236	282	296	308	418	321	383	264	260	251	211	271	238	222	234	196	227	240	315	281	240	270	297	313	309

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

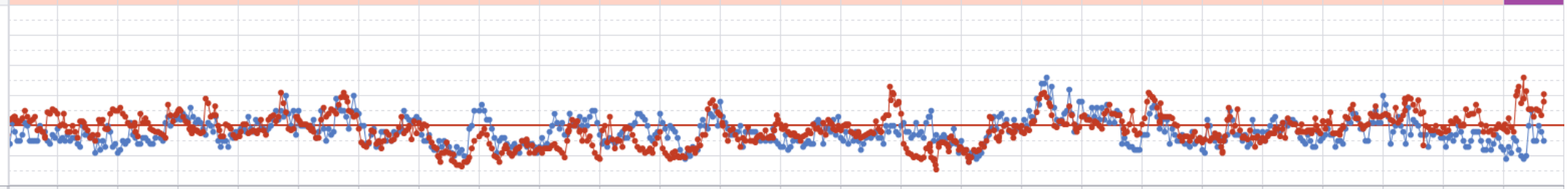
Biomarker-Guided Antibiotic Duration for Hospitalized Patients With Suspected Sepsis

The ADAPT-Sepsis Randomized Clinical Trial

Figure 3. Kaplan-Meier Curves for Probability of Antibiotic Duration and Mortality to 28 Days



The medians of the total antibiotic treatment duration up to 28 days for each of the 3 groups are 7.8 (IQR, 4.5-13.6) days for the daily procalcitonin (PCT)-guided protocol, 8.9 (IQR, 4.5-14.9) days for the daily C-reactive protein (CRP)-guided protocol, and 9.0 (IQR, 4.7-14.6) days for standard care.



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CRP ≈ EIT

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CHICKEN
EIT.
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목차

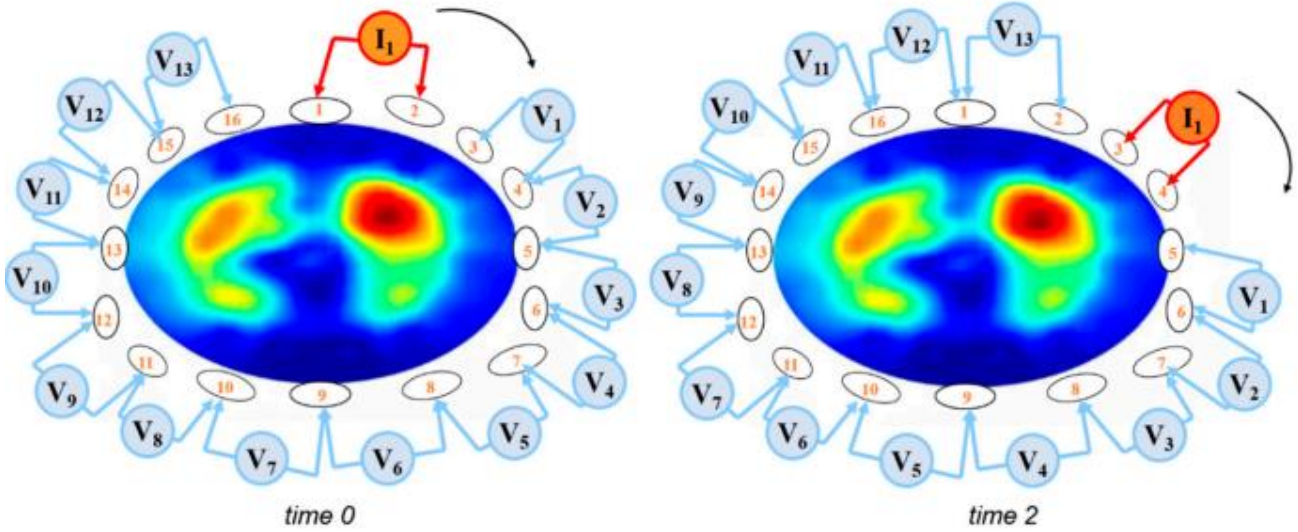
1. Electrical Impedance Tomography

Bioimpedance

The voltage response of biological tissue to an externally applied alternating electric current (AC)

Table 1. Electrical resistivity of thoracic tissues.

Tissue	Resistivity (Ω·cm)
Blood	150
Lungs, inspiration	2400
Lungs, expiration	700
Heart muscle, longitudinal	125
Heart muscle, transversal	1800
Skeletal muscle, longitudinal	160–575
Skeletal muscle, transversal	420–5200
Fat	2000–2700
Bone	16,600



J Clin Med. 2019 Aug 7;8(8):1176.

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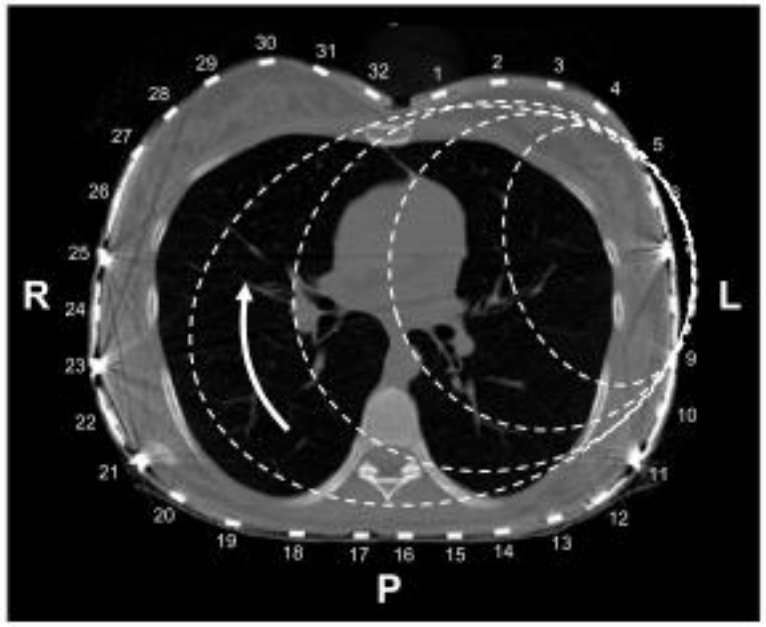

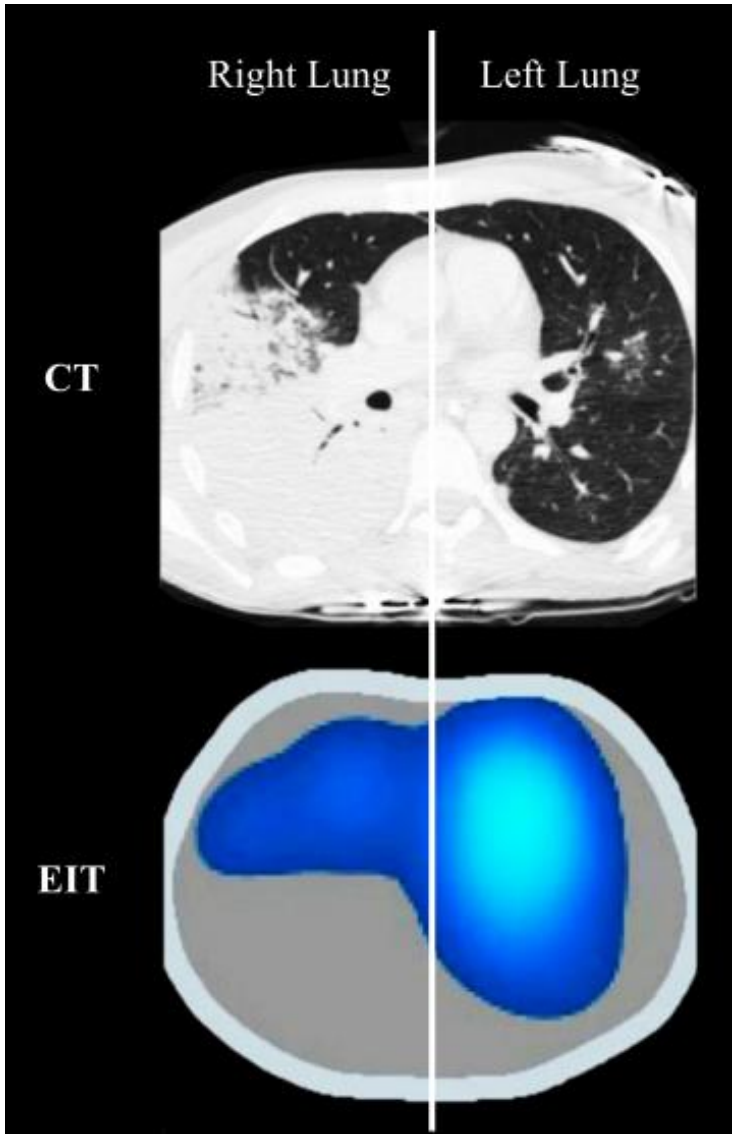

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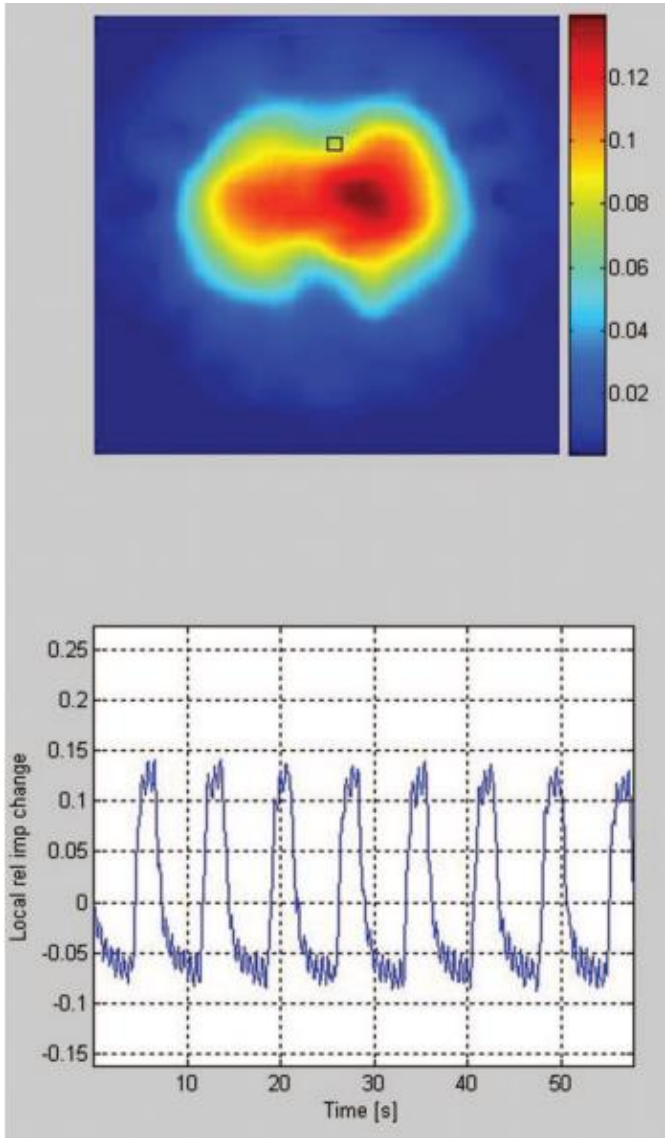

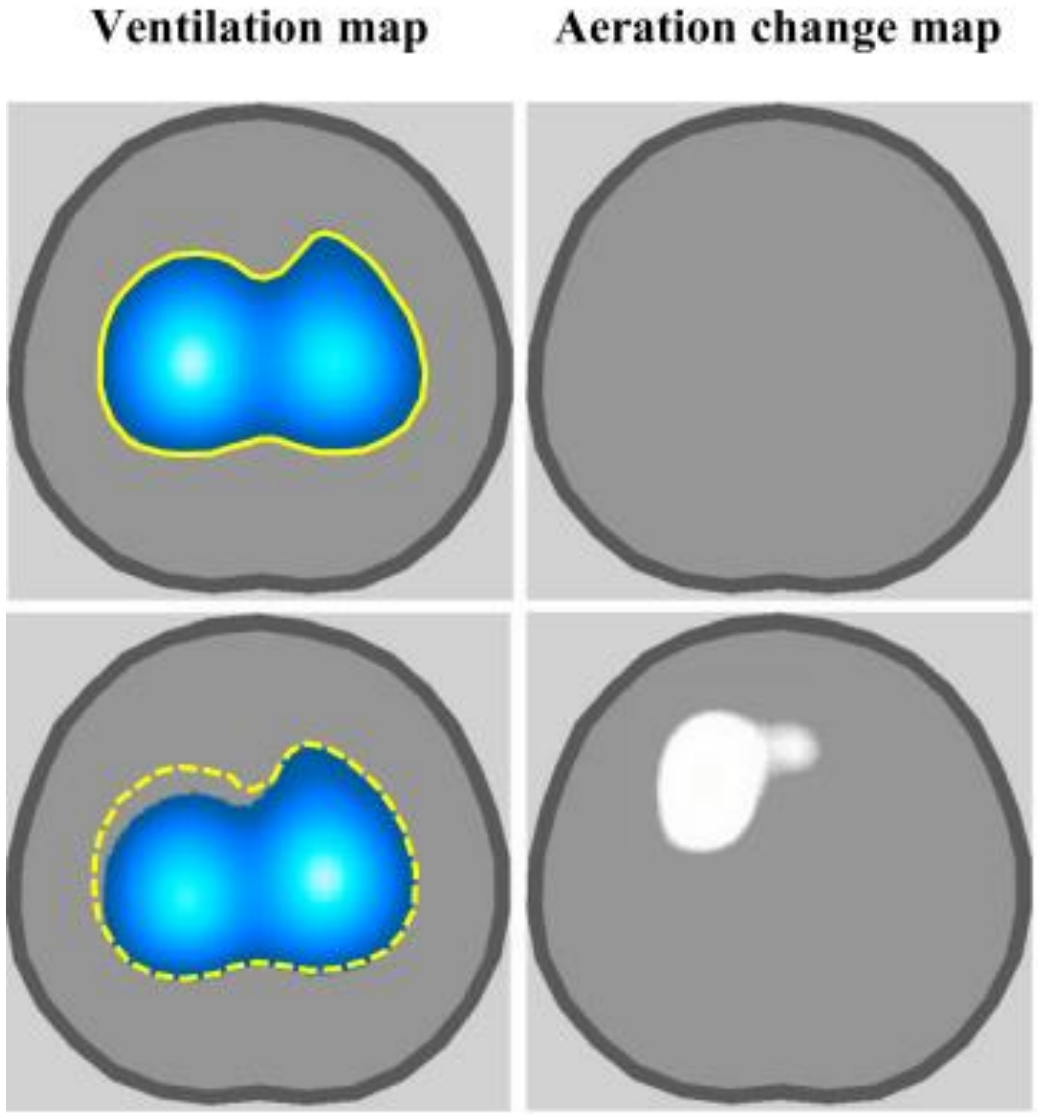

Crit Care Med. 2009 Feb;37(2):713-24.

Crit Care. 2018 Oct 25;22(1):263

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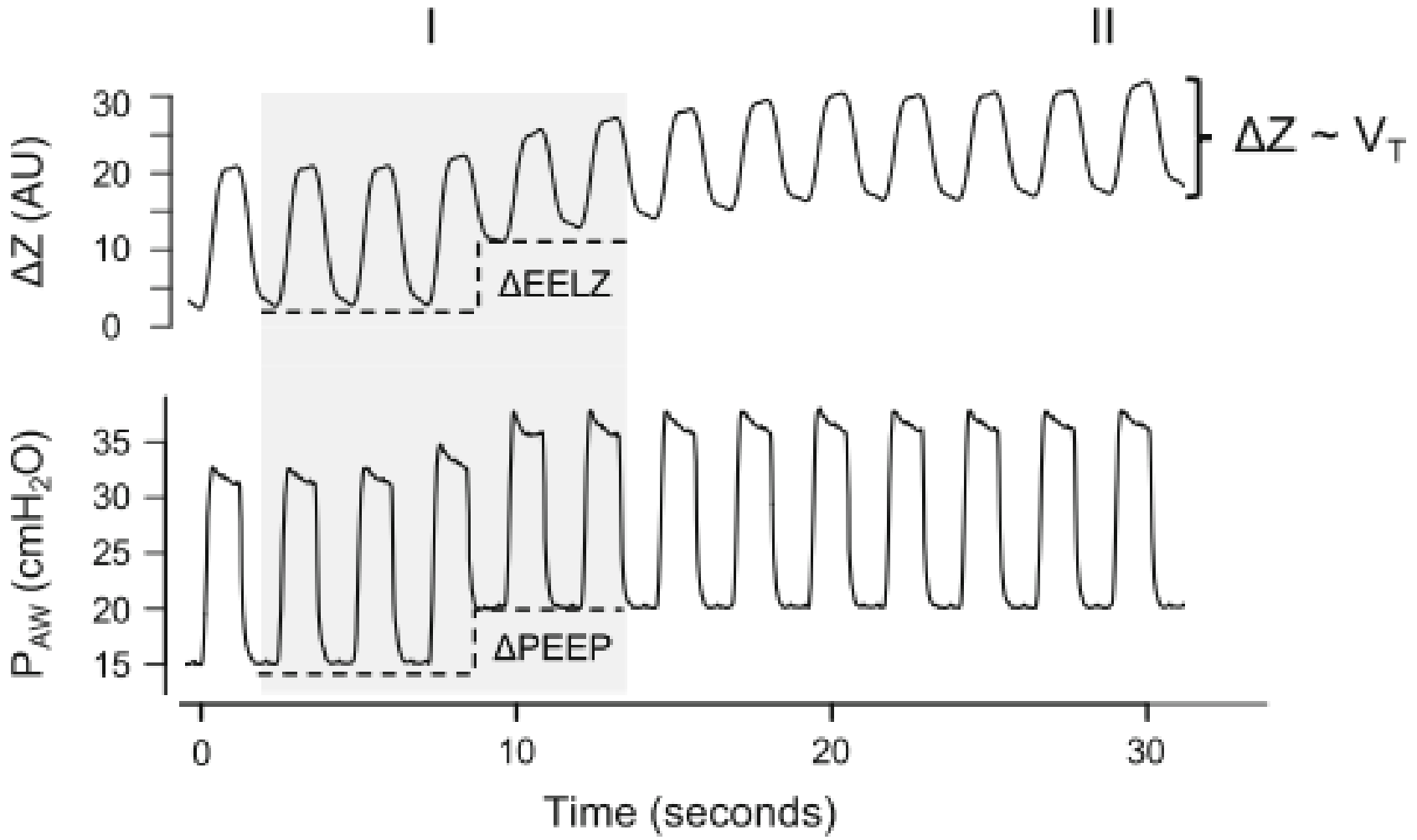
1. Electrical Impedance Tomography



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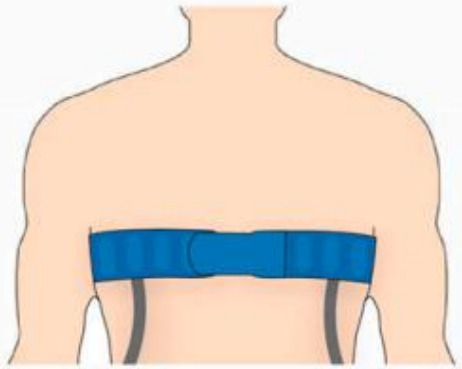
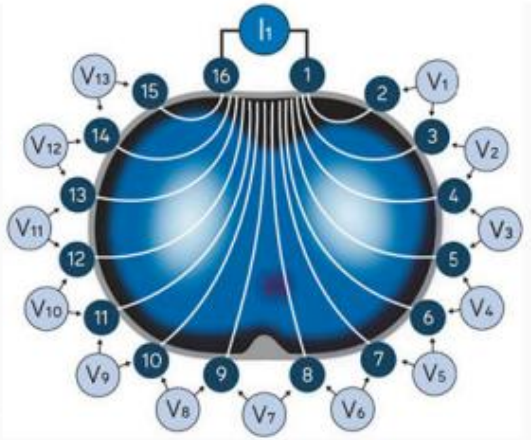
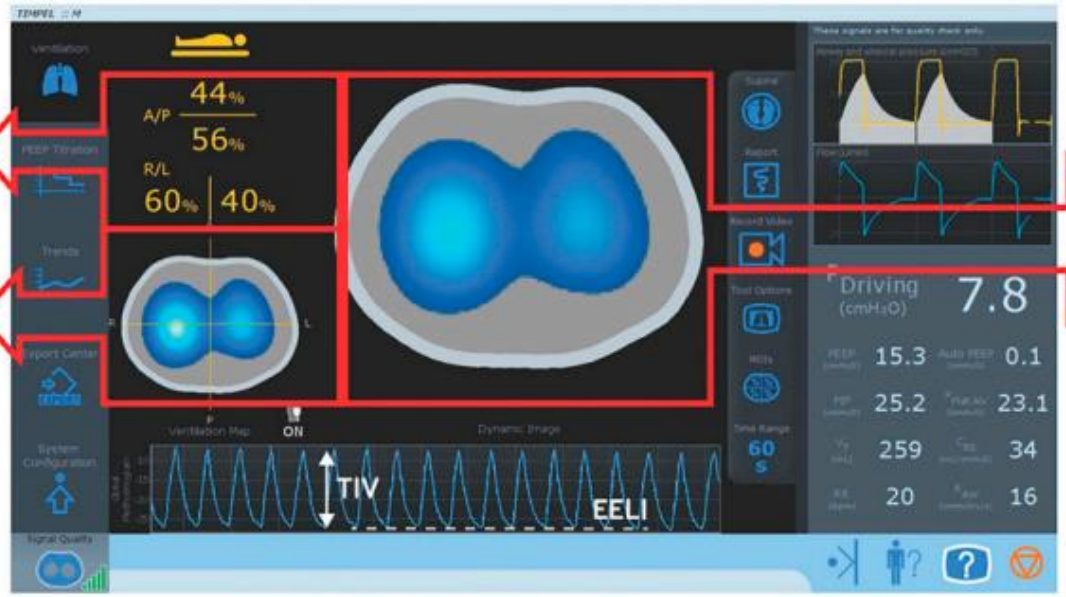




Distribution of ventilation depending on prespecified ROI

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

Am J Respir Crit Care Med . 2024 Mar 15;209(6):670-682

1. Electrical Impedance Tomography

AirTom

A bedside continuous regional lung ventilation monitor

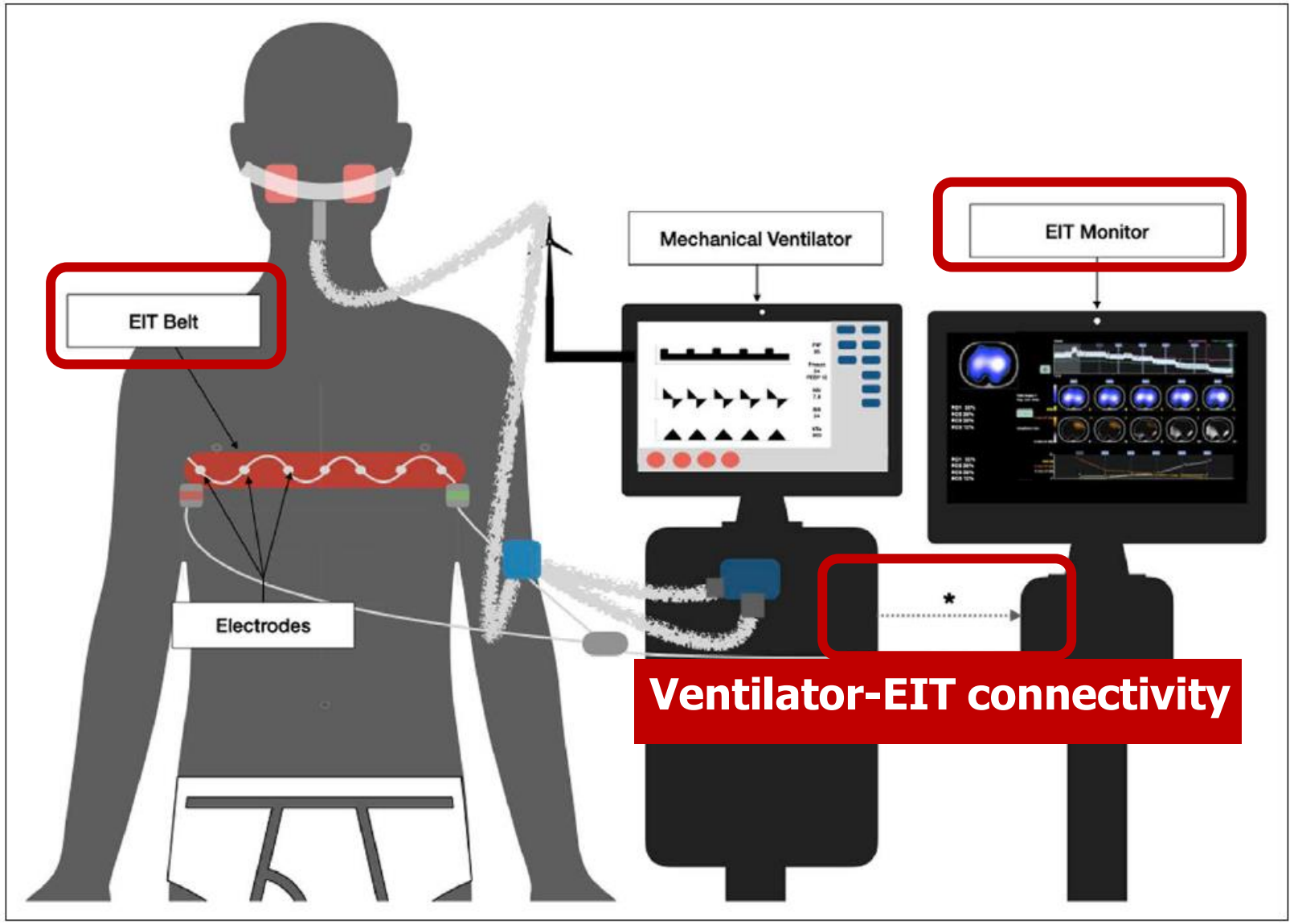
- Real time, Noninvasive, Radiation free

1) An Electrode sensor with up to 16 sensors around the patient's thorax

2) The system measures the change of electrical impedance creating 100 real images per second

제허21-759호(3등급)

1. Electrical Impedance Tomography



Crit Care Med. 2022 Aug 1;50(8):1210-1223.

1. Electrical Impedance Tomography

모델명	AirTom	PulmoVista500
제조사 (제조국)	바이랩 (한국)	Drager (독일)
KFDA (허가일자)	제허21-759호 (2021.09.13)	수허12-216호 (2012.02.01)
기술	16-채널 EIT	16-채널 EIT
Frame rate	100 frames/s	10~50 frames/s
Resoultion	1920 x 1080 pixels	1440 x 900 pixels
센서	일회용 전극 센서	다회용 실리콘 벨트
특징	Stand alone형 Getinge, Medtronic, Hamiltion 인공호흡기와 연동	롤링카트 일체형 Drager사의 인공호흡기와 데이터 케이블로 연결하여 사용

EIT monitor

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EIT belt

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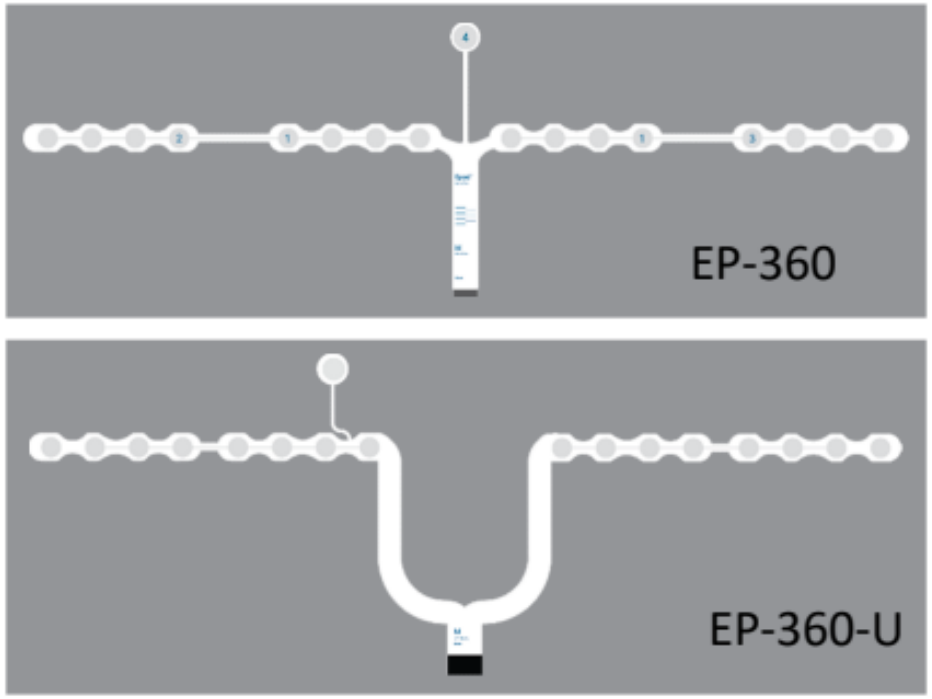
1. Electrical Impedance Tomography

- **AirTom E-pad**



1. Electrical Impedance Tomography

- **PulmoVista500**

https://www.draeger.com/ko_kr/Products/PulmoVista-500

1. Electrical Impedance Tomography

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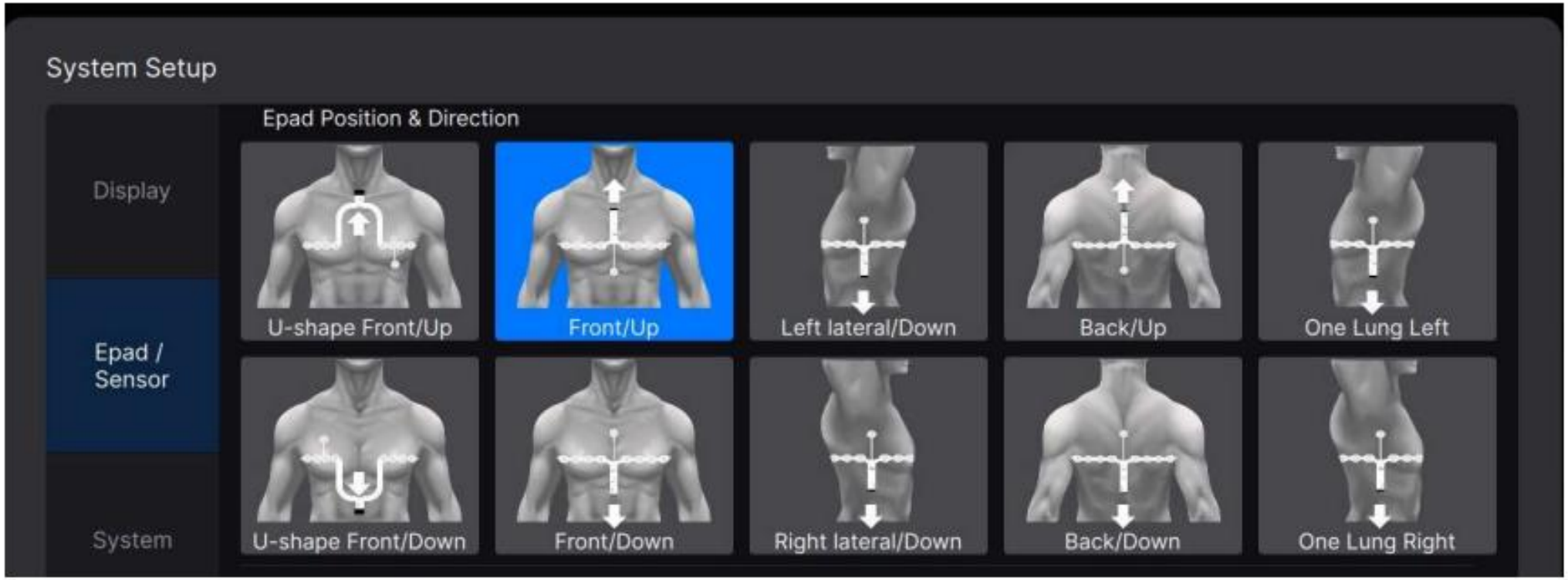

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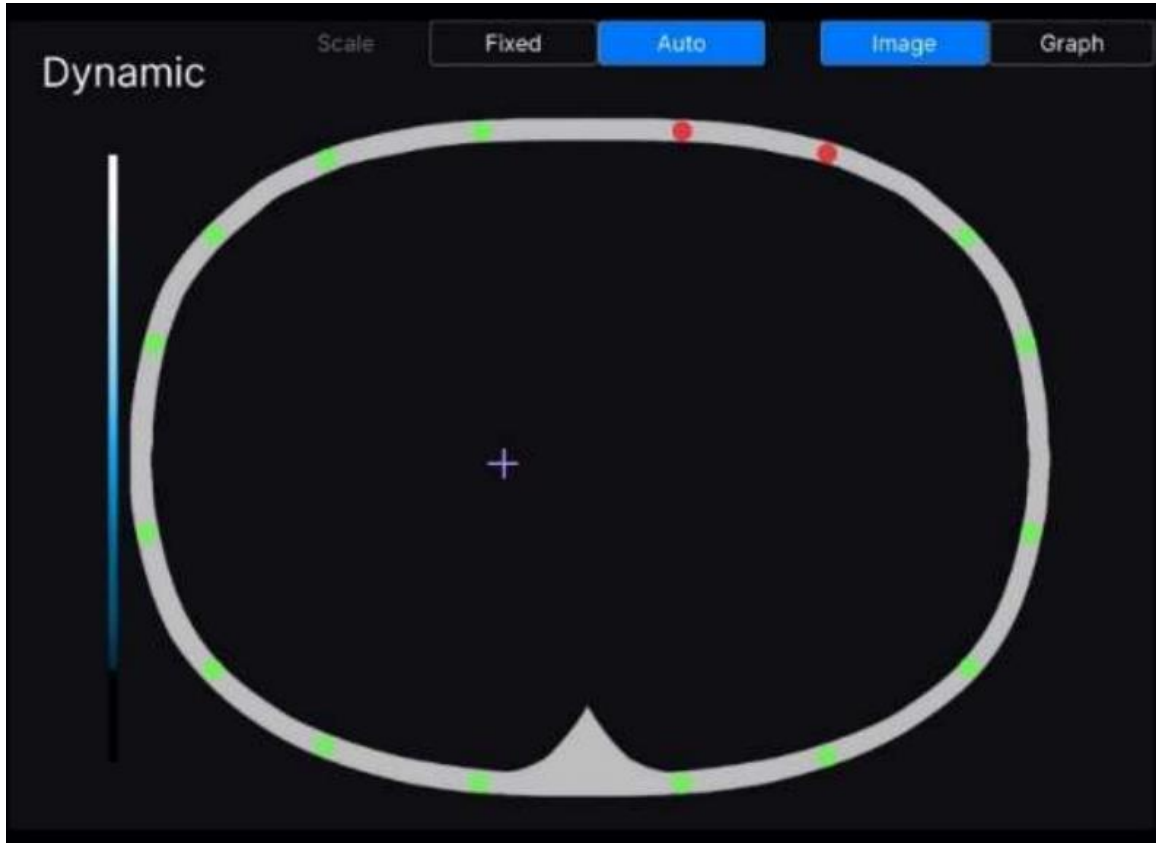

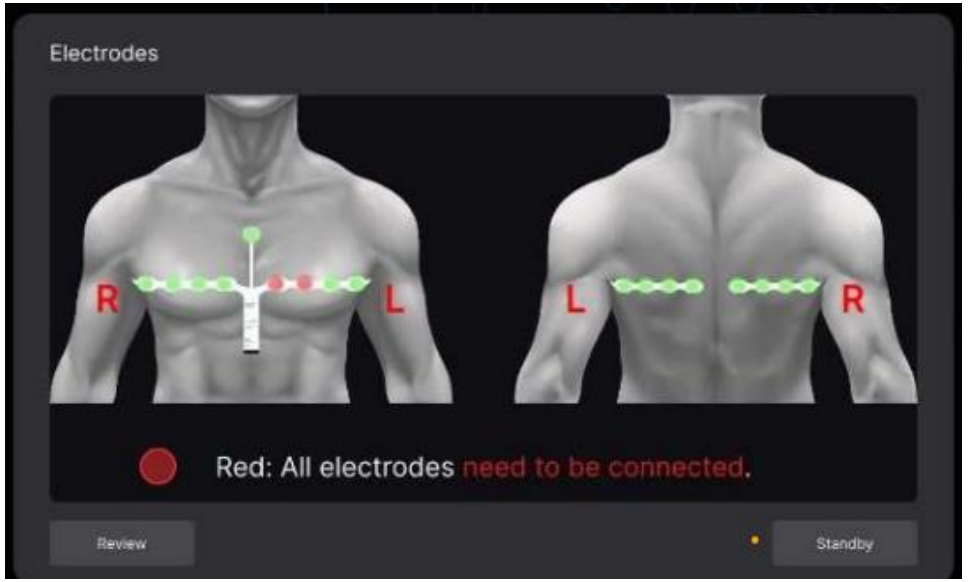

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Ventilator-EIT connectivity

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1. Electrical Impedance Tomography

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1. Electrical Impedance Tomography

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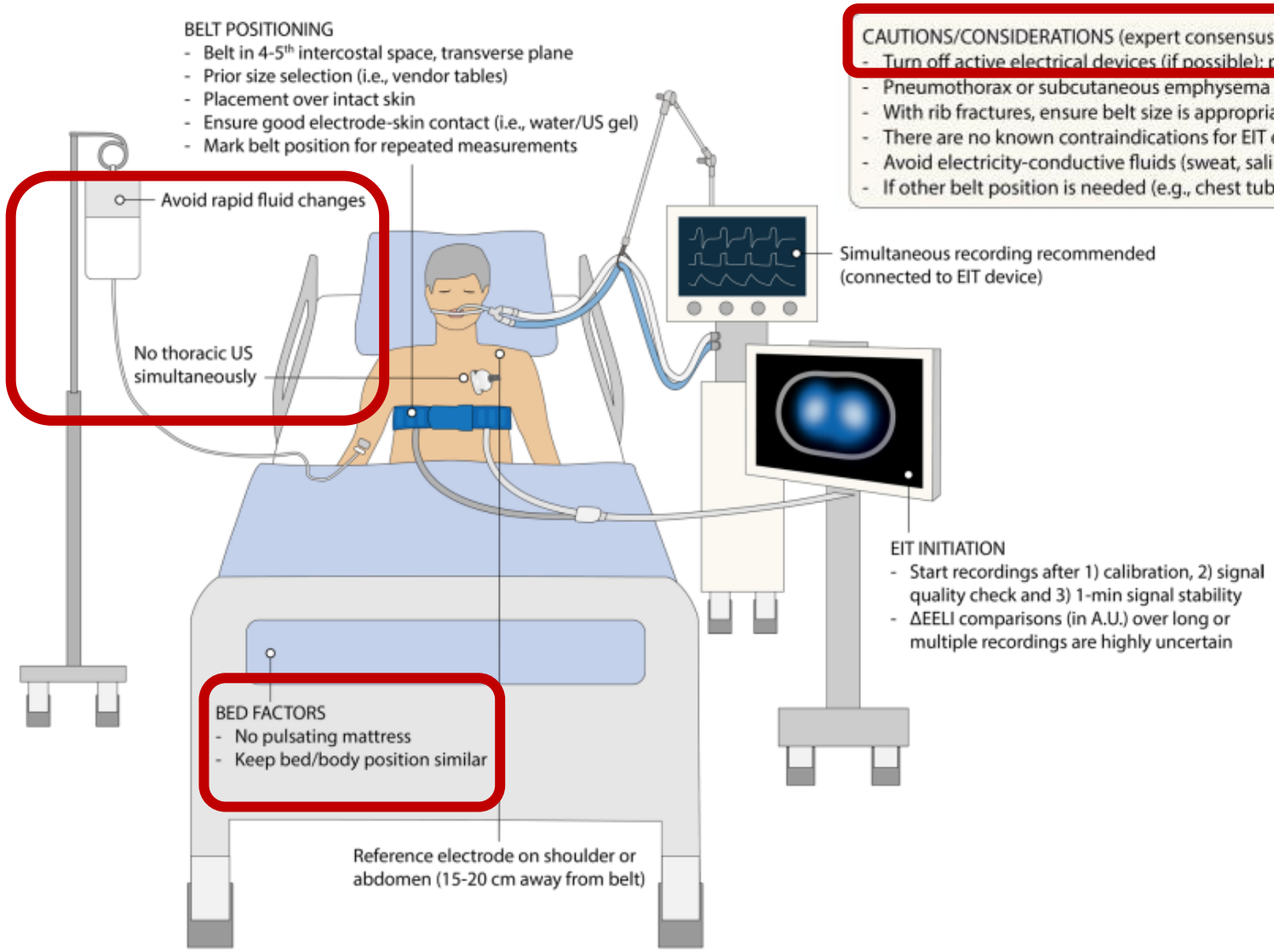

Crit Care. 2024 Nov 19;28(1):377.

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2. ARDS에서 EIT

CONFERENCE REPORTS AND EXPERT PANEL

ESICM guidelines on acute respiratory distress syndrome: definition, phenotyping and respiratory support strategies

Giacomo Grasselli[1,2*], Carolyn S. Calfee[3], Luigi Camporota[4,5], Daniele Poole[6], Marcelo B. P. Amato[7],

Recommendation 6.1

We are **unable to make a recommendation** for or against routine PEEP titration with a higher PEEP/FiO_2 strategy versus a lower PEEP/FiO_2 strategy to reduce mortality in patients with ARDS.
No recommendation; high level of evidence of no effect.

This statement applies also to ARDS from COVID-19.
No recommendation; moderate level of evidence of no effect for indirectness.

Recommendation 6.2

We are **unable to make a recommendation** for or against PEEP titration guided principally by respiratory mechanics, compared to PEEP titration based principally on PEEP/FiO_2 strategy, to reduce mortality in patients with ARDS.
No recommendation; high level of evidence of no effect.

This statement applies also to ARDS from COVID-19.
No recommendation; moderate level of evidence for indirectness.

Intensive Care Med. 2023 Jul;49(7):727-759.

2. ARDS에서 EIT

An Update on Management of Adult Patients with Acute Respiratory Distress Syndrome

An Official American Thoracic Society Clinical Practice Guideline

Nida Qadir*, Sarina Sahetya*, Laveena Munshi*, Charlotte Summers*, Darryl Abrams, Jeremy Beitler, Giacomo Bellani, Roy G. Brower, Lisa Burry, Jen-Ting Chen, Carol Hodgson, Catherine L. Hough, Francois Lamontagne, Anica Law, Laurent Papazian, Tai Pham, Eileen Rubin, Matthew Siuba, Irene Telias, Setu Patolia, Dipayan Chaudhuri, Allan Walkey‡, Bram Rochwerg‡, and Eddy Fan‡; on behalf of the American Thoracic Society Assembly on Critical Care

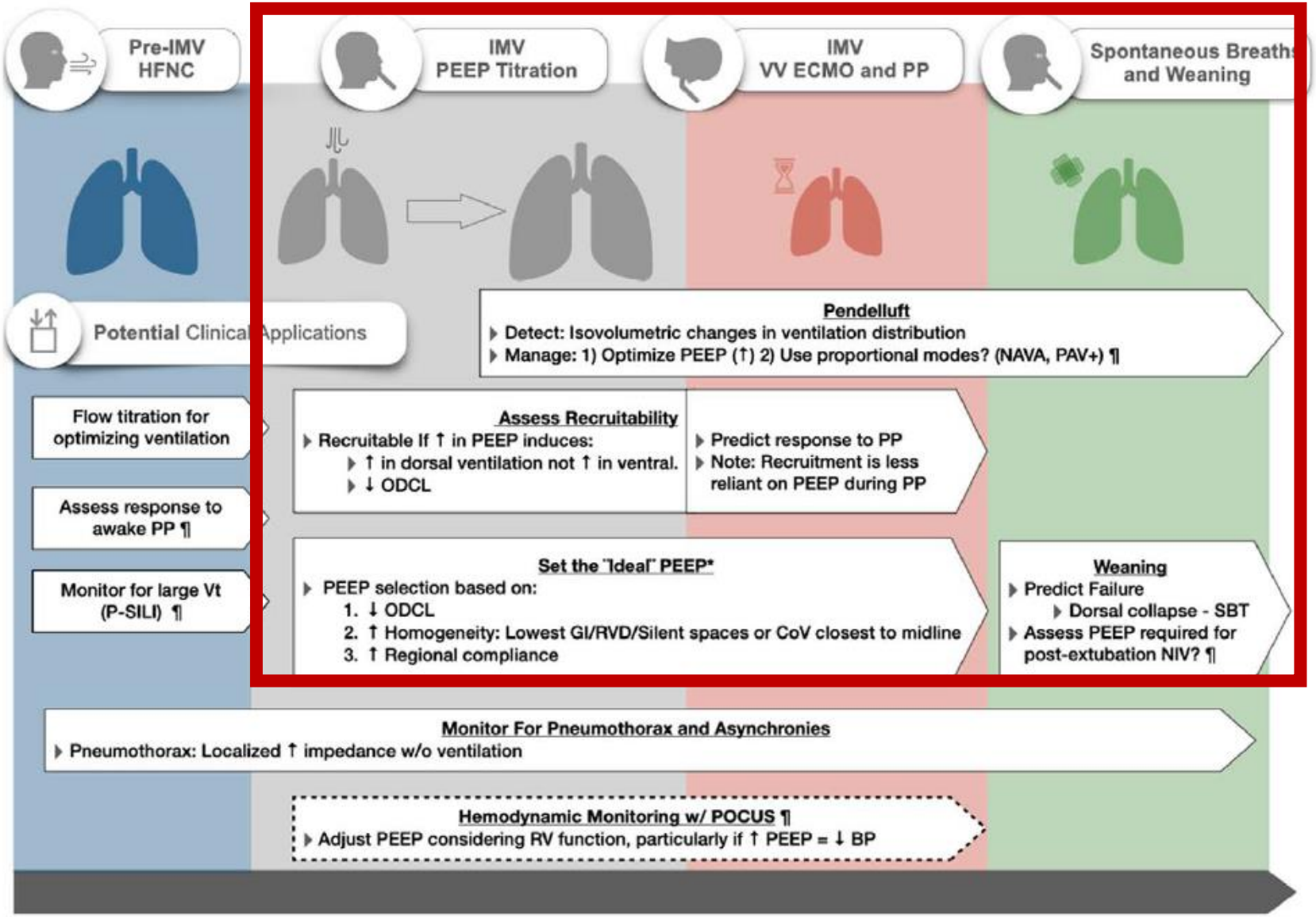
Question 4: Should Patients with ARDS Receive Higher Compared with Lower PEEP, with or without LRMs?

Recommendation. We suggest using higher PEEP without LRMs rather than lower PEEP in patients with moderate to severe ARDS (conditional recommendation, low-moderate certainty). We recommend against using prolonged (PEEP ≥35 cm H_2O for >60 s) LRMs in patients with moderate to severe ARDS (strong recommendation, moderate certainty).

Uncertainties and research priorities. The optimal strategy for setting PEEP in patients with ARDS remains uncertain. None of the included RCTs incorporated assessments of lung "recruitability" in response to higher PEEP strategies. Validating strategies to assess for lung recruitability at the bedside, such as the use of oxygenation response (82), driving pressure change (83), recruitment/inflation ratio (84), stress index (85), or electrical impedance tomography (86), may help guide individualized PEEP titration. A large

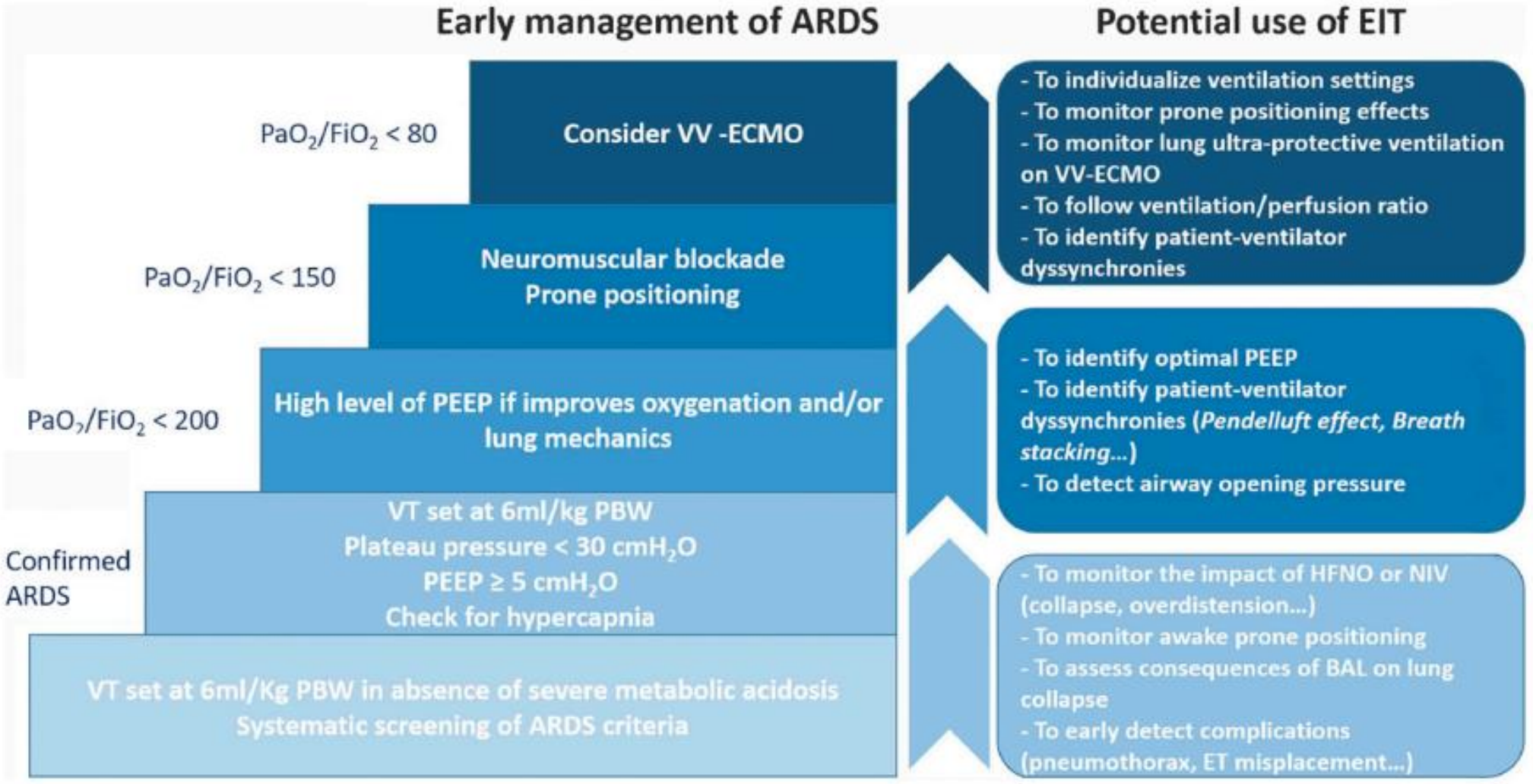
Am J Respir Crit Care Med. 2024 Jan 1;209(1):24-36.

2. ARDS에서 EIT



Crit Care Med. 2022 Aug 1;50(8):1210-1223.

2. ARDS에서 EIT



Am J Respir Crit Care Med . 2024 Mar 15;209(6):670-682

2. ARDS에서 EIT

Table 2 EIT parameters and their applications in different ventilation conditions, for clinical and/or scientific purposes (as per current evidence) as well as bedside availability has been noted

	Ventilatory mode			Purpose		Availability		Comments
	Controlled	Assisted	Non-intubated	Clinical	Research	Bedside	Offline	
VT distribution	+	+	+	+	+	+	+	
EELI distribution	+	+	+	+/−	+	+	+	EELI dependent
Dorsal fraction of ventilation	+	+	+	+	+	+	+	
CoV	+	+	+	+	+	+	+	
Global Inhomogeneity	+/−	+/−	+/−	+/−	+/−	−	+	
OD-CL	+	+/−	+/−	+	+	+	+	Needs standardization
Regional PV-curve	+	−	−	+/−	+	+/−	+	Low-flow insufflation
RVD, RVDi	+	−	−	+/−	+	+	+	Low-flow insufflation
Silent spaces	+	+	+/−	+	+	+	+	
Time constant	+	+/−	+/−	−	+	−	+	
EIT-based R/I ratio	+	+/−	+/−	+/−	+	+	+	EELI dependent
$\dot{V}/Q$ matching	+	+/−	+/−	+/−	+	+/−	+	Needs saline bolus
Volume estimation in SB	NA	NA	+	−	+	+/−	+	
Pendelluft detection	+	+	+	+/−	+	+/−	+	

+, the expert panel recommend the use of this parameter in this condition; +/−, the expert panel cannot state any recommendation in this condition; −, the expert panel does not recommend the use of this parameter in this condition

Abbreviations: NA, not applicable; CoV, center of ventilation; EELI, end-expiratory lung impedance; CL, lung collapse; OD, overdistension; PV-curve, pressure–volume curve; R/I ratio, recruitment-to-inflation ratio; RVD(i), regional ventilation delay (index); SB, spontaneous breathing; VT, tidal volume; $\dot{V}/Q$, ventilation-perfusion

Crit Care. 2024 Nov 19;28(1):377.

3. 실제 적용 사례

Table 2 EIT parameters and their applications in different ventilation conditions, for clinical and/or scientific purposes (as per current evidence) as well as bedside availability has been noted

	Ventilatory mode			Purpose		Availability		Comments
	Controlled	Assisted	Non-intubated	Clinical	Research	Bedside	Offline	
VT distribution	+	+	+	+	+	+	+	
EELI distribution	+	+	+	+/−	+	+	+	EELI dependent
Dorsal fraction of ventilation	+	+	+	+	+	+	+	
CoV	+	+	+	+	+	+	+	
Global Inhomogeneity	+/−	+/−	+/−	+/−	+/−	−	+	
OD-CL	+	+/−	+/−	+	+	+	+	Needs standardization
Regional PV-curve	+	−	−	+/−	+	+/−	+	Low-flow insufflation
RVD, RVDi	+	−	−	+/−	+	+	+	Low-flow insufflation
Silent spaces	+	+	+/−	+	+	+	+	
Time constant	+	+/−	+/−	−	+	−	+	
EIT-based R/I ratio	+	+/−	+/−	+/−	+	+	+	EELI dependent
$\dot{V}$/Q matching	+	+/−	+/−	+/−	+	+/−	+	Needs saline bolus
Volume estimation in SB	NA	NA	+	−	+	+/−	+	
Pendelluft detection	+	+	+	+/−	+	+/−	+	

+, the expert panel recommend the use of this parameter in this condition; +/−, the expert panel cannot state any recommendation in this condition; −, the expert panel does not recommend the use of this parameter in this condition

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Crit Care. 2024 Nov 19;28(1):377.

3. 실제 적용 사례

Table 1. Definition, Clinical Application, and Limitations of the Most Commonly Used EIT Indices in Patients with Hypoxemic Respiratory Failure

EIT Indices	Definition	Potential Applications	Limits
TIV	Variation of impedance values between end of inspiration and end of expiration (amplitude of plethysmogram signal)	• Reflects global and regional relative distribution of V_T in lungs during ventilation • Contributes to identification of pleural effusion, pneumothorax, endotracheal tube malposition, pendelluft	• Cannot be used for detailed anatomic diagnosis • Only relative distribution of V_T
EELI	Regional lung impedance at end of expiration	• EELI changes are correlated with EELV variation • Reflects lung recruitment/derecruitment • Contributes to identification of pneumothorax	• Affected by factors other than lung volume (inflatable mattress, fluid infusion)
Center of ventilation	Describes geometrical center of ventilation	• Reflects global ventilation homogeneity to guide and monitor impact of mechanical ventilation management or adjunct therapies (i.e., prone positioning) • Identification of adverse events (e.g., malpositioning of endotracheal tube or development of pneumothorax)	• Reflects ventilation shifts but not their origin • Imprecise interpretation of ventilation distribution (ventilation on one side can be compensated by other side). • Setting PEEP aiming for >50% dorsal distribution could imply overdistension of whole lung
Dorsal fraction of ventilation	Describes percentage of V_T distributed in dorsal region		

Definition of abbreviations: ΔP = driving pressure; ECMO = extracorporeal membrane oxygenation; EELI = end-expiratory lung impedance; EELV = end-expiratory lung volume; EIT = electrical impedance tomography; PEEP = positive end-expiratory lung pressure; TIV = tidal impedance variation.

실제 사례

- **Case 1:** Male/75 yr

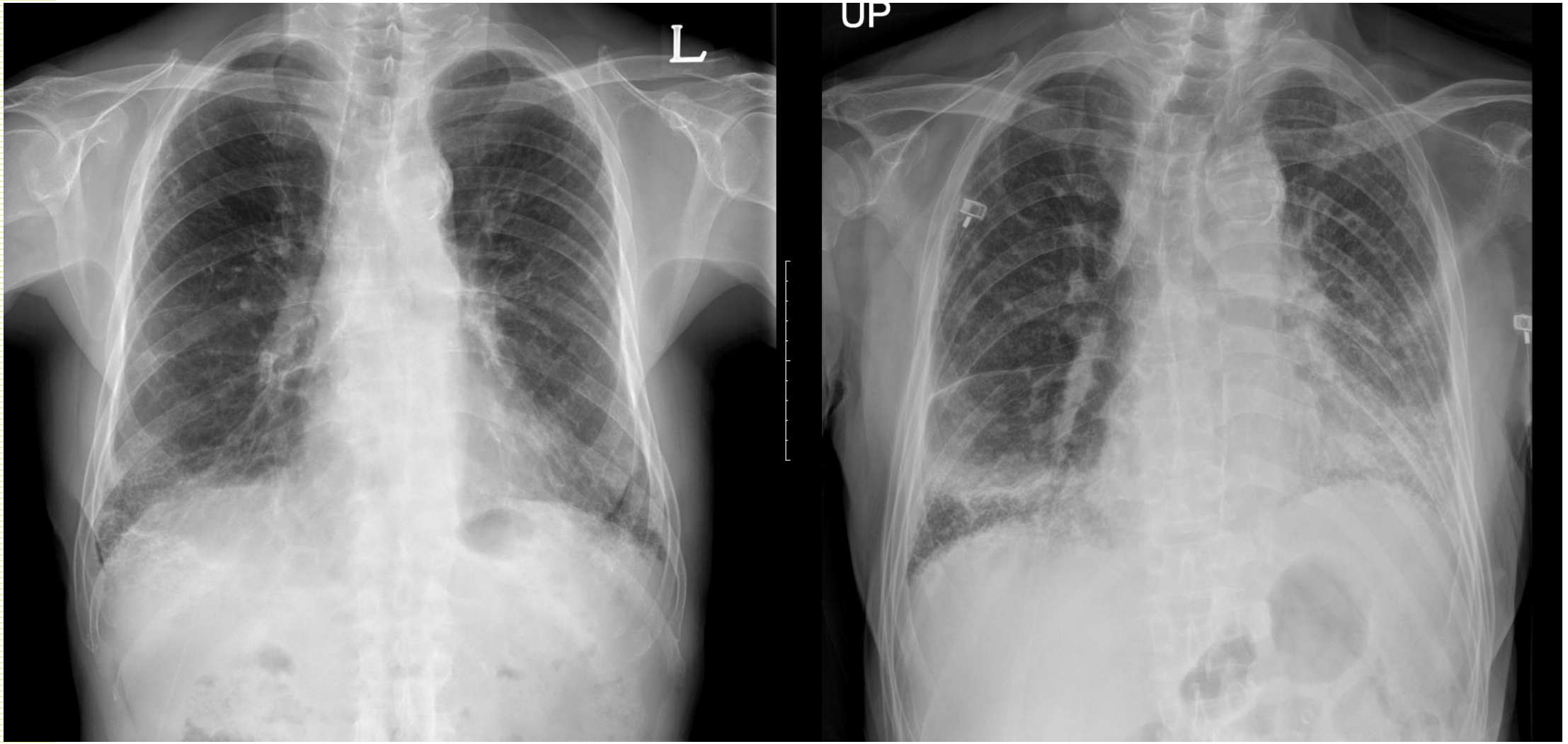
Main problem: ARDS d/t Inf A pneumonia

- Comorbidity: s/p KT (14YA), cIPF

> Ventilator: PC mode FiO2 50% RR 20

Driving Pressure 20 cmH2O

PEEP 4 cmH2O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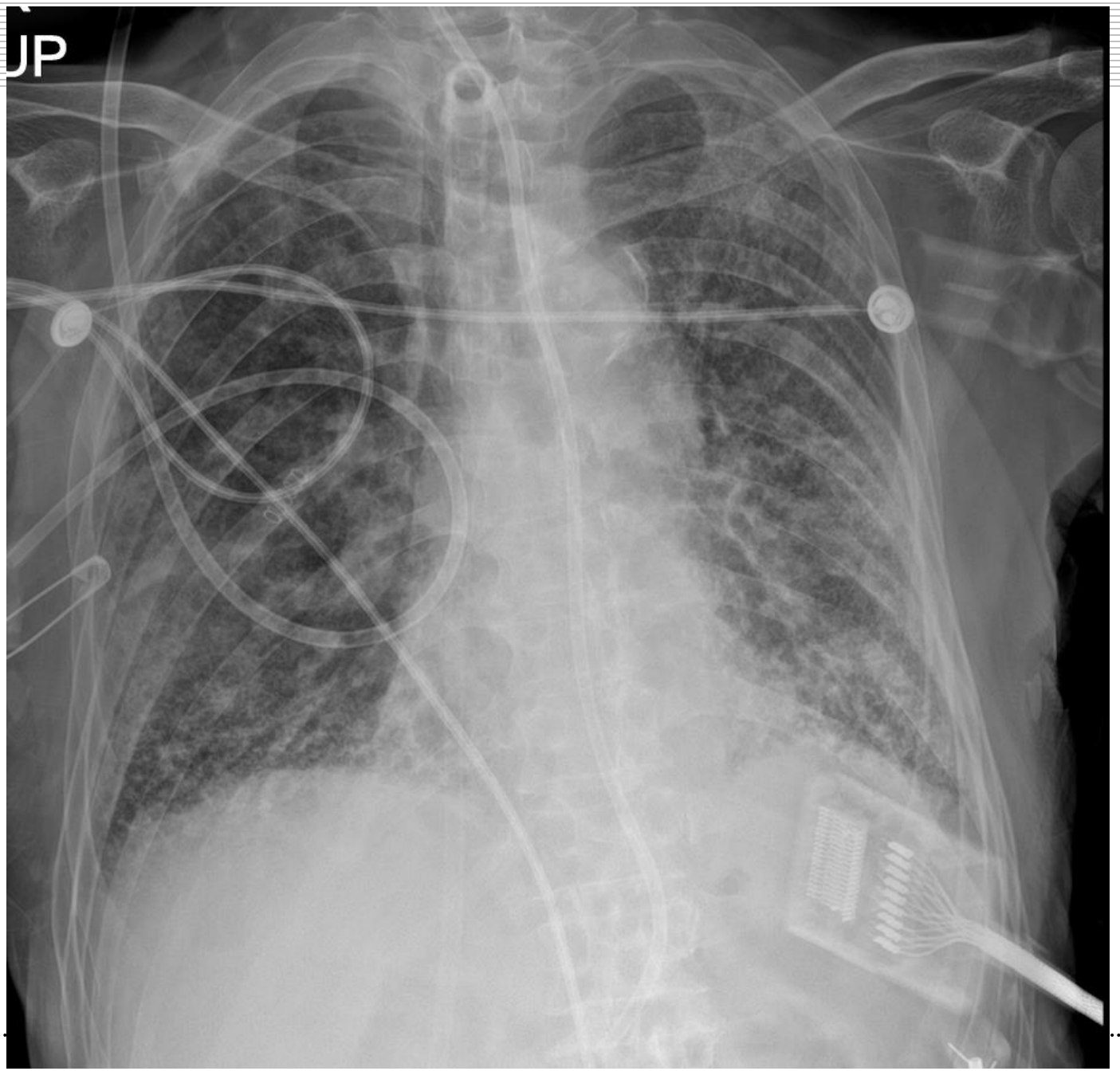
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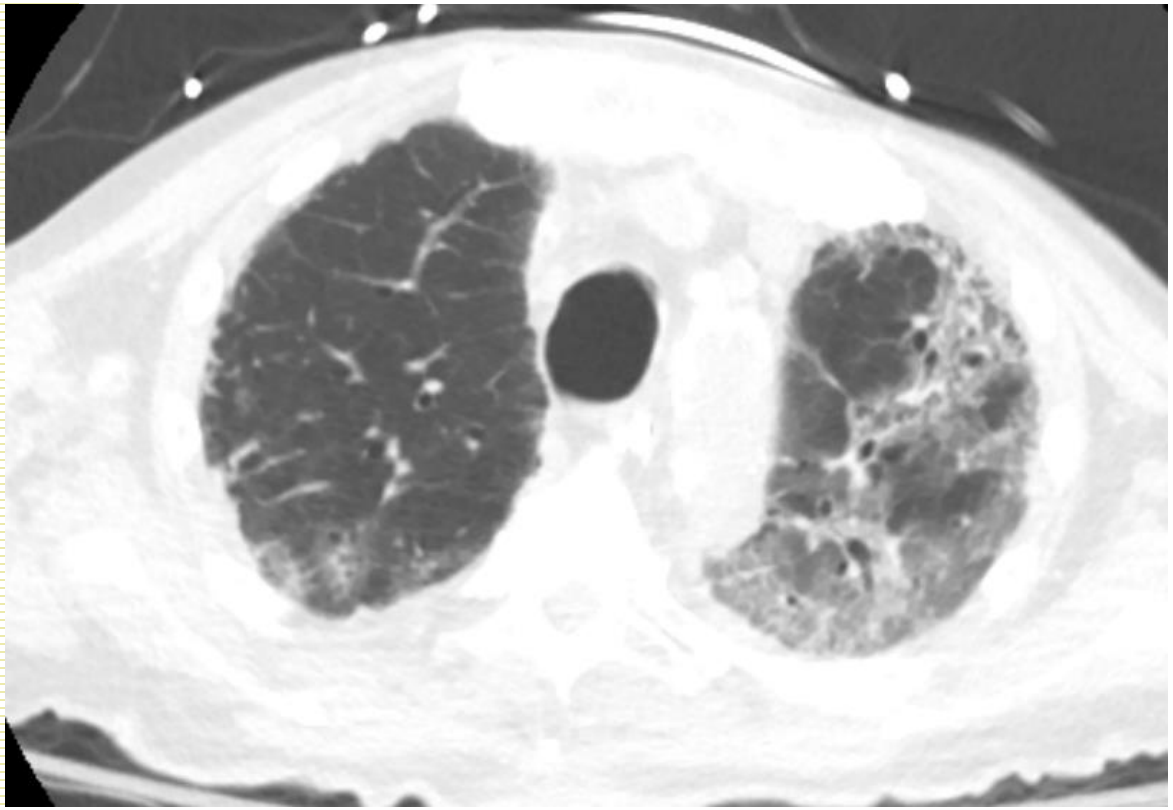

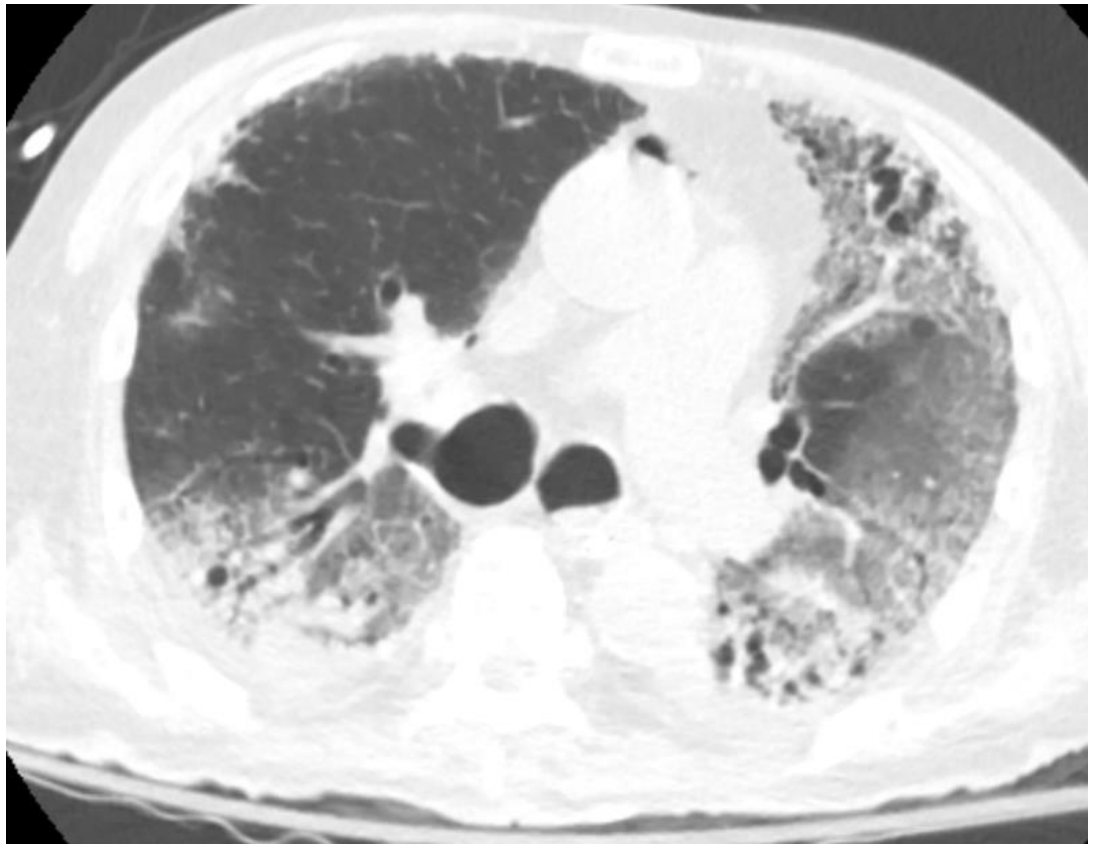

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3. 실제 적용 사례

- **Case 2:** Male/72 yr

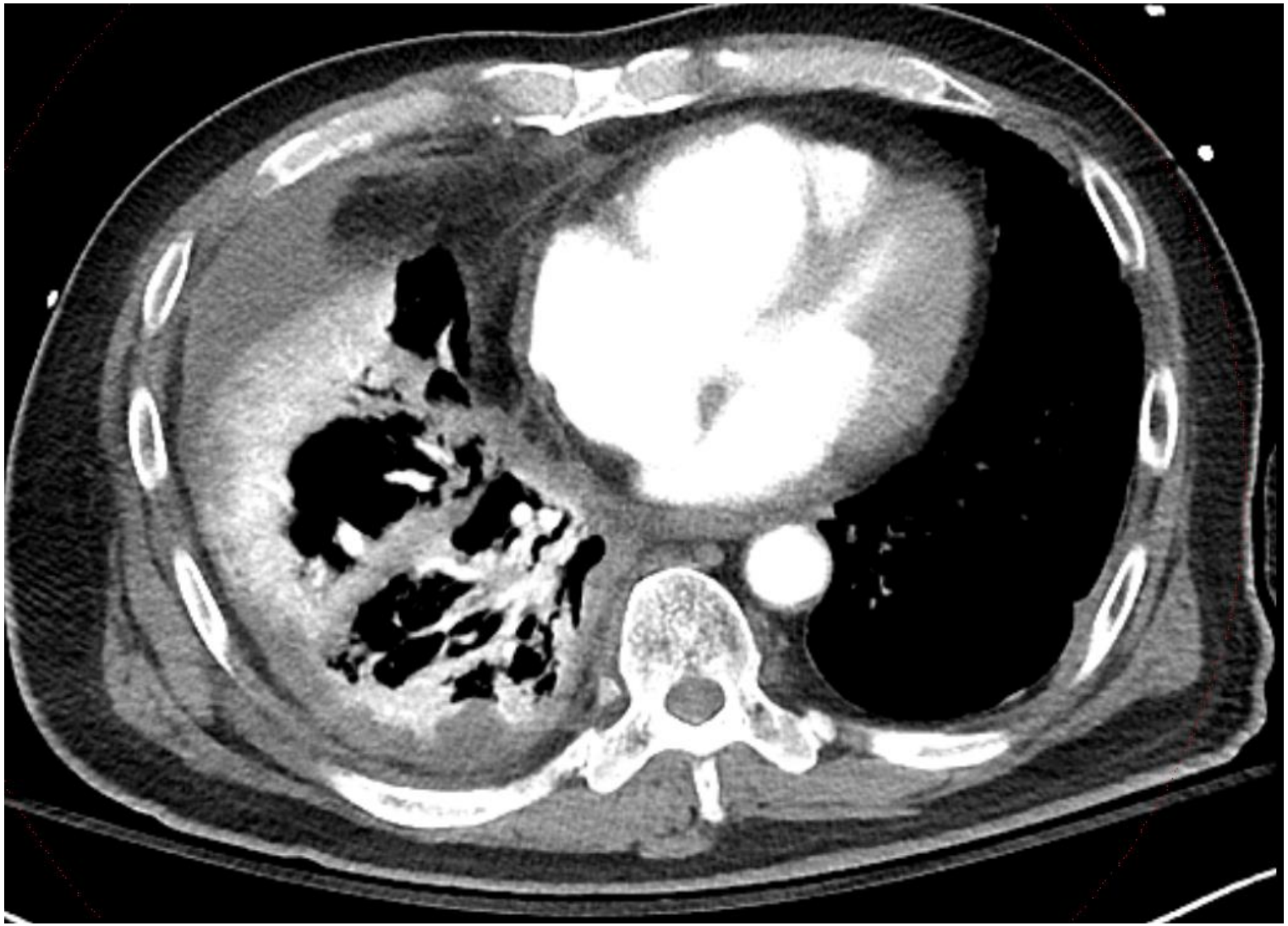
Main problem: PTE s/p OP (POD#9)

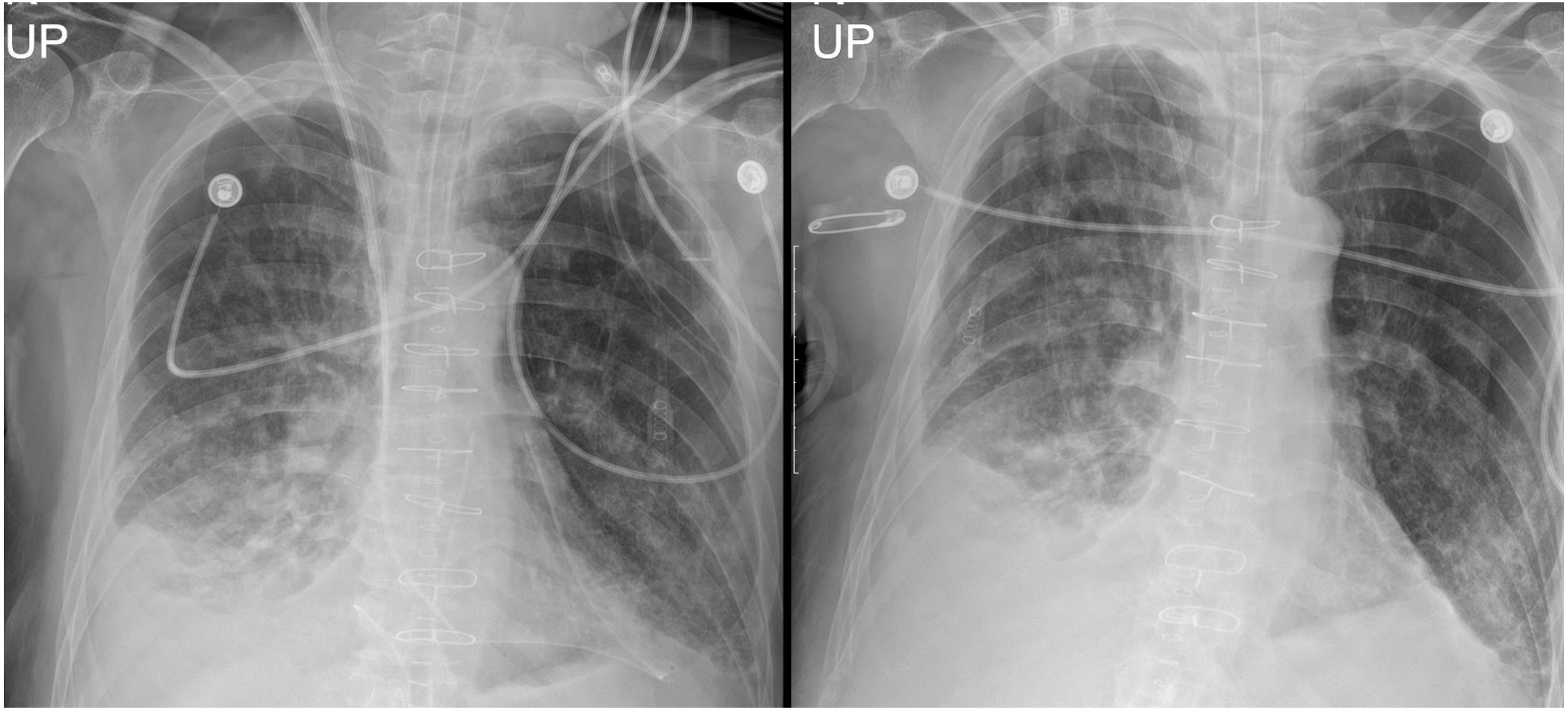
- Comorbidity: Recurred lung cancer at Rt.pleura

> Ventilator: PC mode FiO2 50% RR 26

Driving Pressure 17 cmH2O

PEEP 10 cmH2O

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3. 실제 적용 사례

Table 2 EIT parameters and their applications in different ventilation conditions, for clinical and/or scientific purposes (as per current evidence) as well as bedside availability has been noted

	Ventilatory mode			Purpose		Availability		Comments
	Controlled	Assisted	Non-intubated	Clinical	Research	Bedside	Offline	
VT distribution	+	+	+	+	+	+	+	
EELI distribution	+	+	+	+/−	+	+	+	EELI dependent
Dorsal fraction of ventilation	+	+	+	+	+	+	+	
CoV	+	+	+	+	+	+	+	
Global Inhomogeneity	+/−	+/−	+/−	+/−	+/−	−	+	
OD-CL	+	+/−	+/−	+	+	+	+	Needs standardization
Regional PV-curve	+	−	−	+/−	+	+/−	+	Low-flow insufflation
RVD, RVDi	+	−	−	+/−	+	+	+	Low-flow insufflation
Silent spaces	+	+	+/−	+	+	+	+	
Time constant	+	+/−	+/−	−	+	−	+	
EIT-based R/I ratio	+	+/−	+/−	+/−	+	+	+	EELI dependent
$\dot{V}$/Q matching	+	+/−	+/−	+/−	+	+/−	+	Needs saline bolus
Volume estimation in SB	NA	NA	+	−	+	+/−	+	
Pendelluft detection	+	+	+	+/−	+	+/−	+	

+, the expert panel recommend the use of this parameter in this condition; +/−, the expert panel cannot state any recommendation in this condition; −, the expert panel does not recommend the use of this parameter in this condition

Abbreviations: NA, not applicable; CoV, center of ventilation; EELI, end-expiratory lung impedance; CL, lung collapse; OD, overdistension; PV-curve, pressure–volume curve; R/I ratio, recruitment-to-inflation ratio; RVD(i), regional ventilation delay (index); SB, spontaneous breathing; VT, tidal volume; $\dot{V}$/Q, ventilation-perfusion

Crit Care. 2024 Nov 19;28(1):377.

3. 실제 적용 사례

Table 1. Definition, Clinical Application, and Limitations of the Most Commonly Used EIT Indices in Patients with Hypoxemic Respiratory Failure

EIT Indices	Definition	Potential Applications	Limits
Global inhomogeneity index	Sum of absolute differences between median TIV and each pixel TIV normalized to sum of each pixel TIV	• Reflects heterogeneity of ventilation	• Does not reflect local distribution of TIV • Does not take into account overdistension, collapse, or any other pathological situation
Overdistension and collapse estimation	Estimation of relative local compliance loss presented as percentage of collapse and overdistension during decremental PEEP trial	• Selection of PEEP level that jointly minimizes collapse and overdistension • Applicable even on venovenous ECMO when V_T is very low	• Assumes that ΔP on ventilator is reliable surrogate of regional ΔP • Depends on highest and lowest values of PEEP applied during PEEP trial
Regional ventilation delay	Time between start of inspiration and aeration of lung regions	• Identify recruitable lung regions and cyclic opening/closing phenomenon • Could be used to identify best PEEP level with most homogenized tidal inflation	• Requires a slow inflation maneuver with constant flow • Depends on defined threshold • Does not detect not-recruitable or overdistended regions

Definition of abbreviations: ΔP = driving pressure; ECMO = extracorporeal membrane oxygenation; EELI = end-expiratory lung impedance; EELV = end-expiratory lung volume; EIT = electrical impedance tomography; PEEP = positive end-expiratory lung pressure; TIV = tidal impedance variation.

Am J Respir Crit Care Med . 2024 Mar 15;209(6):670-682

3. 실제 적용 사례

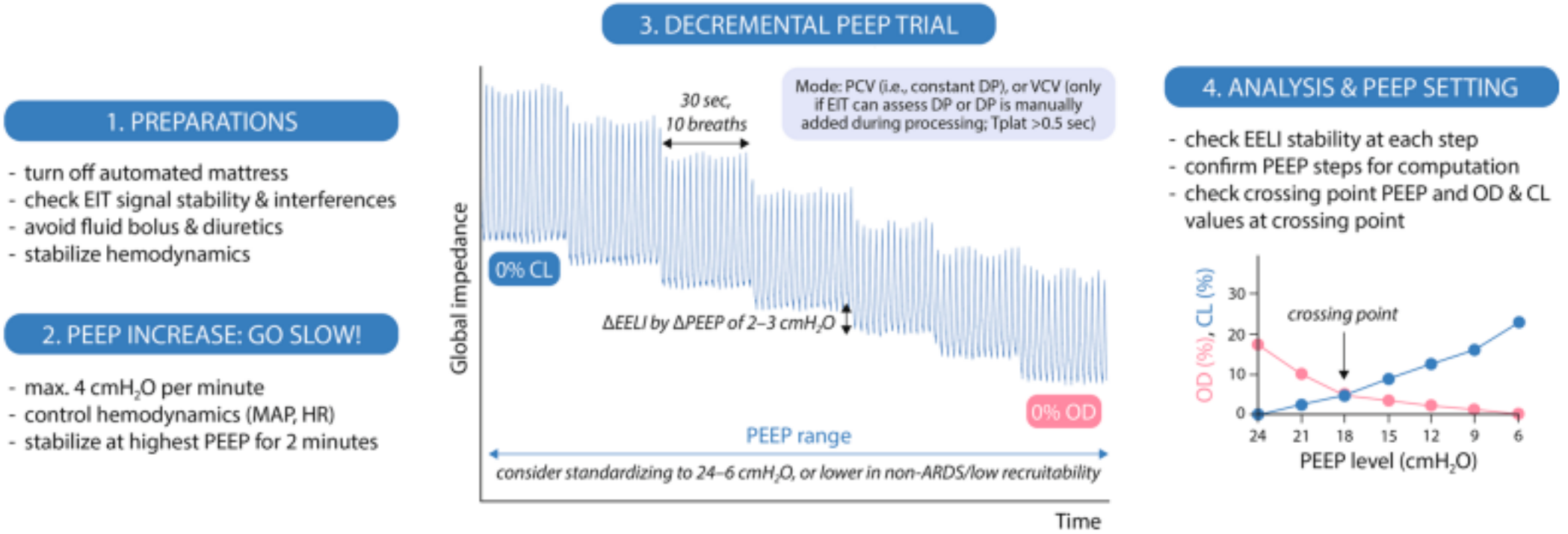


Fig. 2 EIT-based PEEP titration: step-by-step recommendations. The PEEP selection is generally made at the crossing point of the OD and CL curves; if the crossing point is between two PEEP levels, values are usually rounded up to the nearest integer. Abbreviations: ARDS, acute respiratory distress syndrome; DP, driving pressure; EELI, end-expiratory lung impedance; EIT, electrical impedance tomography; HR, heart rate; CL, lung collapse; MAP, mean arterial pressure; OD, overdistension, PEEP, positive end-expiratory pressure; PCV, pressure-controlled ventilation; Tplat, time (duration) of plateau pressure; VCV, volume-controlled ventilation

3. 실제 적용 사례

- **Case 3: Fe**Male/56 yr

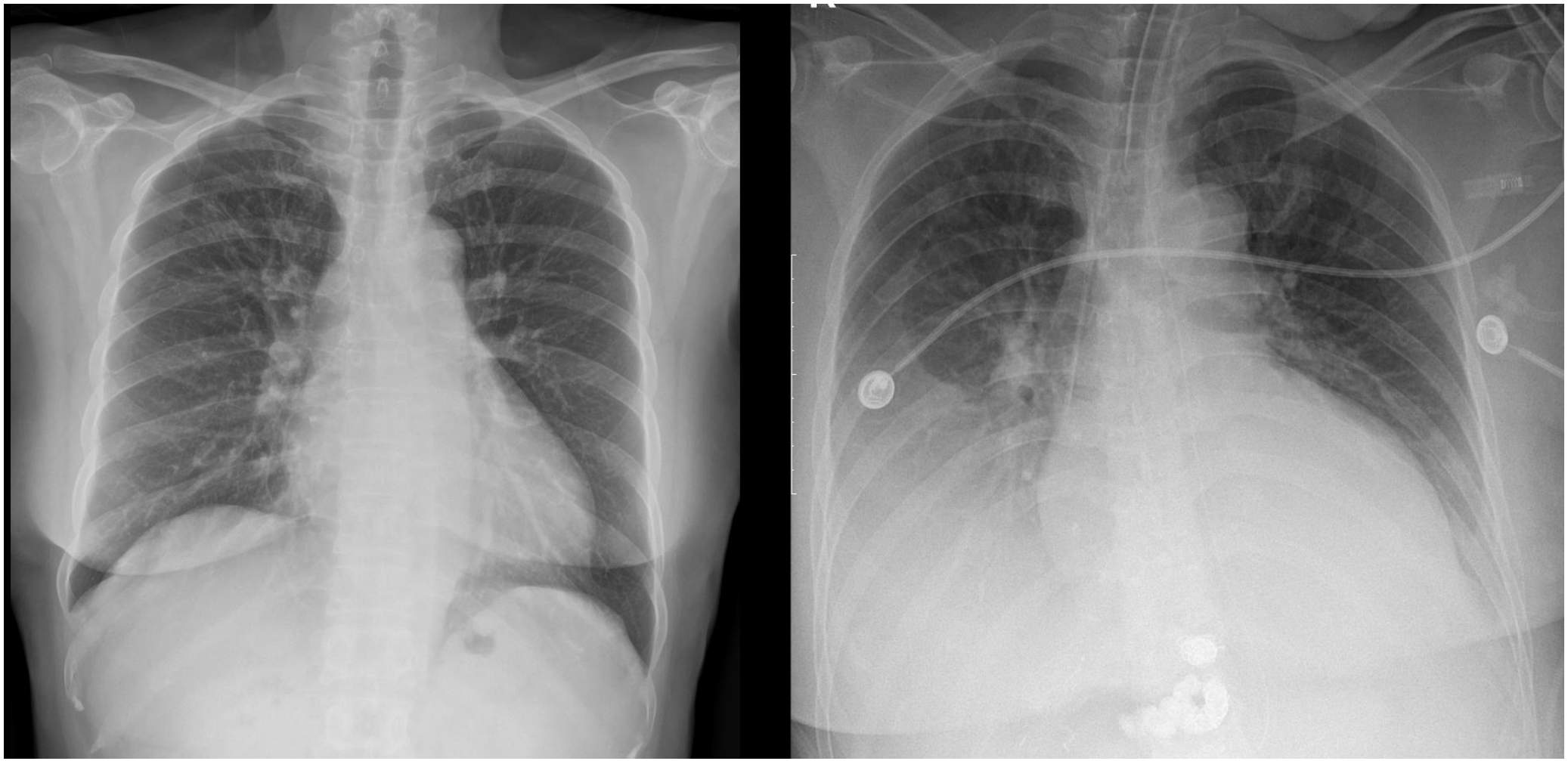
Main problem: Weaning failure

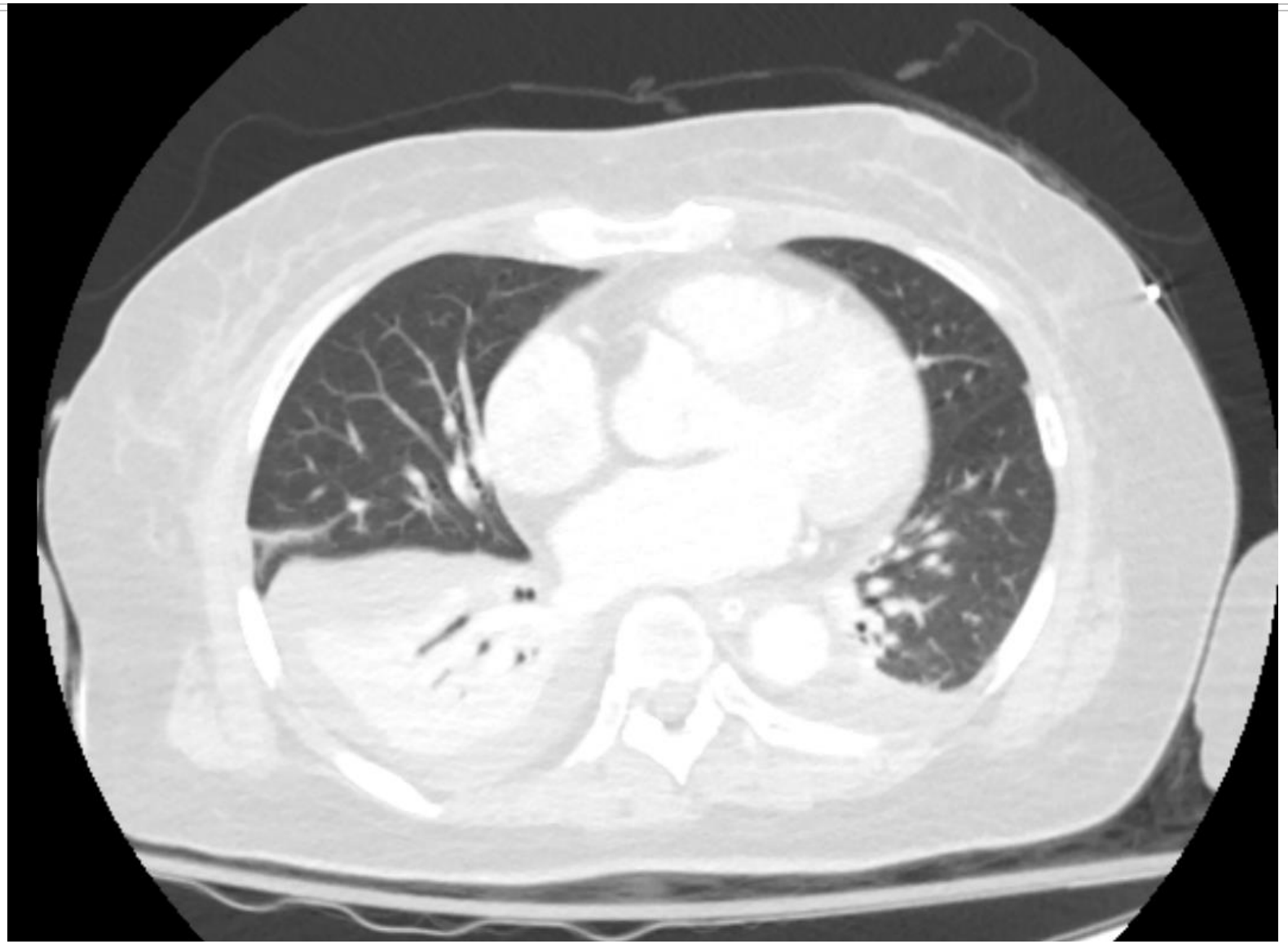
- Comorbidity: Post-liver transplantation status (#POD 6)

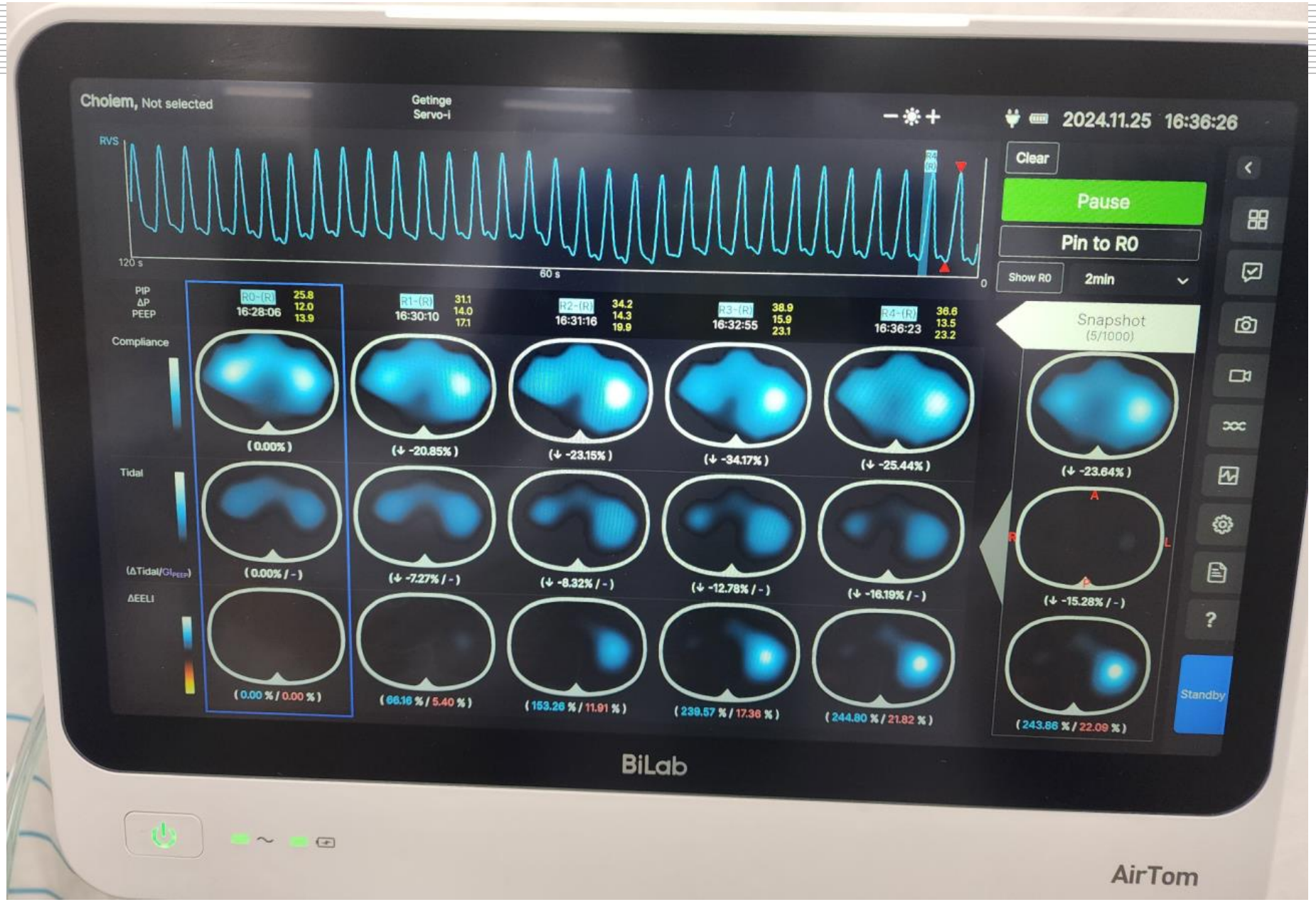
> Ventilator: PC mode FiO2 60% RR 15

Driving Pressure 13 cmH2O

PEEP 10 cmH2O







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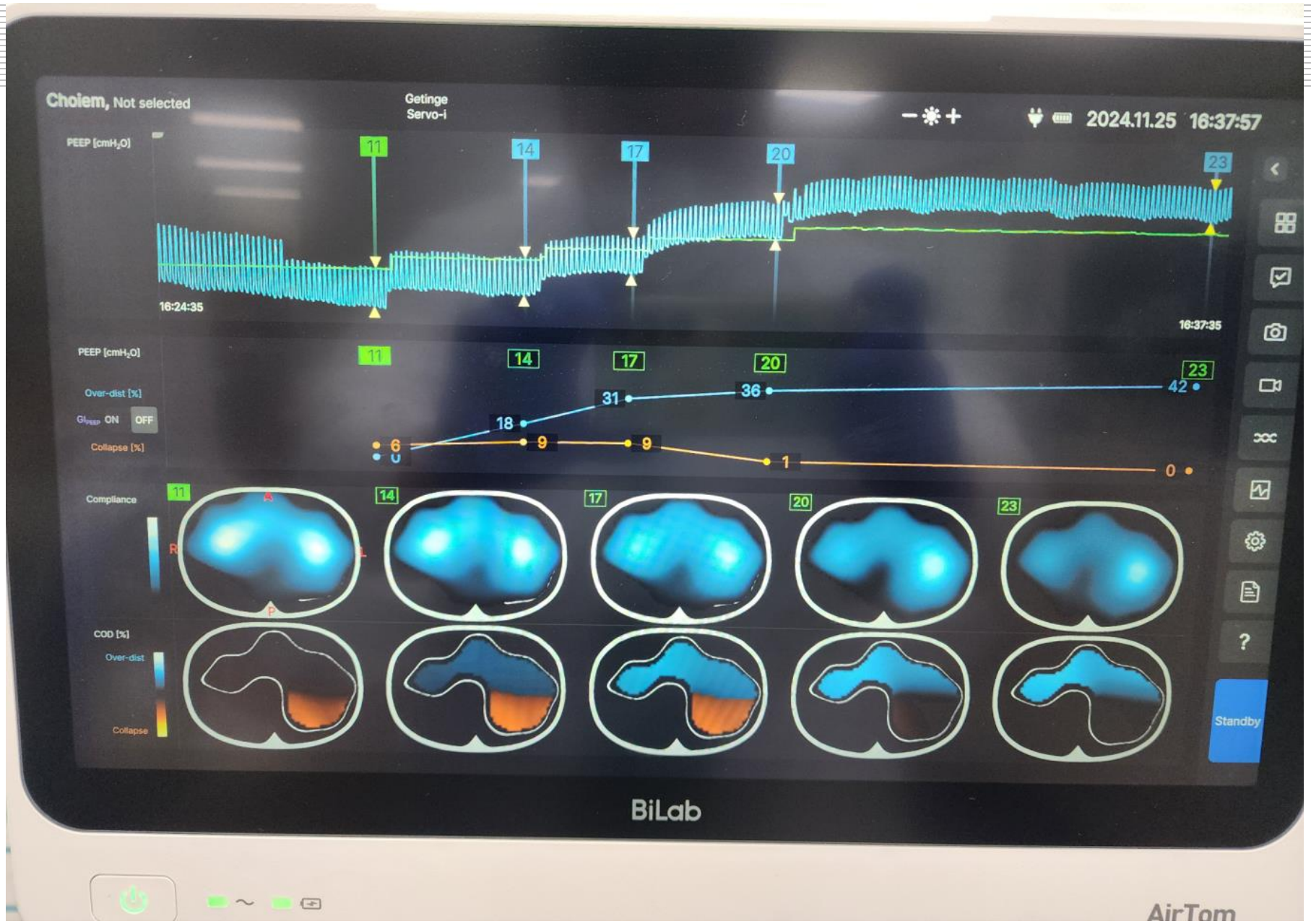

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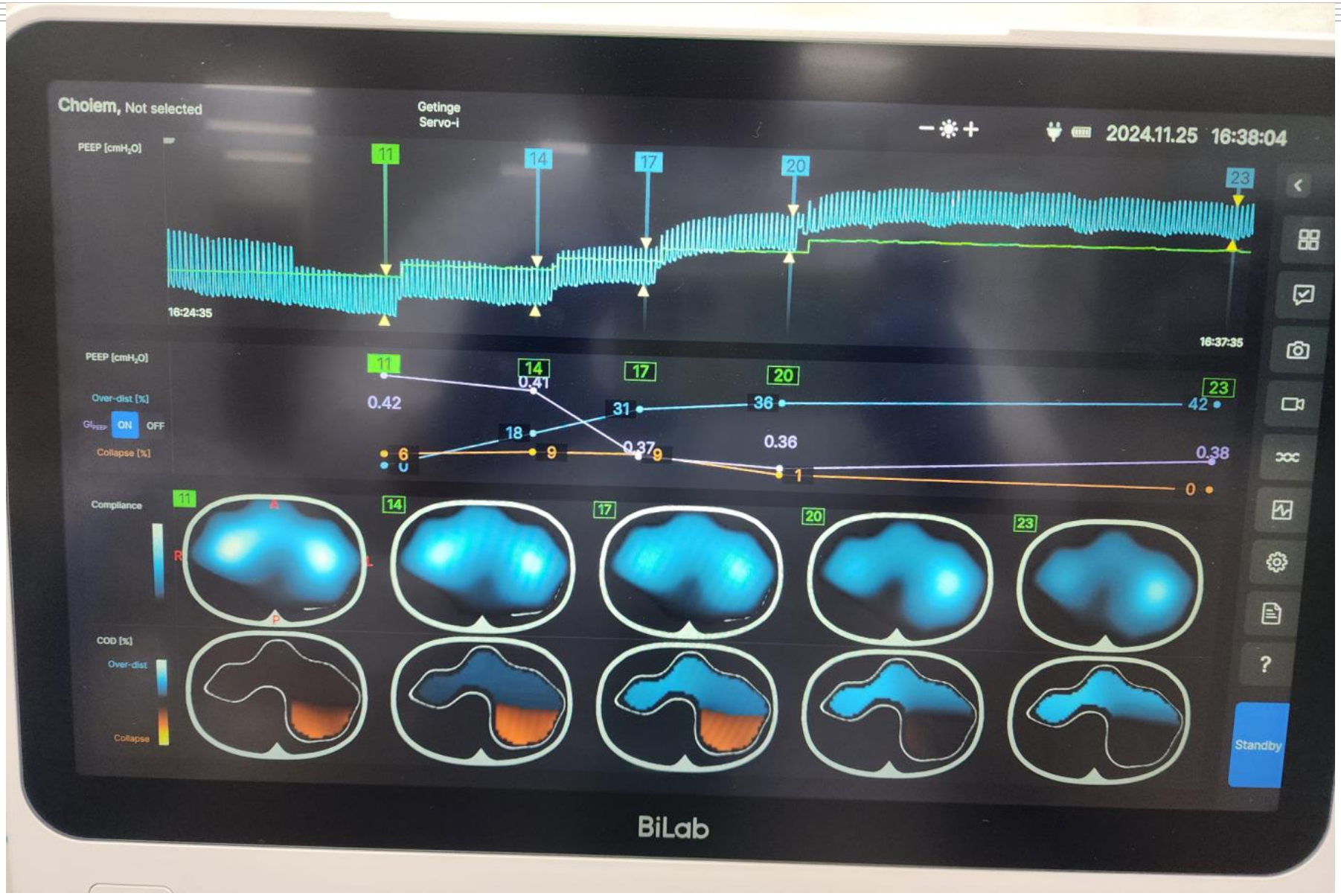

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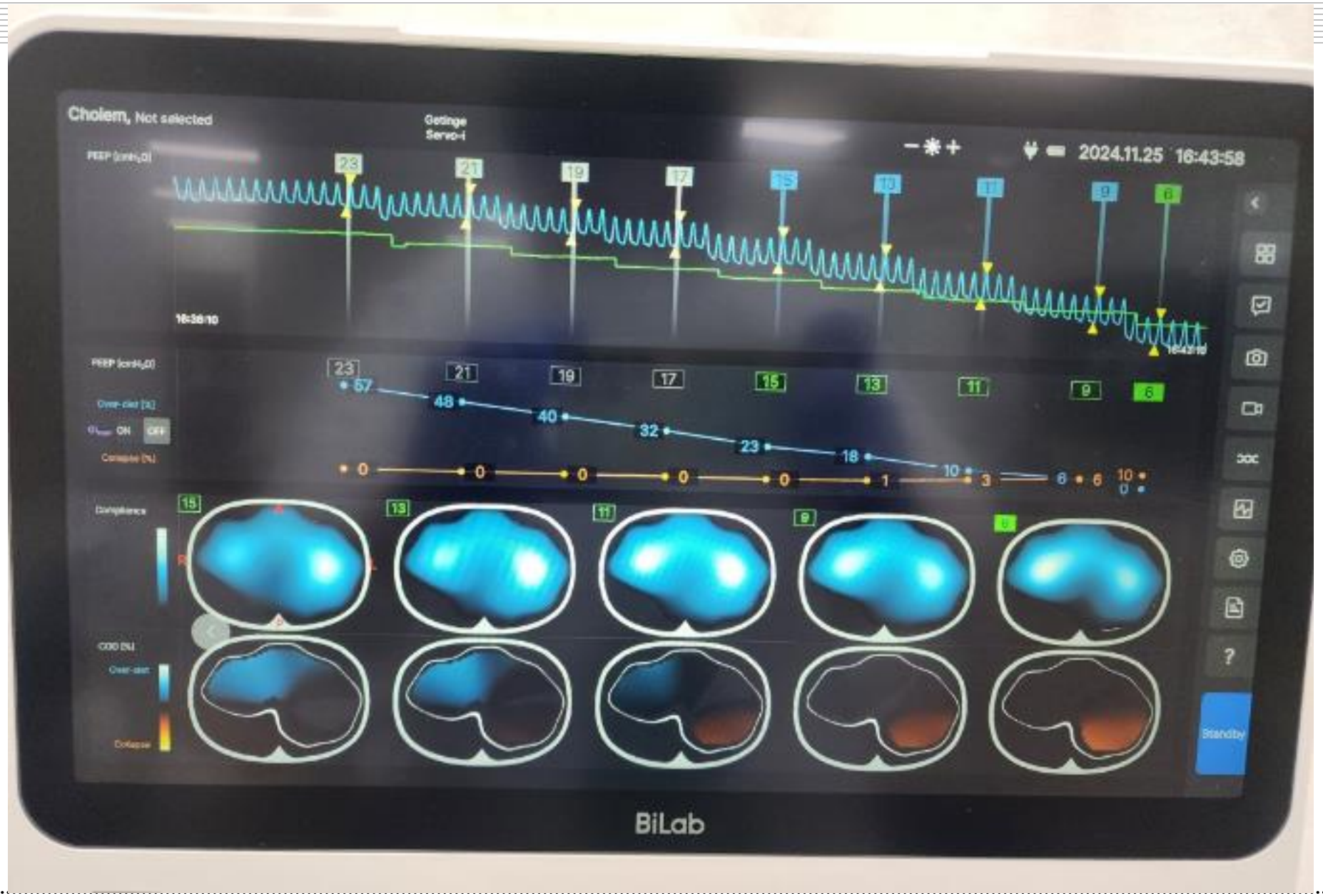

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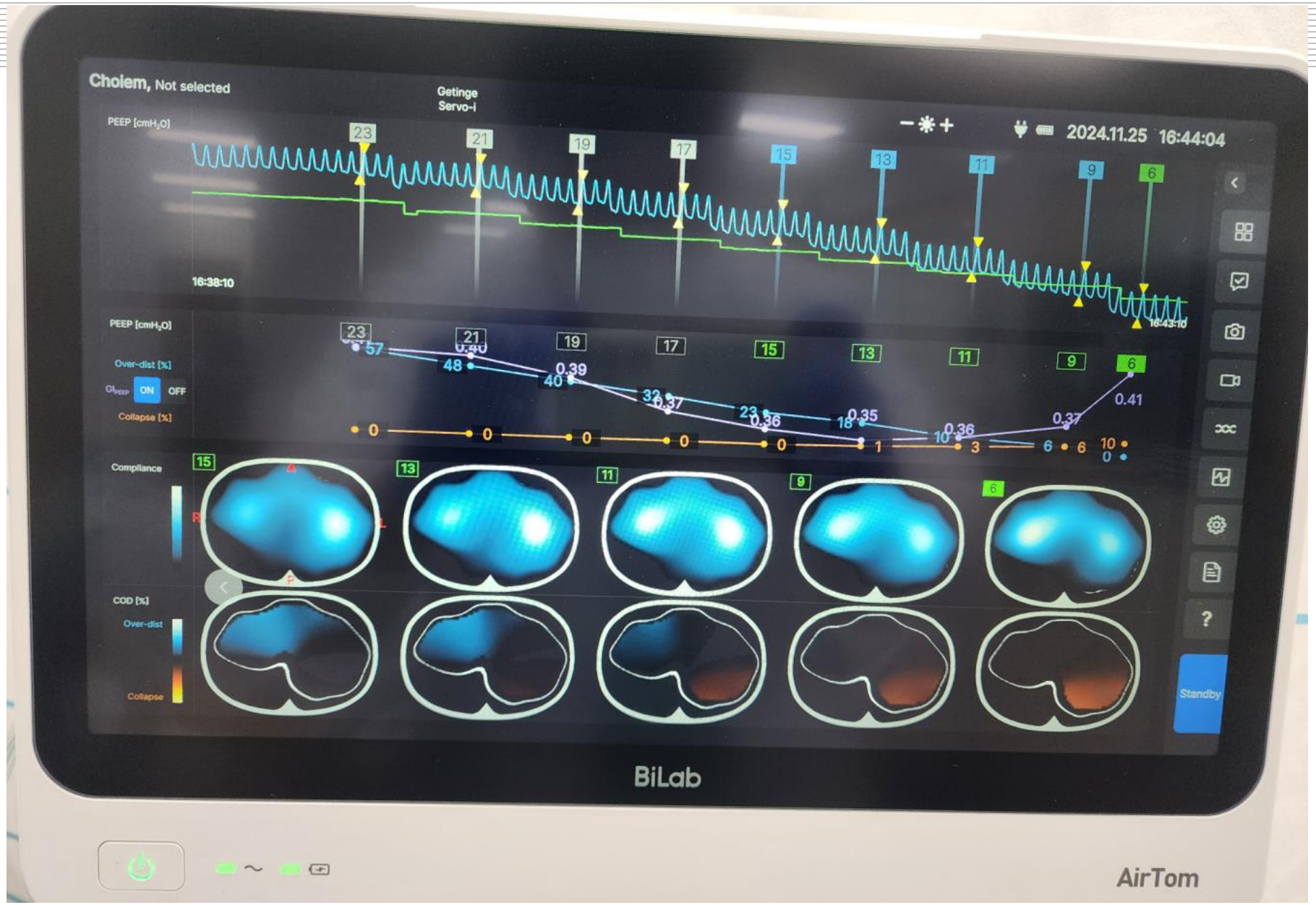

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오후 2:02

읽음
오후 5:18

폴더 열기 | 드라이브에 저장

선생님, [redacted]님 저희 EIT 장비로 PEEP titration 해봤습니다. PEEP을 올려서 LLL ccollapse를 펼려면 PEEP이 20 이상이 필요하고 그정도에서도 RLL은 펴지지 않았습니다. EIT 장비로 측정 시에는 9~10 정도가 현재 lung 상태에서는 가장 적절한 PEEP으로 나와서 10으로 설정했습니다. Volume control하시면 pleural pressure가 줄어드셔야 양측 폐 하부가 펴질 것 같습니다. 우측은 컨디션이 되시면 thoracentesis나 pigtail insertion으로 effusion을 빼보시는 것도 고려해보시기 바랍니다.

읽음
오후 5:21

메시지를 입력해주세요. (Enter: 전송 / Shift + Enter: 줄바꿈)

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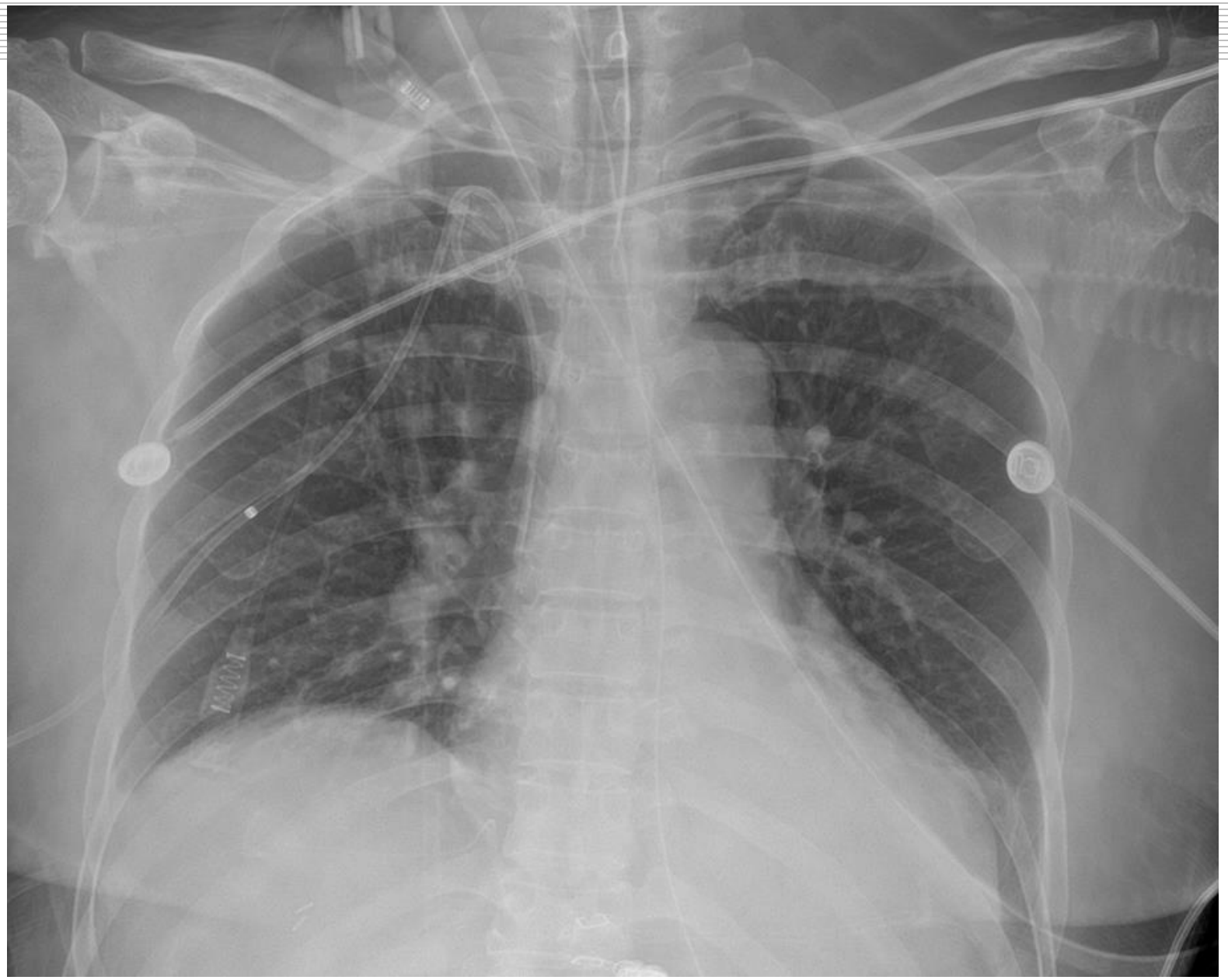

3. 실제 적용 사례

- **Case 4:** FeMale/63 yr

Main problem: IPF AE

- Comorbidity: DM

> Ventilator: PC mode FiO2 45% RR 16

Driving pressure 20 cmH2O PEEP 5 cmH2O

> VV ECMO: Fem-Jug Flow 3.8 L/min (95%) Gas 3.5 L/min


K AP

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Online calculators for advanced respiratory monitoring. Use the calculators or create an account for access to a more advanced assessment form.

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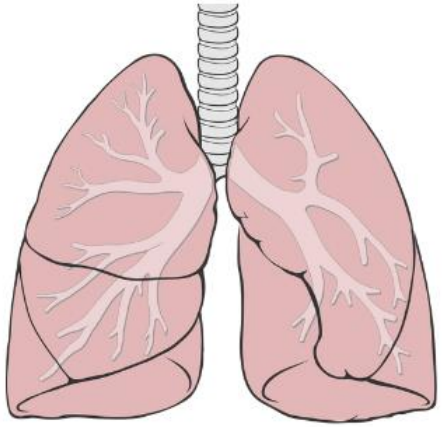

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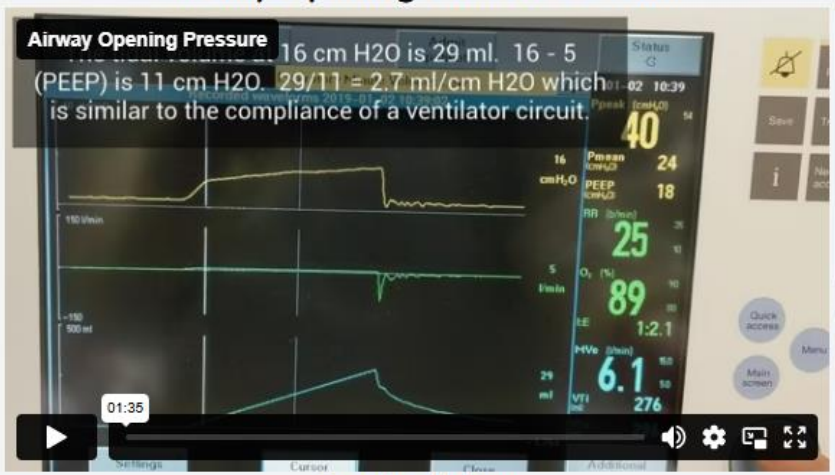
Created by Thomas Piraino RRT in collaboaration with Lu Chen MD, Michele Bertoni MD and Ewan Goligher MD PhD

Reference Videos

Airway Opening Pressure Servoi



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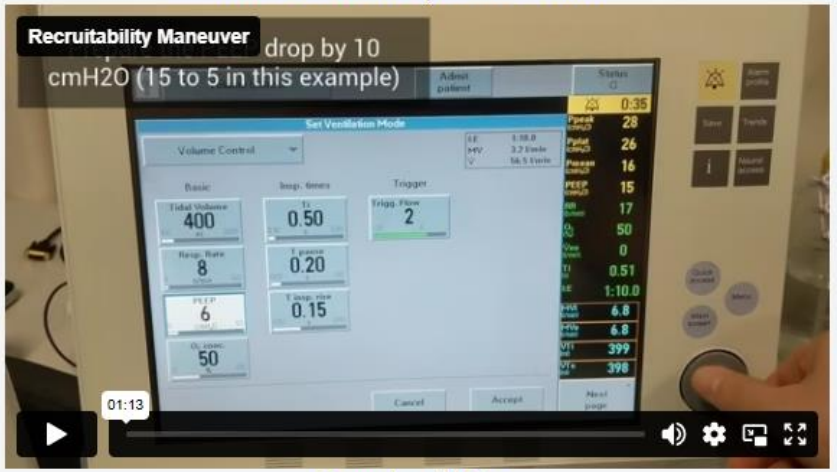
Recruitability Maneuver



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Airway Opening Pressure PB980

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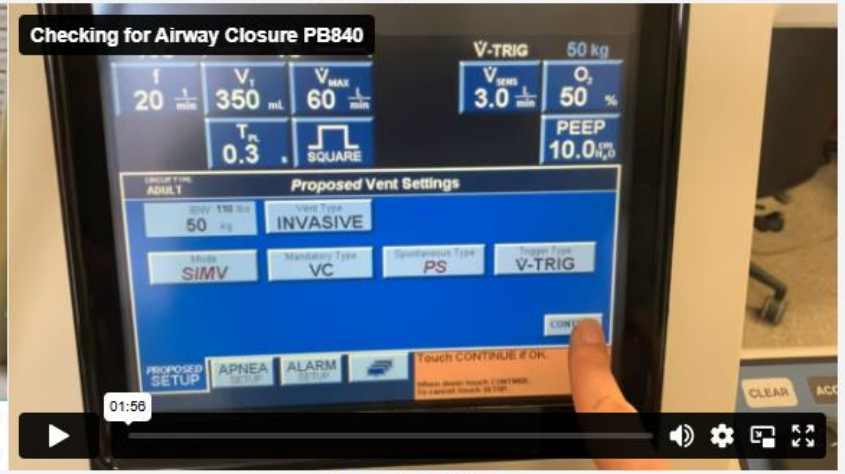
Airway Opening Pressure PB840



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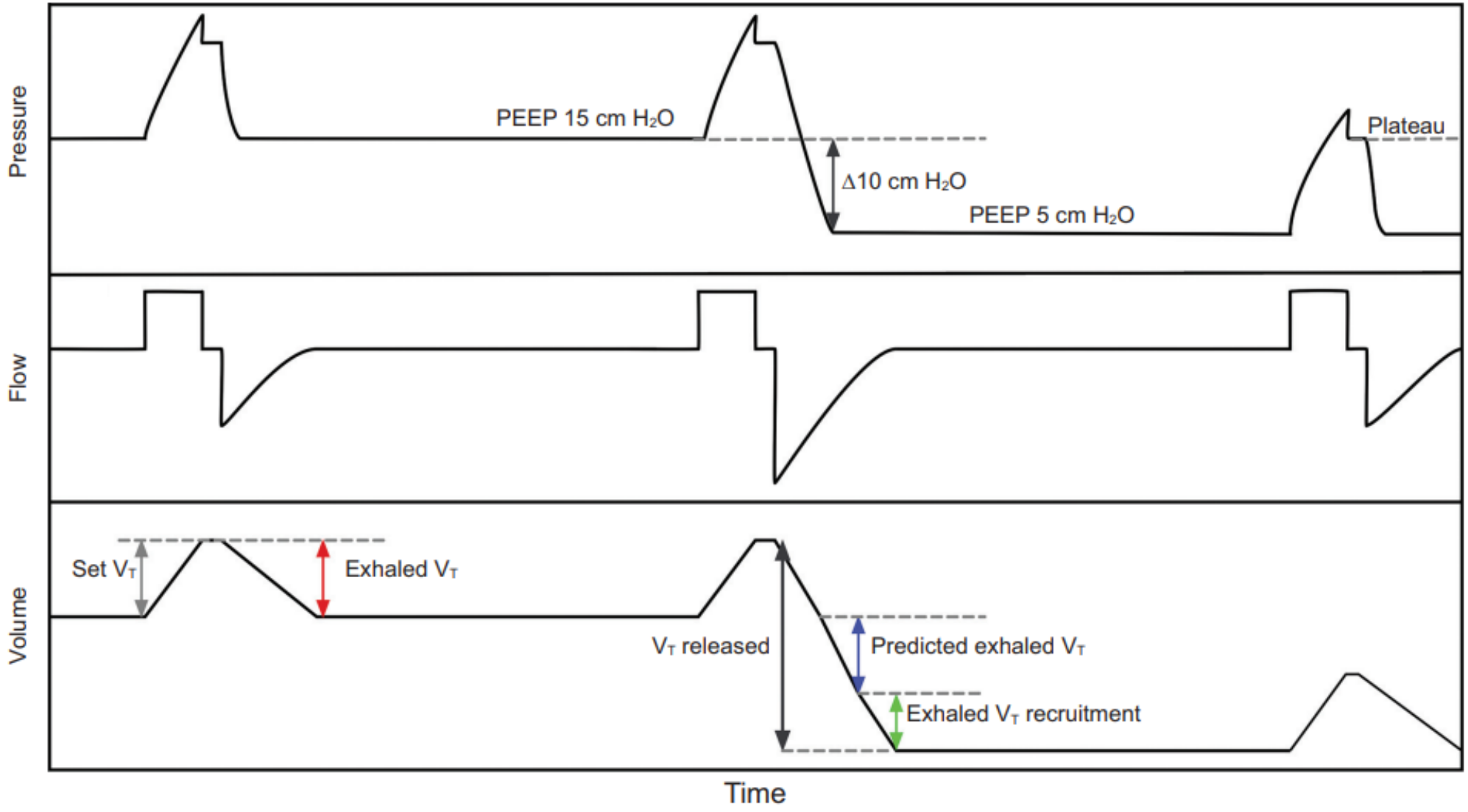
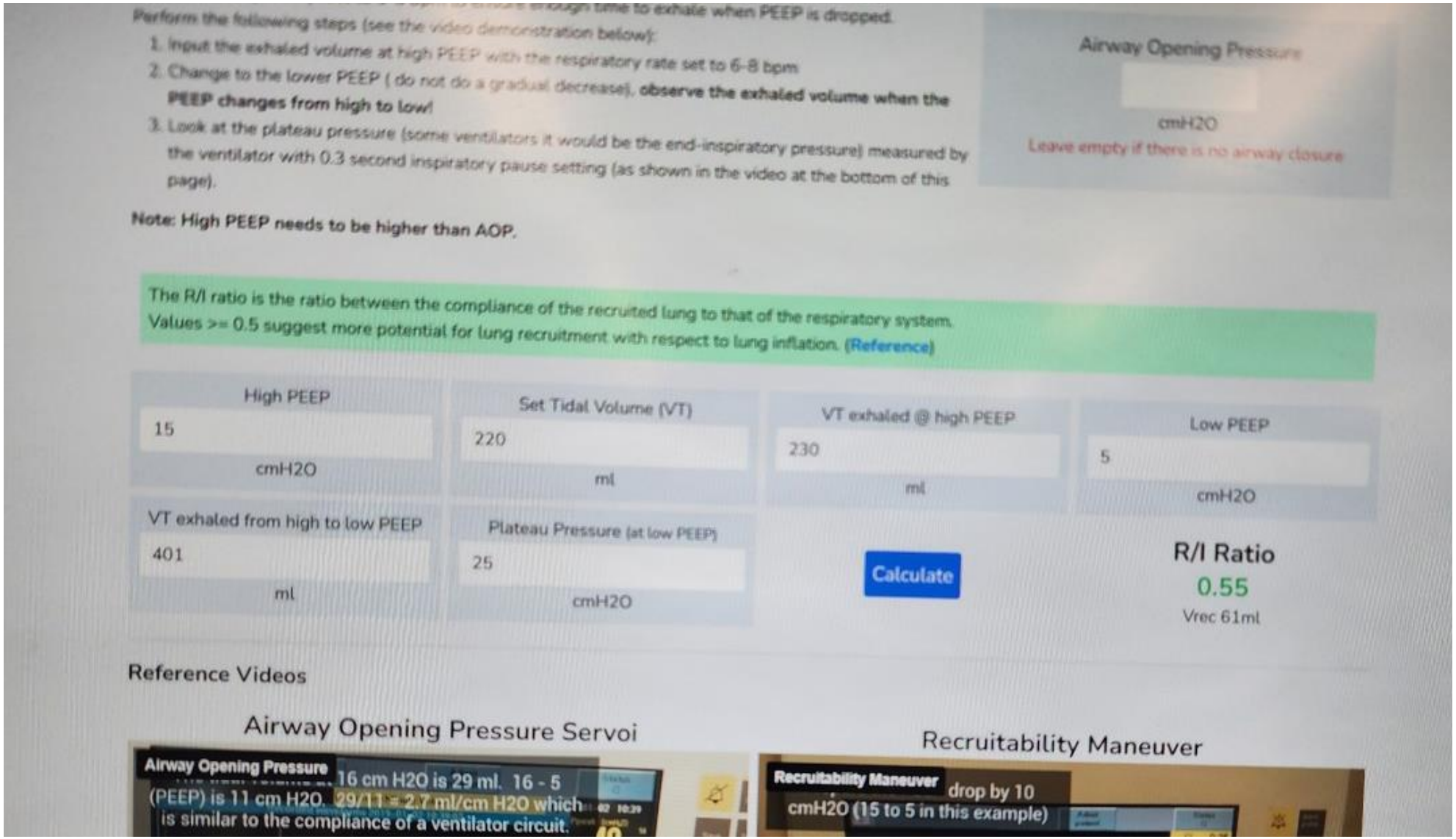


Respir Care . 2020 Jun;65(6):760-771.



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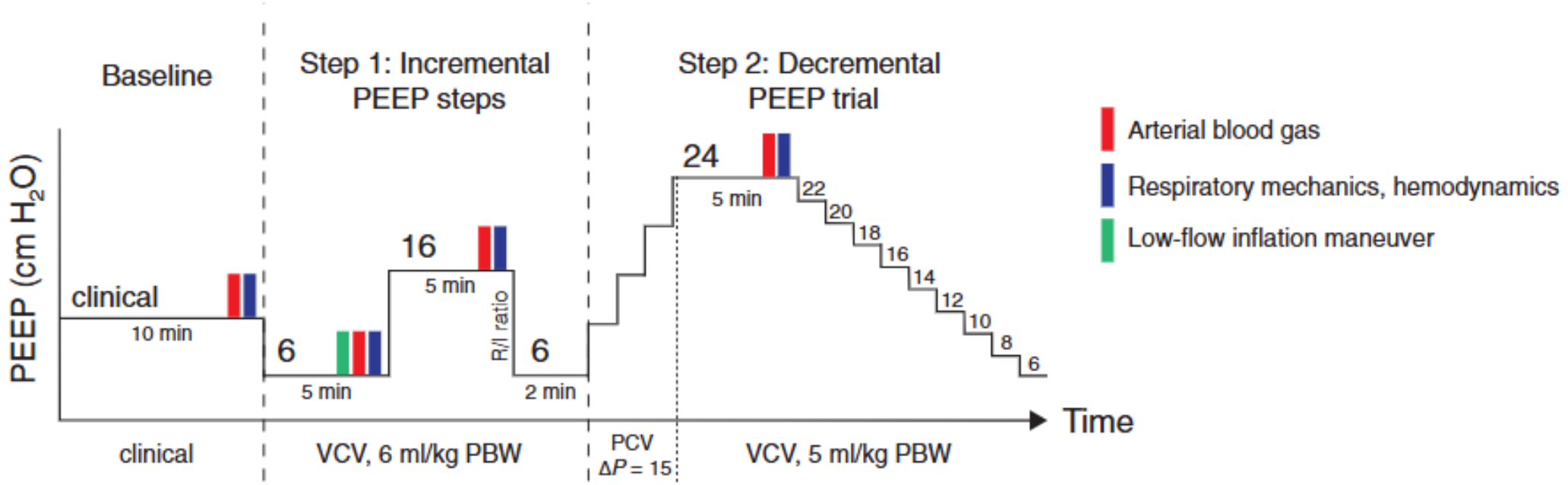
Lung Recruitment Assessed by Electrical Impedance Tomography (RECRUIT)

A Multicenter Study of COVID-19 Acute Respiratory Distress Syndrome

Annemijn H. Jonkman[1,2,3*], Glasiele C. Alcala[4*], Bertrand Pavlovsky[5,6], Oriol Roca[7,8], Savino Spadaro[9,10], Gaetano Scaramuzzo[9,10], Lu Chen[1,2], Jose Dianti[2,11], Mayson L. de A. Sousa[1,2,4], Michael C. Sklar[1,2], Thomas Piraino[1,2], Huiqing Ge[12], Guang-Qiang Chen[13], Jian-Xin Zhou[13], Jie Li[14], Ewan C. Goligher[2,11,15], Eduardo Costa[4], Jordi Mancebo[16†], Tommaso Mauri[17‡], Marcelo Amato[4‡], and Laurent J. Brochard[1,2‡]; for the Pleural Pressure Working Group (PLUG)



Am J Respir Crit Care Med. 2023 Jul 1;208(1):25-38.

3. 실제 적용 사례

- **Case 5:** Male/57 yr

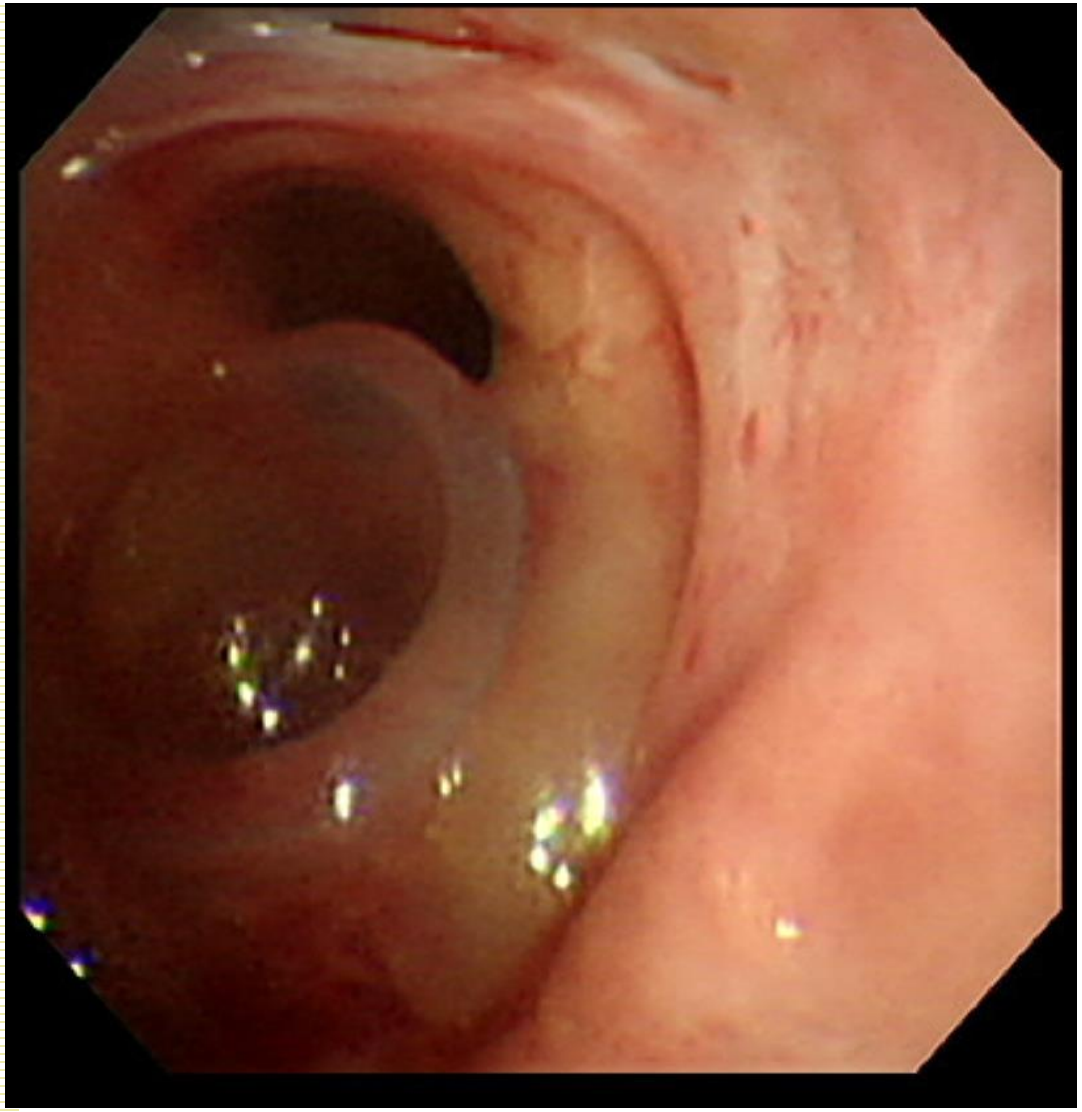
Main problem: Chronic lung allograft dysfunction

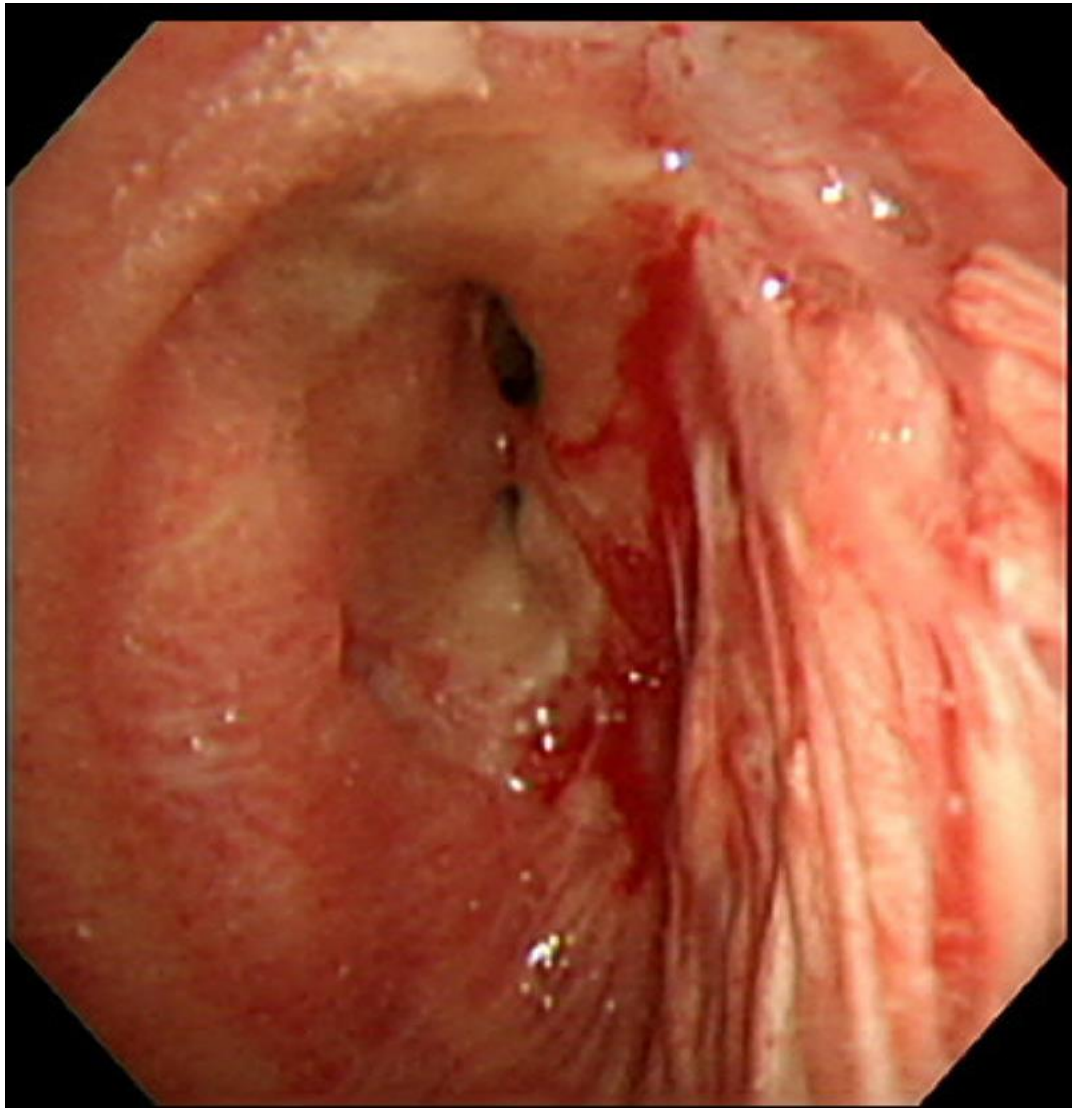
- Comorbidity: COPD s/p LTPL #2 (2024.4, 2024.5)

> Ventilator: PC mode FiO2 40% RR 20

Driving Pressure 18 cmH2O

PEEP 8 cmH2O





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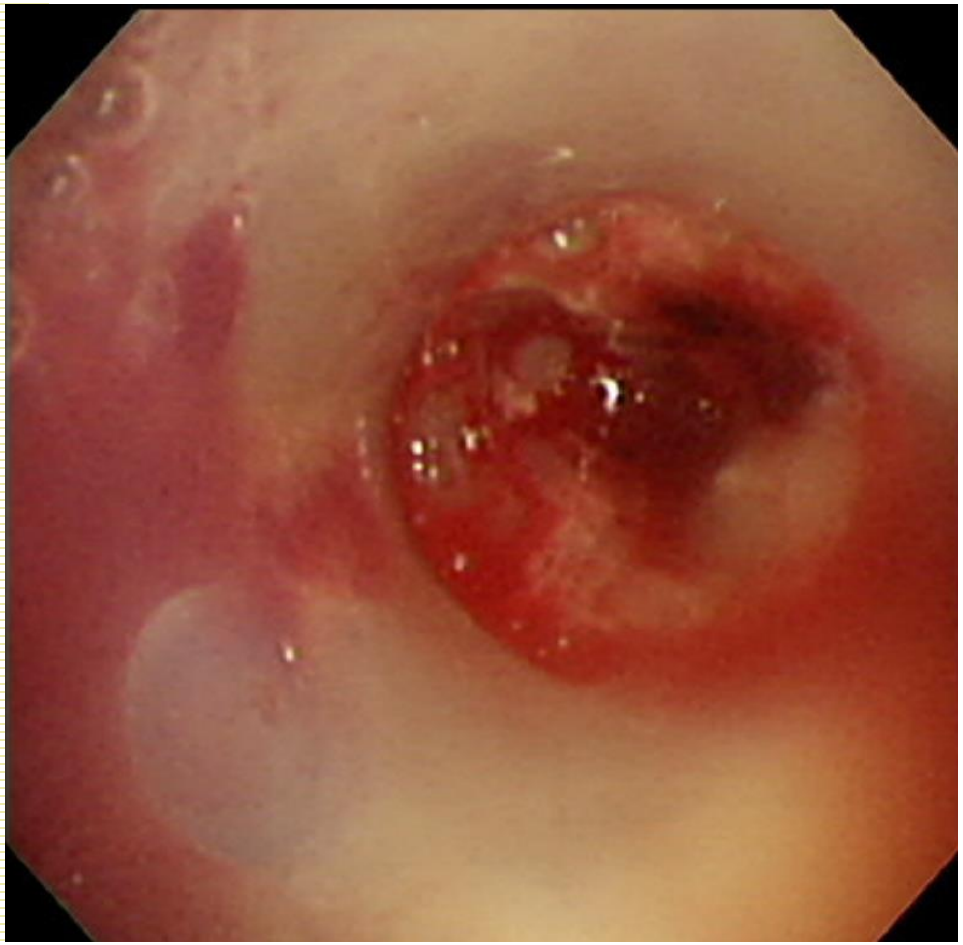

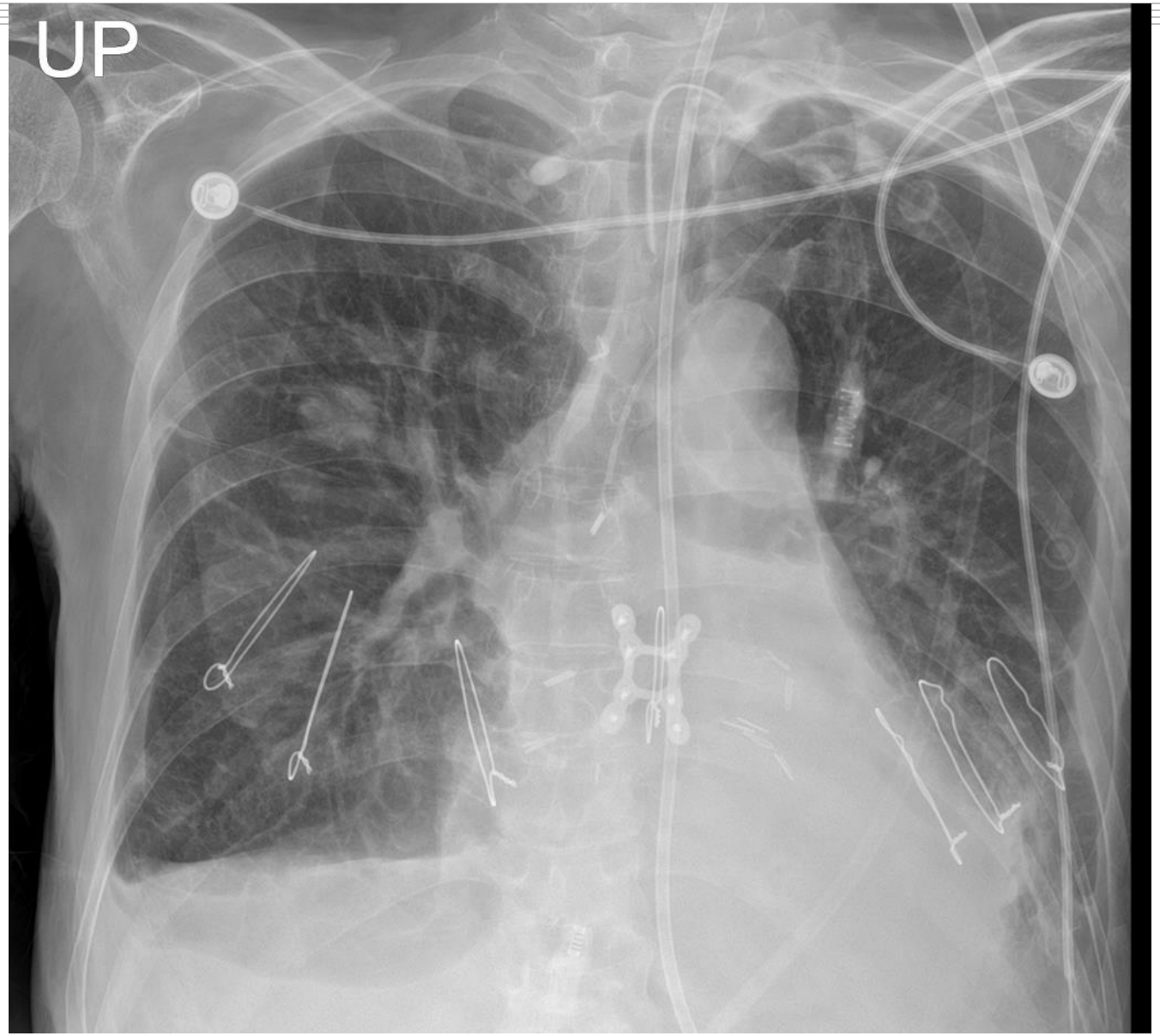
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3. 실제 적용 사례

- **Case 6:** Male/62 yr

Main problem: Fungal pneumonia

- Comorbidity: s/p LT (3YA), h/o organizing pneumonia

> Ventilator: PC mode FiO2 40% RR 22

Driving Pressure 10 cmH2O

PEEP 10 cmH2O

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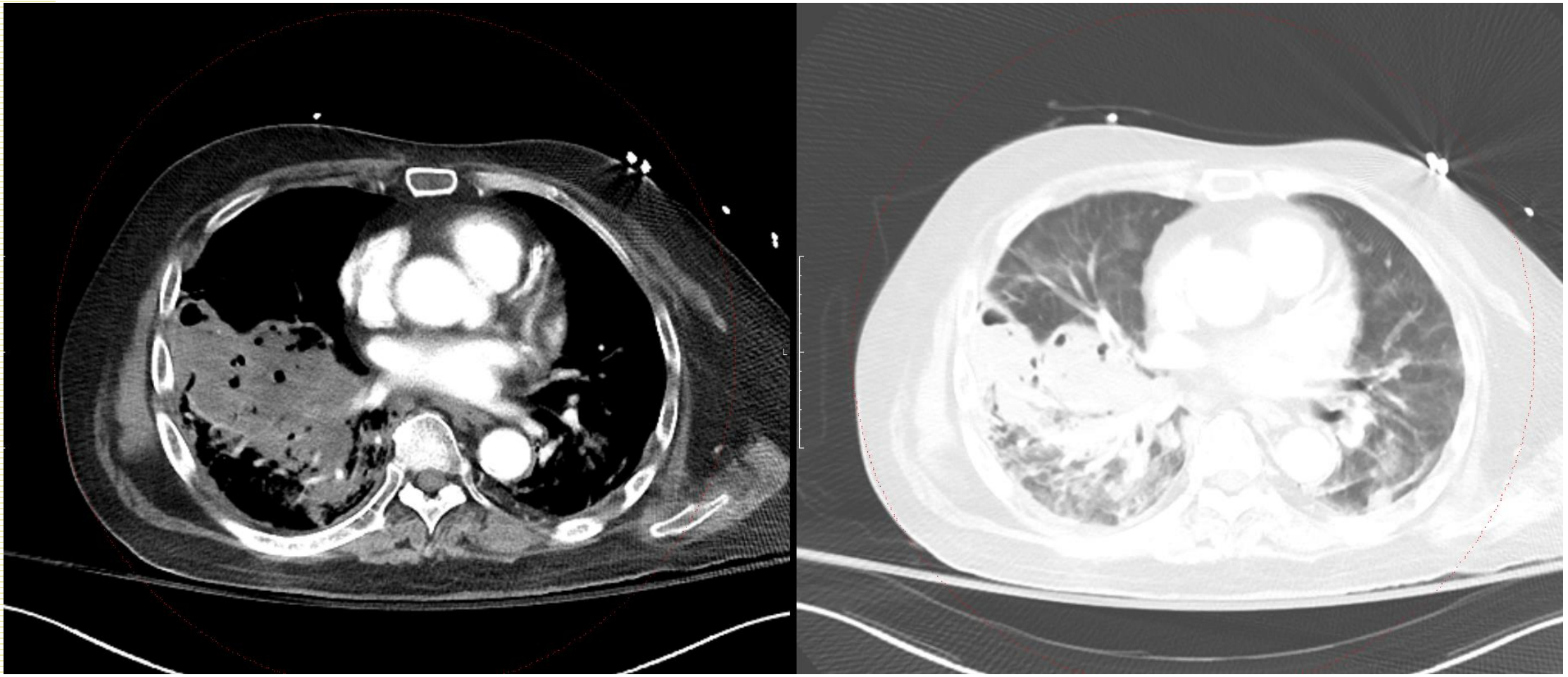

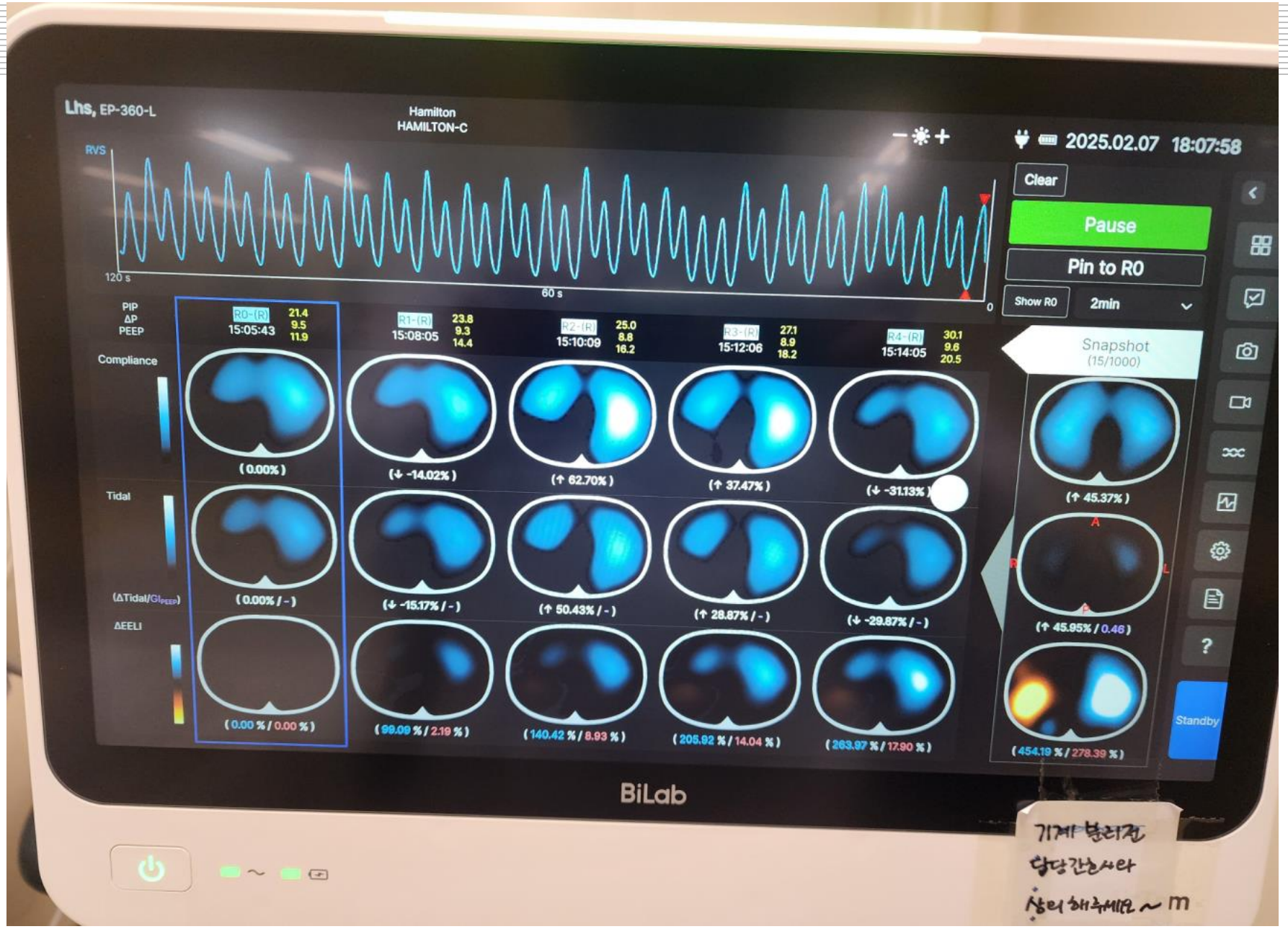
Lhs, EP-360-L
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HAMILTON-C
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RVS
120 s
60 s
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Clear
Pause
Pin to R0
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PEEP
Compliance
Tidal
(ΔTidal/GI PEEP)
ΔEELI
R0-(R) 15:05:43 21.4 9.5 11.9
R1-(R) 15:08:05 23.8 9.3 14.4
R2-(R) 15:10:09 25.0 8.8 16.2
R3-(R) 15:12:06 27.1 8.9 18.2
R4-(R) 15:14:05 30.1 9.6 20.5
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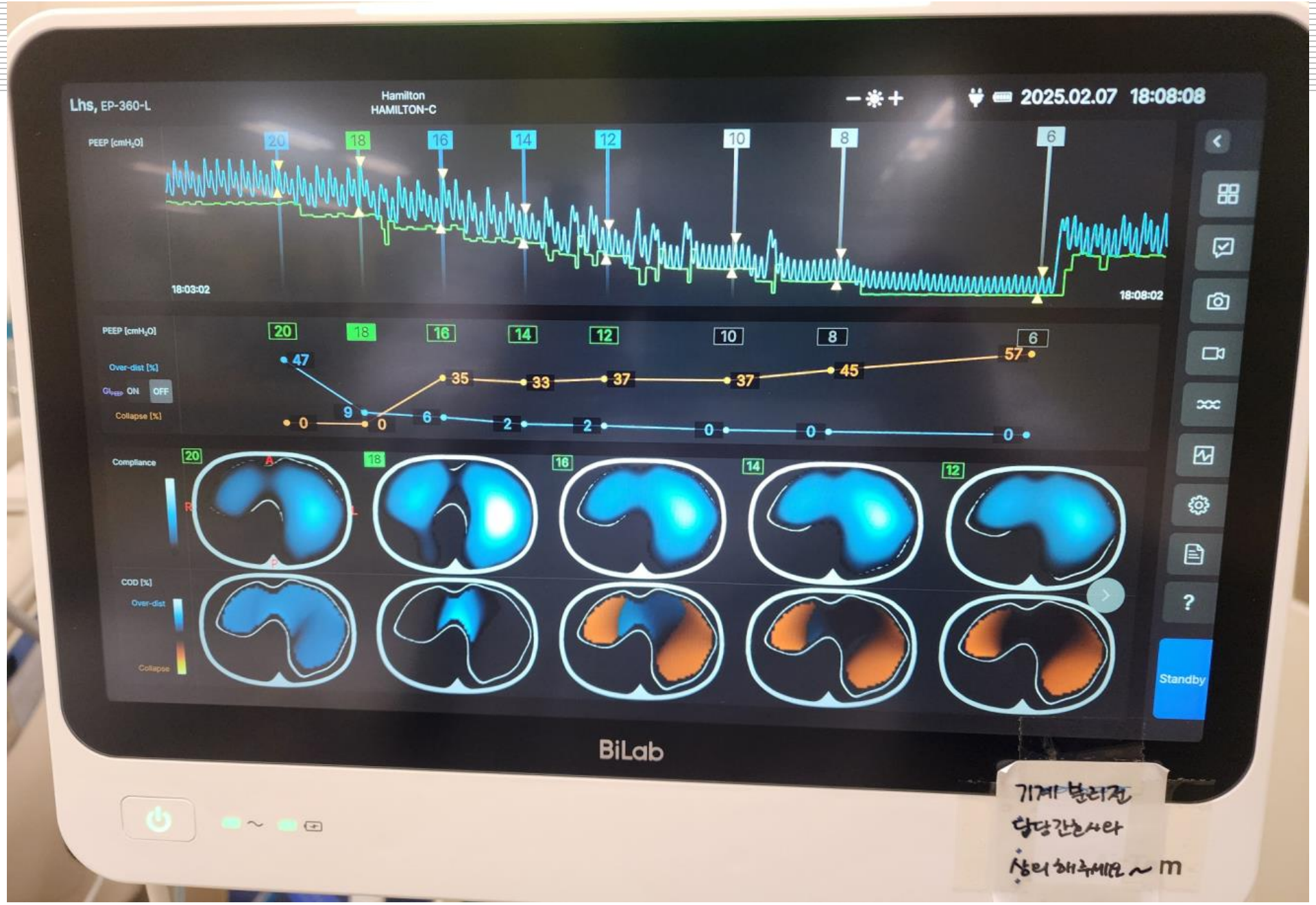
(↑ 62.70%)
(↑ 37.47%)
(↓ -31.13%)
(↑ 45.37%)
(0.00% / -)
(↓ -15.17% / -)
(↑ 50.43% / -)
(↑ 28.87% / -)
(↓ -29.87% / -)
(↑ 45.95% / 0.46)
(0.00 % / 0.00 %)
(99.09 % / 2.19 %)
(140.42 % / 8.93 %)
(205.92 % / 14.04 %)
(283.97 % / 17.90 %)
(454.19 % / 278.39 %)
Standby
BiLab



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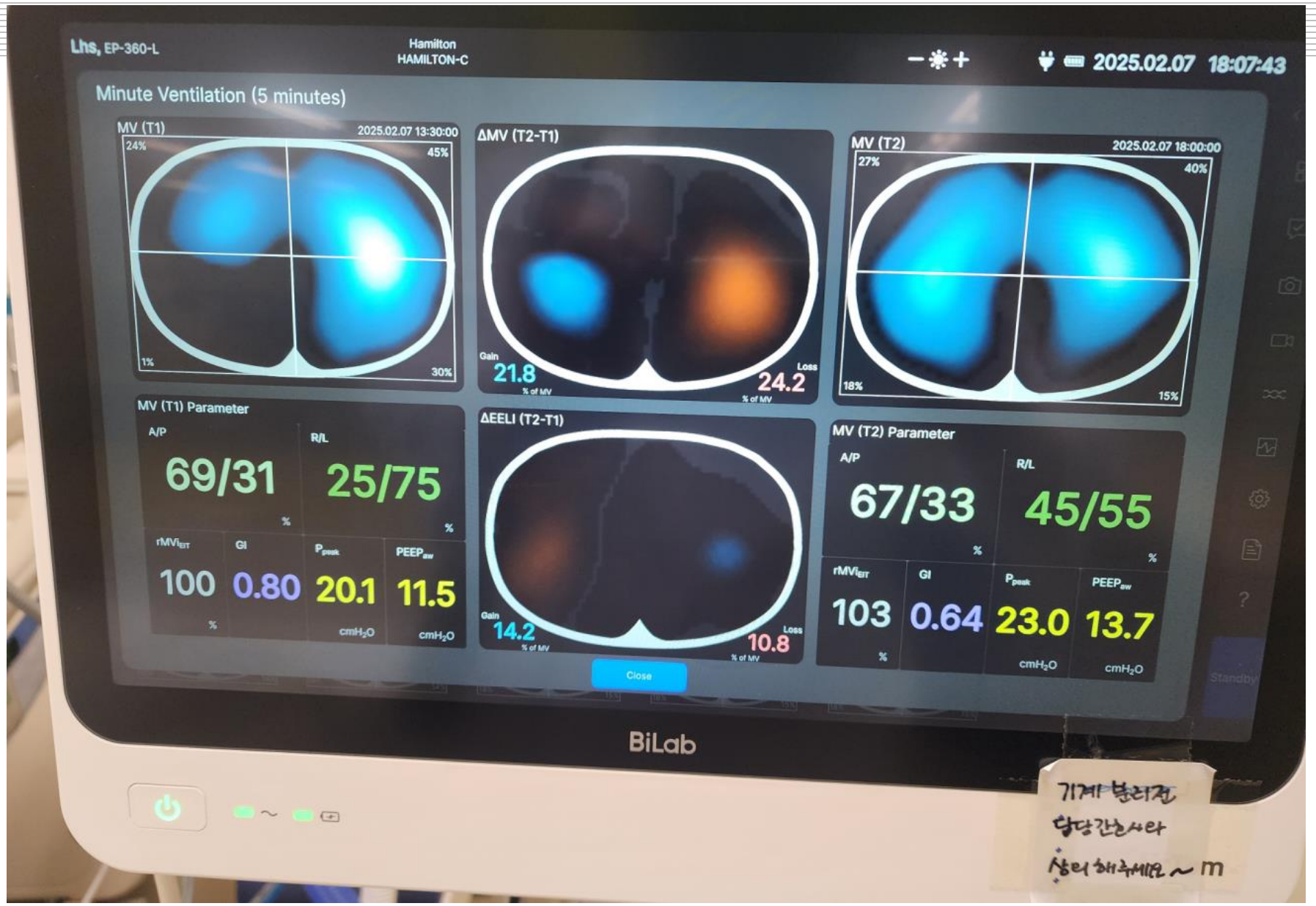

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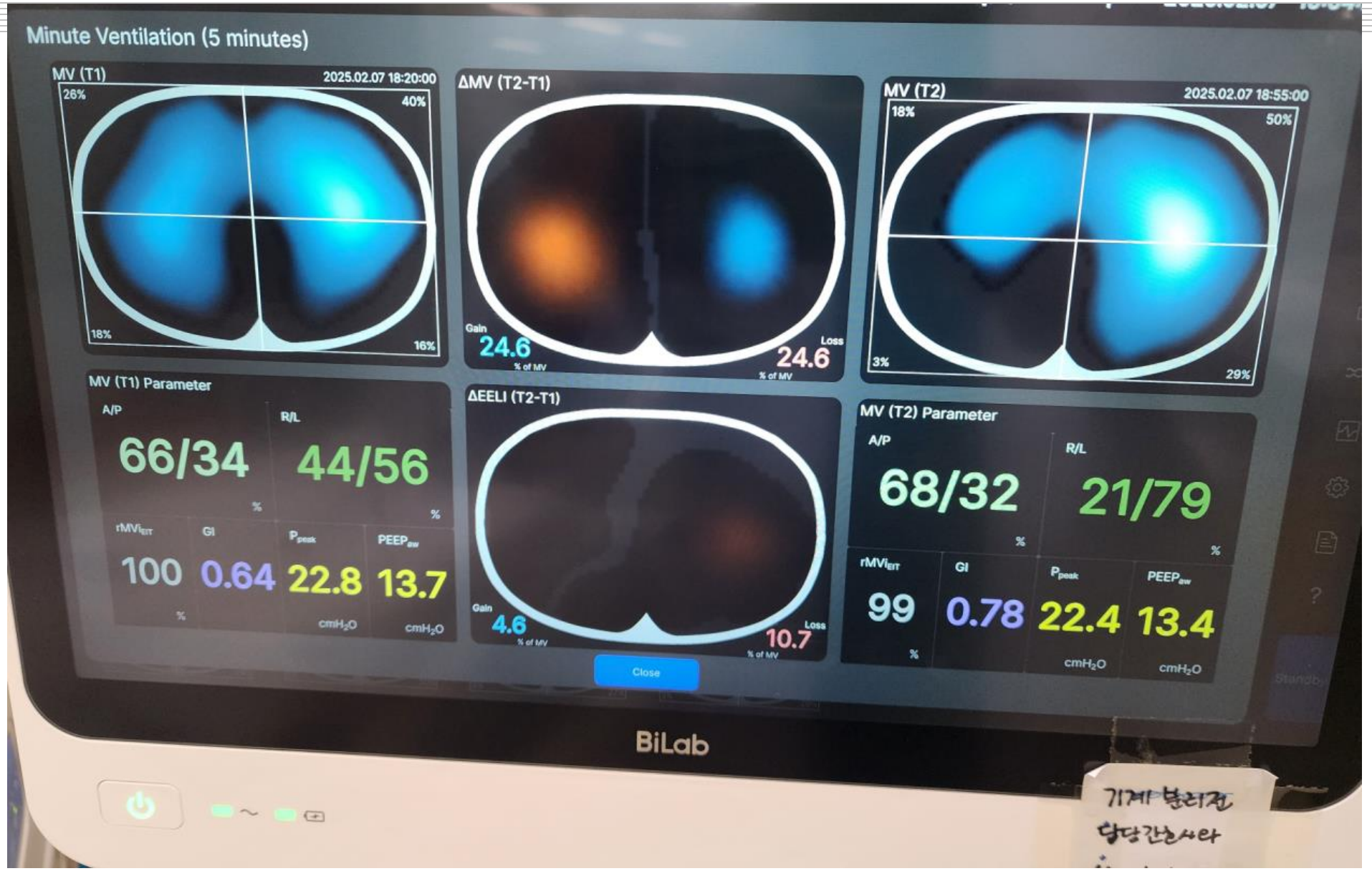

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3. 실제 적용 사례

Table 2 EIT parameters and their applications in different ventilation conditions, for clinical and/or scientific purposes (as per current evidence) as well as bedside availability has been noted

	Ventilatory mode			Purpose		Availability		Comments
	Controlled	Assisted	Non-intubated	Clinical	Research	Bedside	Offline	
VT distribution	+	+	+	+	+	+	+	
EELI distribution	+	+	+	+/−	+	+	+	EELI dependent
Dorsal fraction of ventilation	+	+	+	+	+	+	+	
CoV	+	+	+	+	+	+	+	
Global Inhomogeneity	+/−	+/−	+/−	+/−	+/−	−	+	
OD-CL	+	+/−	+/−	+	+	+	+	Needs standardization
Regional PV-curve	+	−	−	+/−	+	+/−	+	Low-flow insufflation
RVD, RVDi	+	−	−	+/−	+	+	+	Low-flow insufflation
Silent spaces	+	+	+/−	+	+	+	+	
Time constant	+	+/−	+/−	−	+	−	+	
EIT-based R/I ratio	+	+/−	+/−	+/−	+	+	+	EELI dependent
$\dot{V}$/Q matching	+	+/−	+/−	+/−	+	+/−	+	Needs saline bolus
Volume estimation in SB	NA	NA	+	−	+	+/−	+	
Pendelluft detection	+	+	+	+/−	+	+/−	+	

+, the expert panel recommend the use of this parameter in this condition; +/−, the expert panel cannot state any recommendation in this condition; −, the expert panel does not recommend the use of this parameter in this condition

Abbreviations: NA, not applicable; CoV, center of ventilation; EELI, end-expiratory lung impedance; CL, lung collapse; OD, overdistension; PV-curve, pressure–volume curve; R/I ratio, recruitment-to-inflation ratio; RVD(i), regional ventilation delay (index); SB, spontaneous breathing; VT, tidal volume; $\dot{V}$/Q, ventilation-perfusion

Crit Care. 2024 Nov 19;28(1):377.

3. 실제 적용 사례

Table 1. Definition, Clinical Application, and Limitations of the Most Commonly Used EIT Indices in Patients with Hypoxemic Respiratory Failure

EIT Indices	Definition	Potential Applications	Limits
Global inhomogeneity index	Sum of absolute differences between median TIV and each pixel TIV normalized to sum of each pixel TIV	• Reflects heterogeneity of ventilation	• Does not reflect local distribution of TIV • Does not take into account overdistension, collapse, or any other pathological situation
Overdistension and collapse estimation	Estimation of relative local compliance loss presented as percentage of collapse and overdistension during decremental PEEP trial	• Selection of PEEP level that jointly minimizes collapse and overdistension • Applicable even on venovenous ECMO when V_T is very low	• Assumes that ΔP on ventilator is reliable surrogate of regional ΔP • Depends on highest and lowest values of PEEP applied during PEEP trial
Regional ventilation delay	Time between start of inspiration and aeration of lung regions	• Identify recruitable lung regions and cyclic opening/closing phenomenon • Could be used to identify best PEEP level with most homogenized tidal inflation	• Requires a slow inflation maneuver with constant flow • Depends on defined threshold • Does not detect not-recruitable or overdistended regions

Definition of abbreviations: ΔP = driving pressure; ECMO = extracorporeal membrane oxygenation; EELI = end-expiratory lung impedance; EELV = end-expiratory lung volume; EIT = electrical impedance tomography; PEEP = positive end-expiratory lung pressure; TIV = tidal impedance variation.

3. 실제 적용 사례

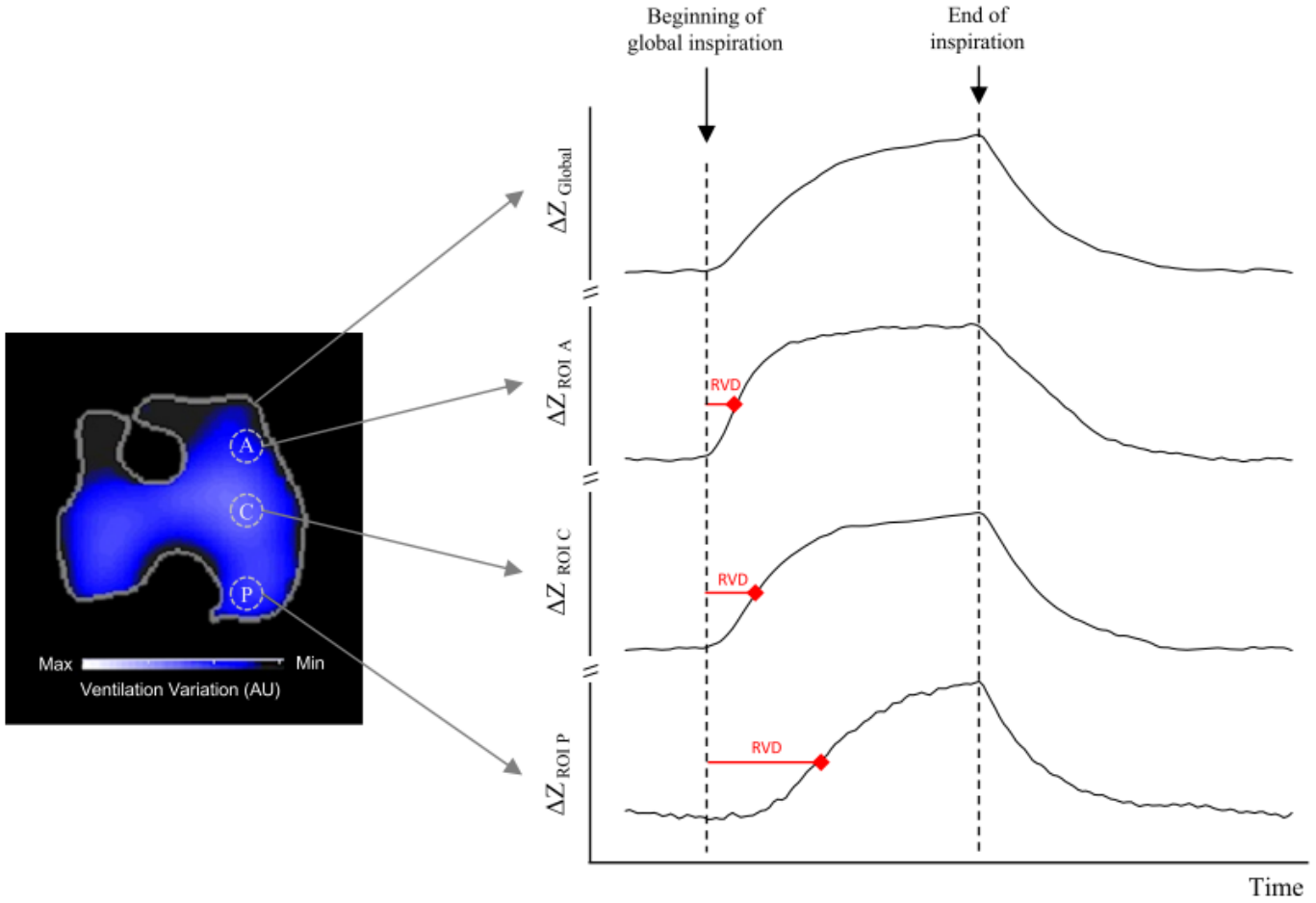

Fig. 12 Regional ventilation delay (RVD). Ventral region. Patient in mechanical ventilation. Slice 1, ventral region; Slice 2, central ventral; Slice 3, central dorsal; Slice 4, dorsal region. A anterior, AU arbitrary units, C central, P posterior, ROI region of interest, ΔZ variation of impedance. Courtesy of Wildberg Alencar

Crit Care . 2018 Oct 25;22(1):263.

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3. 실제 적용 사례

- **Case 7:** Male/66 yr

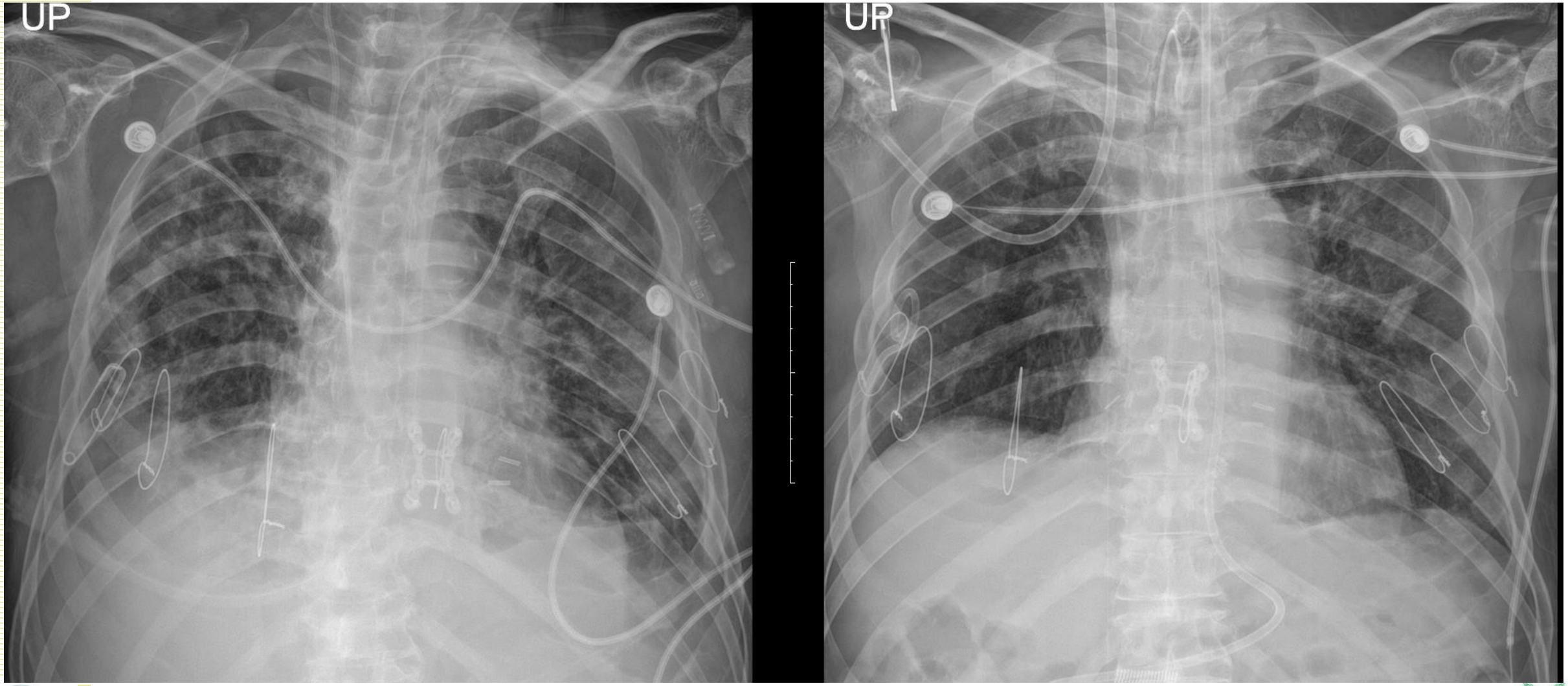
Main problem: Aspiration pneumonia

- Comorbidity: s/p LTPL (4mo)

> Ventilator: PC mode FiO2 25% RR 20

Driving Pressure 12 cmH2O

PEEP 5 cmH2O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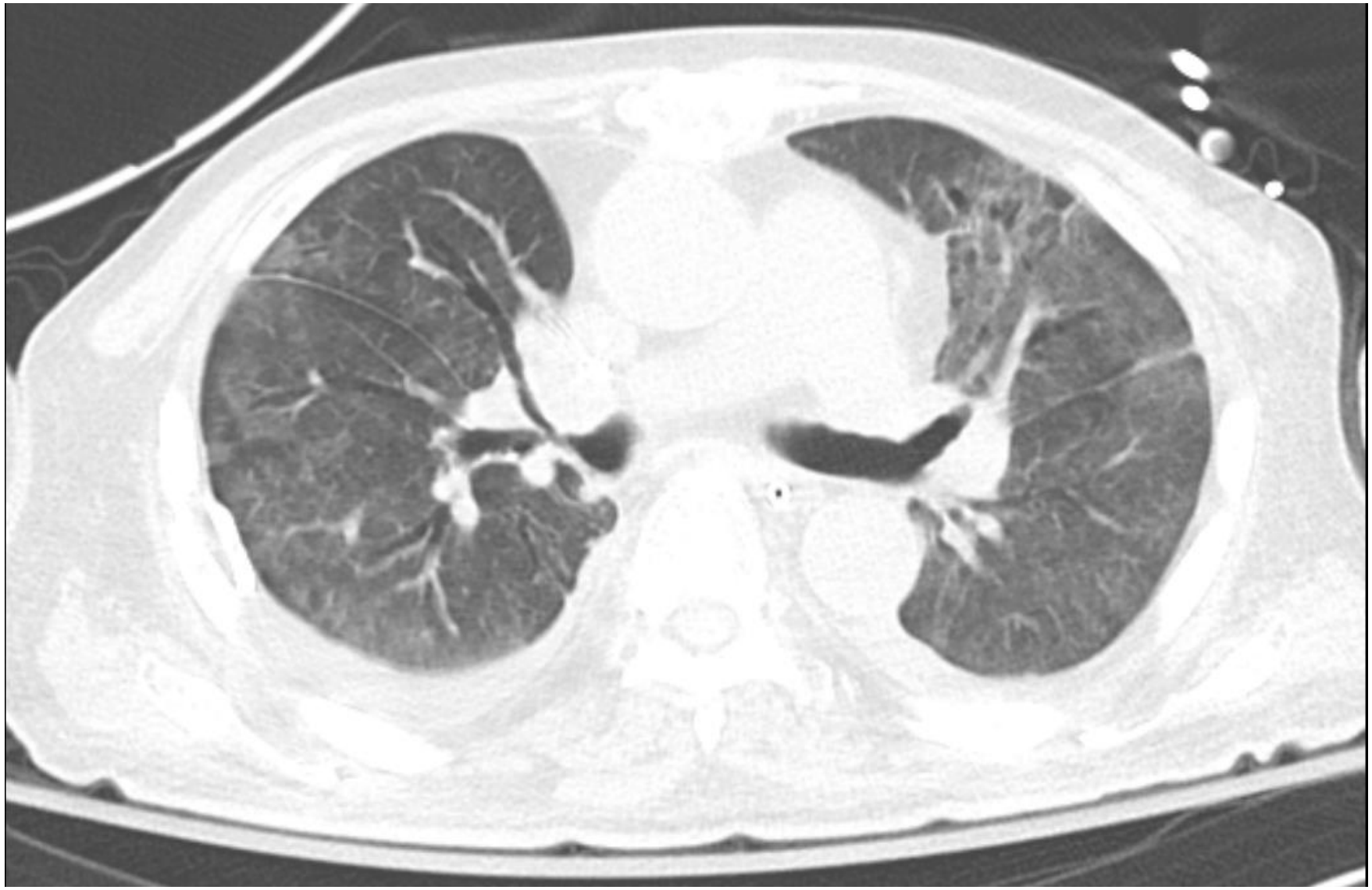

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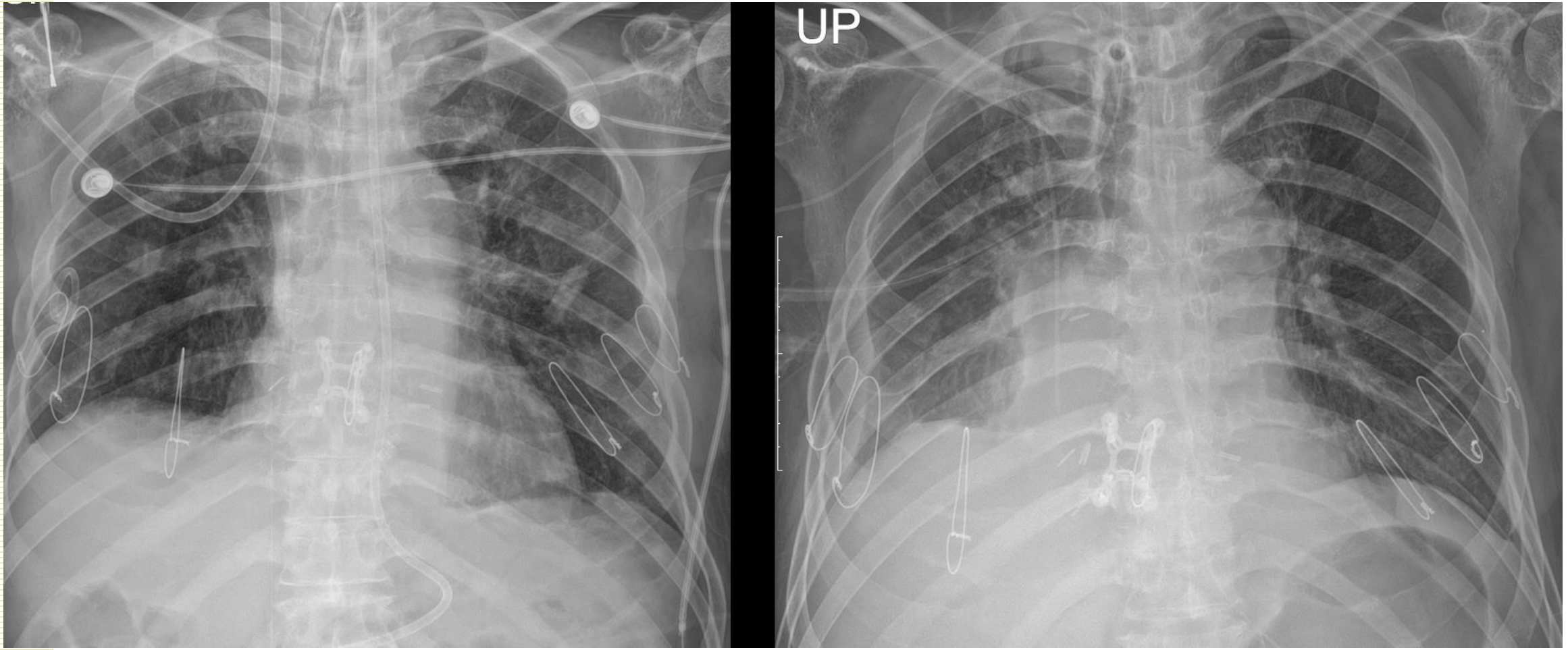
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3. 실제 적용 사례

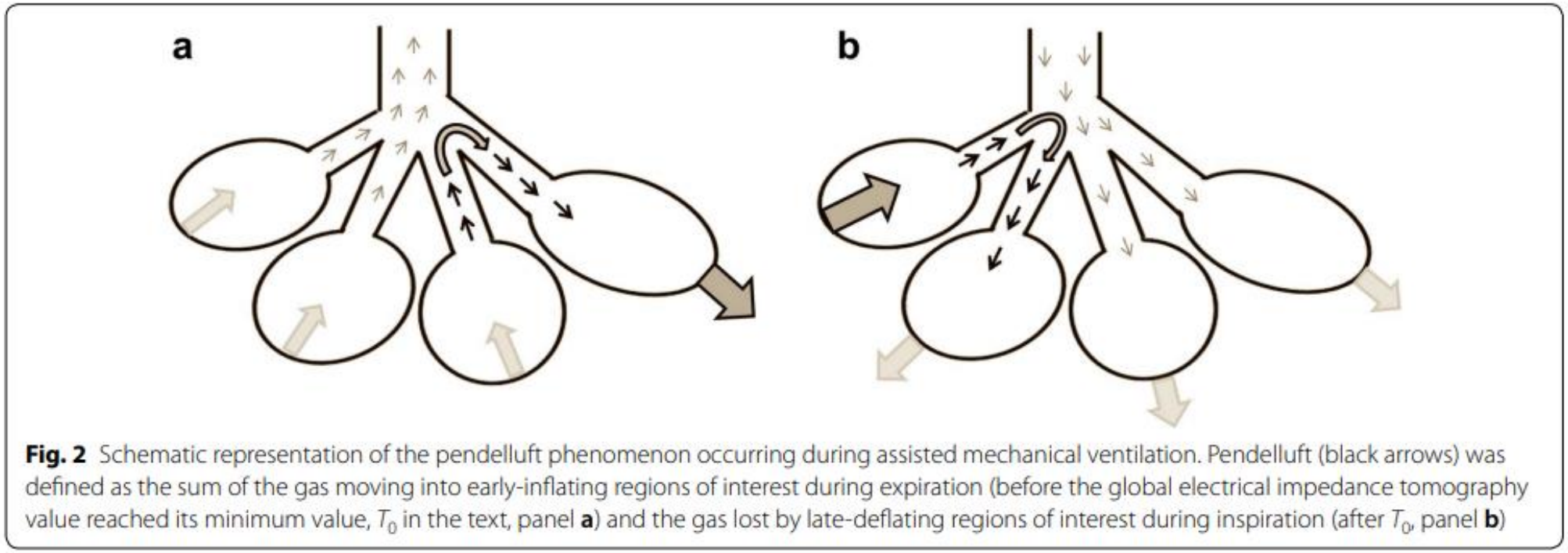


Fig. 2 Schematic representation of the pendelluft phenomenon occurring during assisted mechanical ventilation. Pendelluft (black arrows) was defined as the sum of the gas moving into early-inflating regions of interest during expiration (before the global electrical impedance tomography value reached its minimum value, T_0 in the text, panel **a**) and the gas lost by late-deflating regions of interest during inspiration (after T_0, panel **b**)

3. 실제 적용 사례

- **Case 8:** Female/88 yr

Main problem: Pneumonia with pul.edema

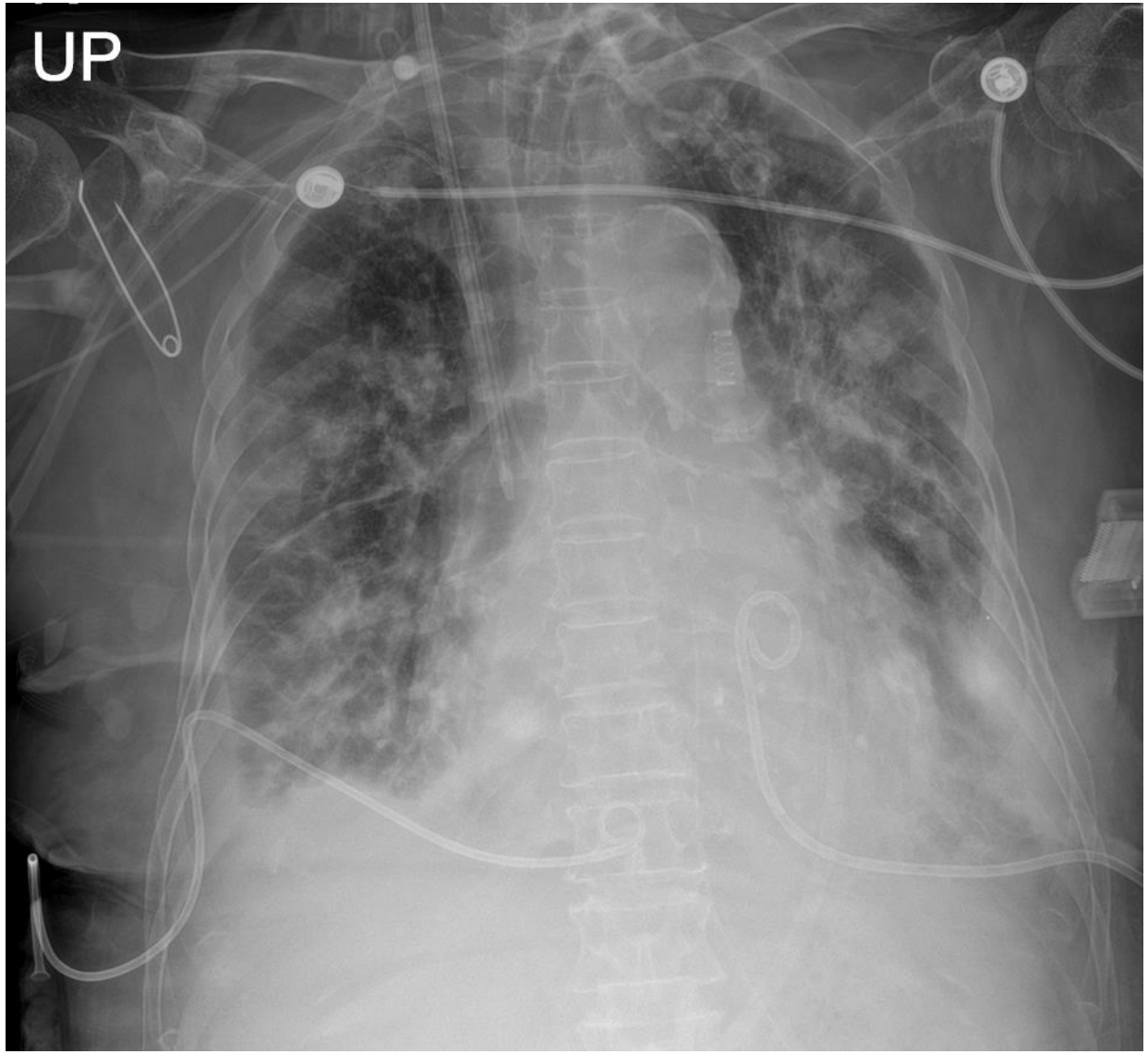
- Comorbidity: DM A.fib Stroke both leg necrosis

- TTE: Mild RV dysfunction

> Ventilator: PC mode FiO2 35% RR 26

Driving Pressure 16 cmH2O

PEEP 6 cmH2O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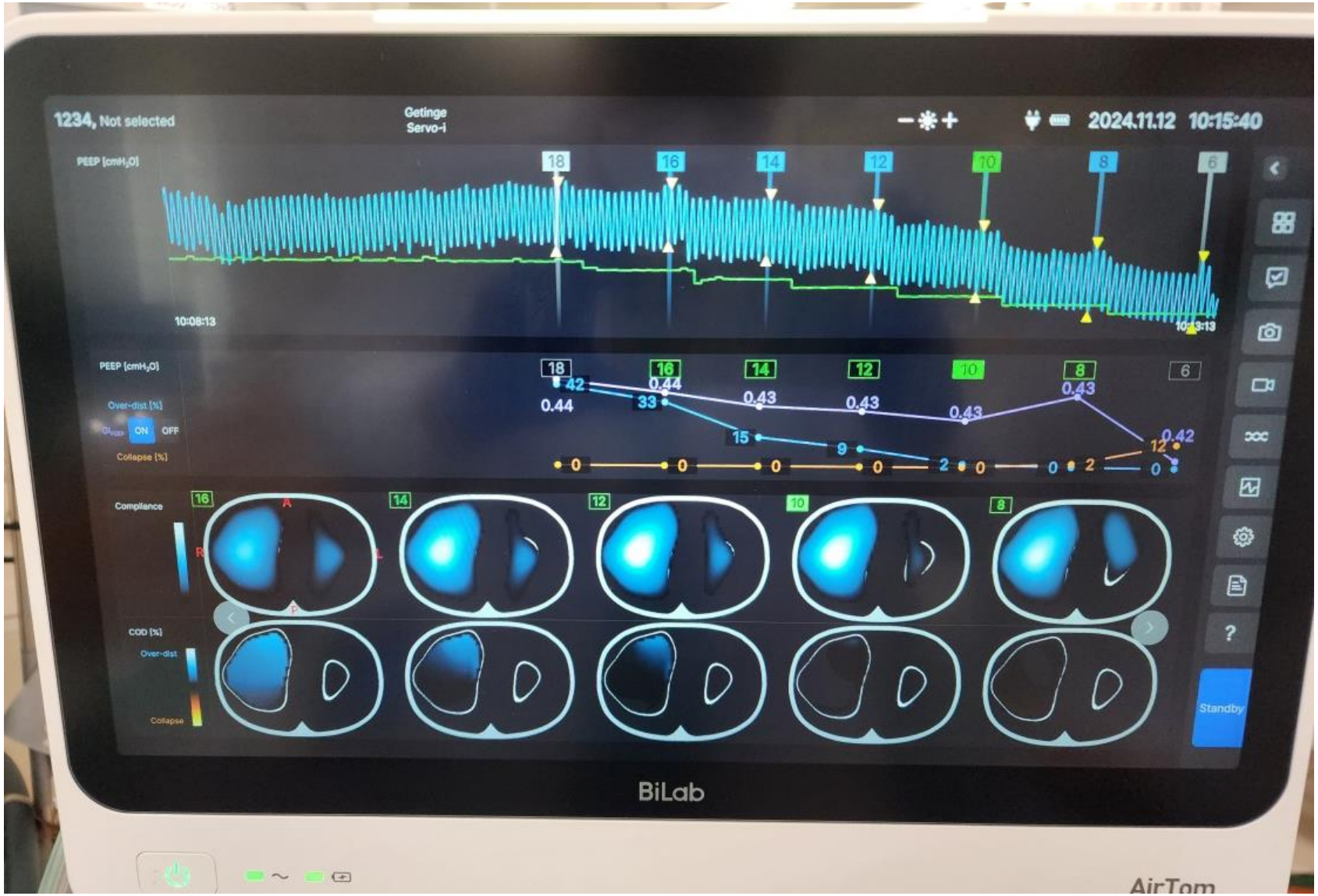

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3. 실제 적용 사례

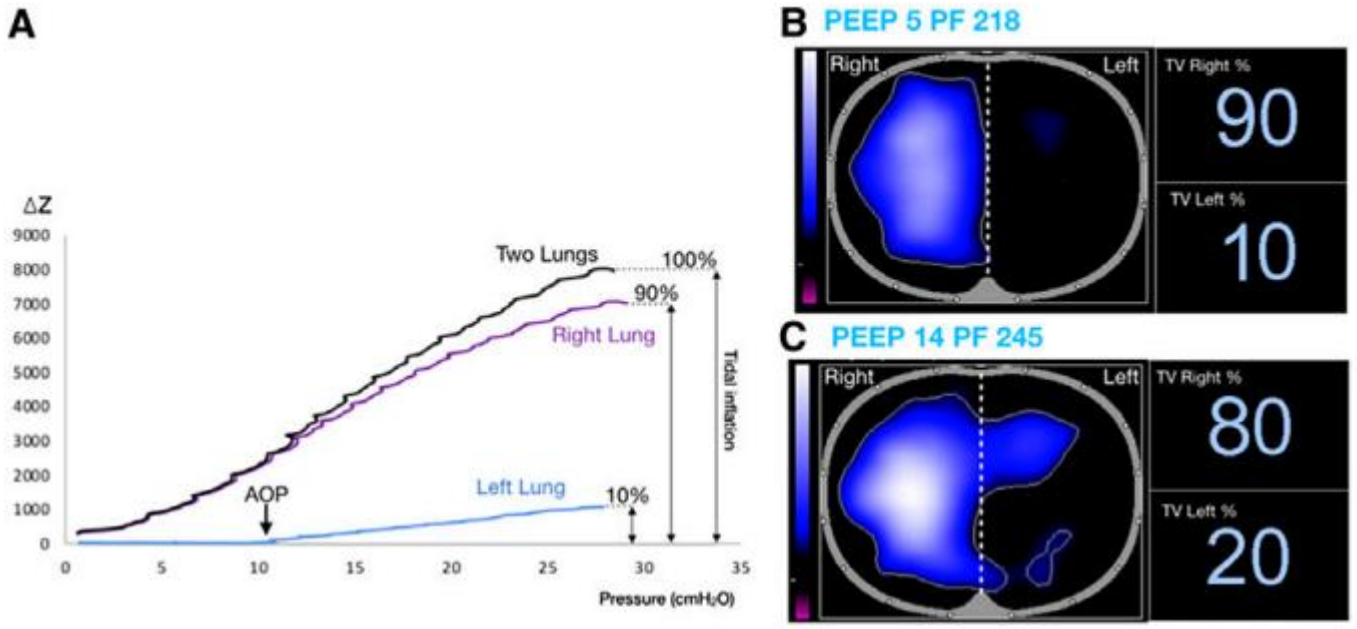

Figure 4. Electrical impedance tomography–derived pressure–volume curves in a patient undergoing invasive mechanical ventilation with unilateral left pneumonia. (*A*) Electrical impedance tomography–derived pressure–volume curves of both lungs and the right and left lungs individually in a patient with unilateral left pneumonia. This figure illustrates an airway opening pressure (AOP) of the left lung that is not captured when both lungs are analyzed simultaneously. (*B*) At a positive end-expiratory pressure of 5 cm H_2O (i.e., lower than the AOP of the left lung), tidal ventilation of the left lung represents only 10% of total tidal ventilation, with the Pa_{O_2}/FI_{O_2} ratio at 173 mm Hg. (*C*) At a positive end-expiratory pressure of 14 cm H_2O (i.e., higher than the AOP of the left lung), tidal ventilation of the left lung increases to 20% of total tidal ventilation, and the Pa_{O_2}/FI_{O_2} ratio increases to 245 mm Hg. PEEP = positive end-expiratory pressure; PF = Pa_{O_2}/FI_{O_2} ratio; TIV = tidal impedance variation.

3. 실제 적용 사례

- **Case 9:** FeMale/67 yr

Main problem: Decreased tidal volume

- Comorbidity: DM HTN A.fib Pul.HTN CPCR survivor (2da)

> Ventilator: PC mode FiO2 25% RR 16

Driving Pressure 12 cmH2O

PEEP 5 cmH2O

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	17:24	17:30	17:40	17:42	17:44	17:45	17:50	17:51	17:57	18:00	18:12	18:13	18:55	19:00	19:15	19:18
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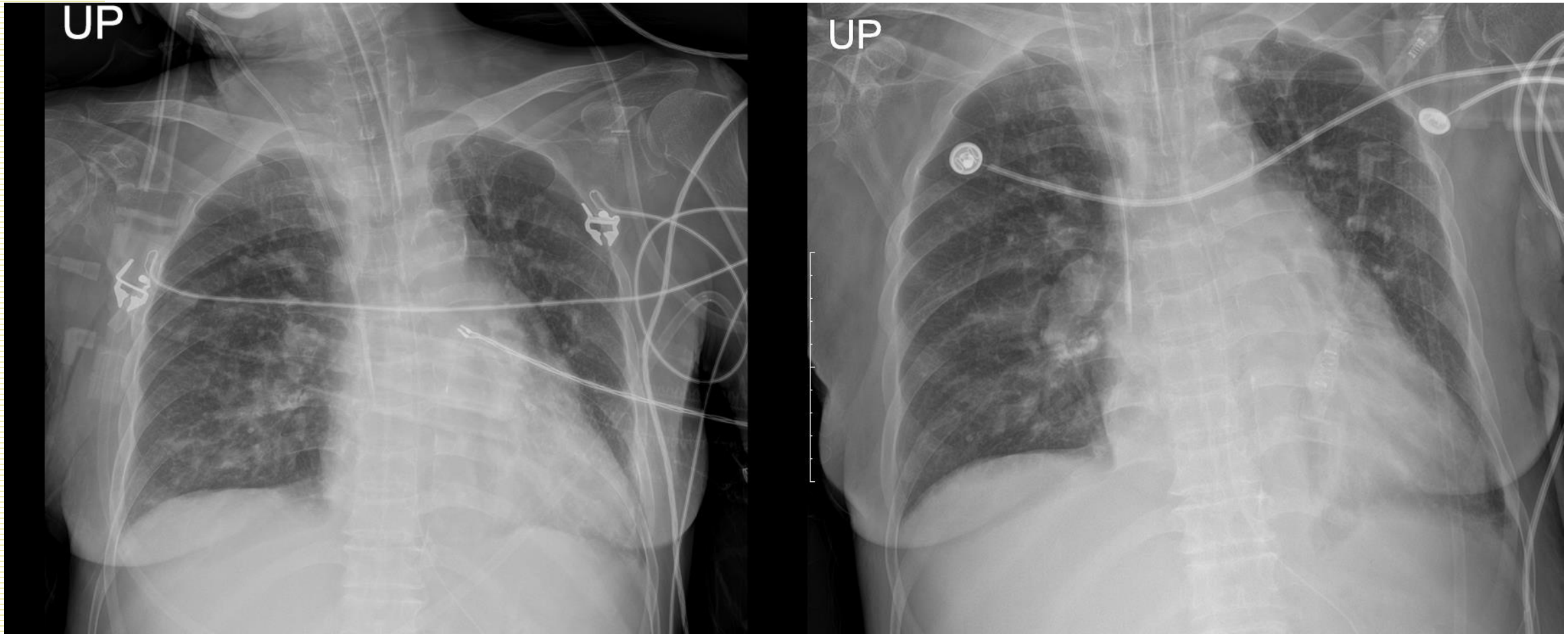
19:30:39	7.320		45.9	130.5		-3.2		23.1		98.4						
19:24:01	7.318		45.9	311.7		-3.3		23.0		99.7		1.1				
18:49:06	7.305		48.5	120.8		-3.1		23.6		98.0				16/...		
18:01:09	7.321		47.2	130.9		-2.4		23.8		98.4		1.6		20-...		
17:22:55	7.360		44.3	73.3		-1.1		24.5		94.2		1.4				
														1:1.5		
														1.00		
	18	18	18	18	18	18	18	18	20	20	20	20	20	20	20	20
	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10
	260	242	265	268	267	267	227	219	228	231	234	240	224	230	203	213
	4.1	3.8	4.3	4.3	4.3	4.3	3.7	3.6	3.6	3.7	3.8	3.9	3.6	3.7	3.3	3.4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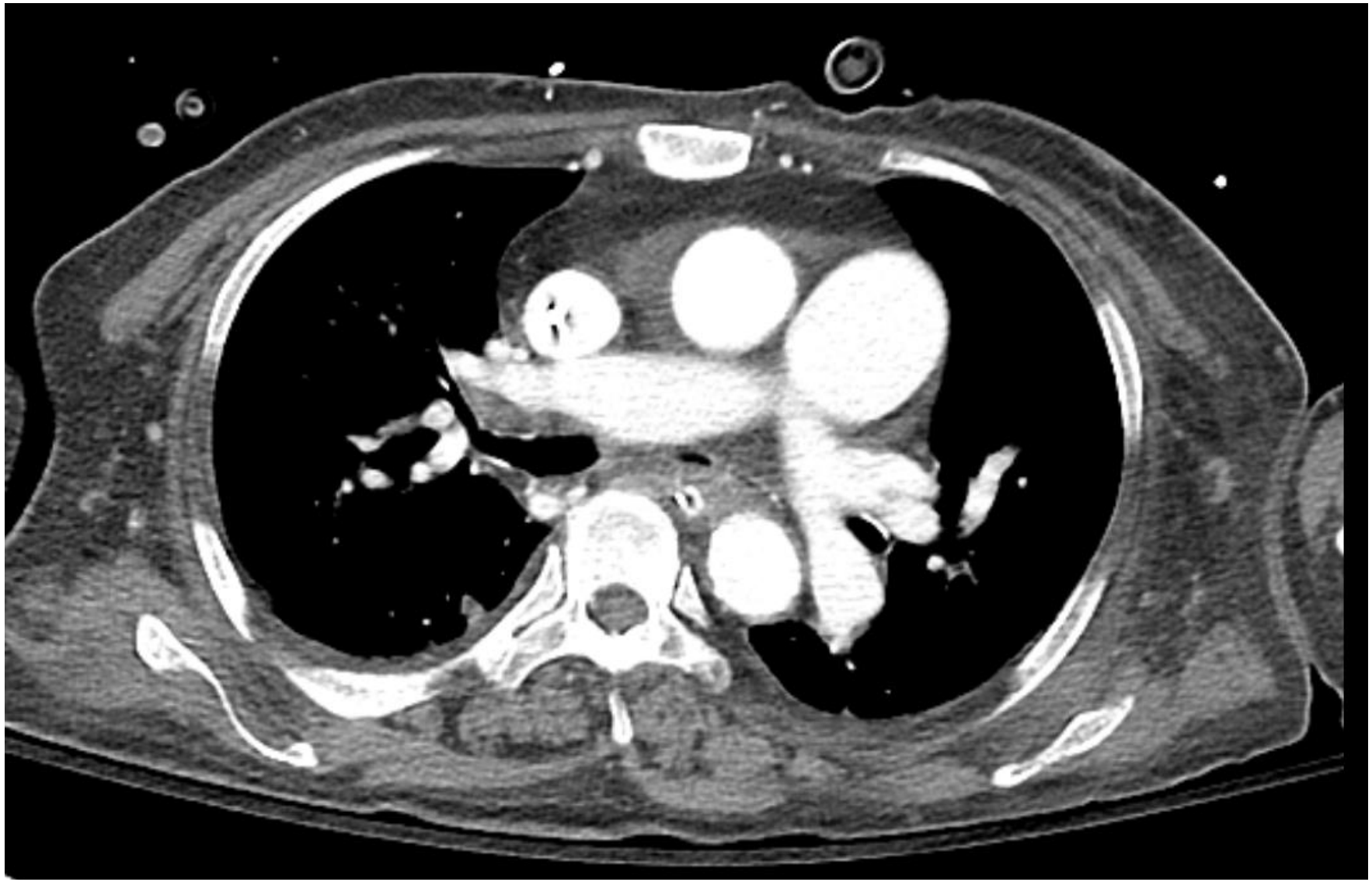

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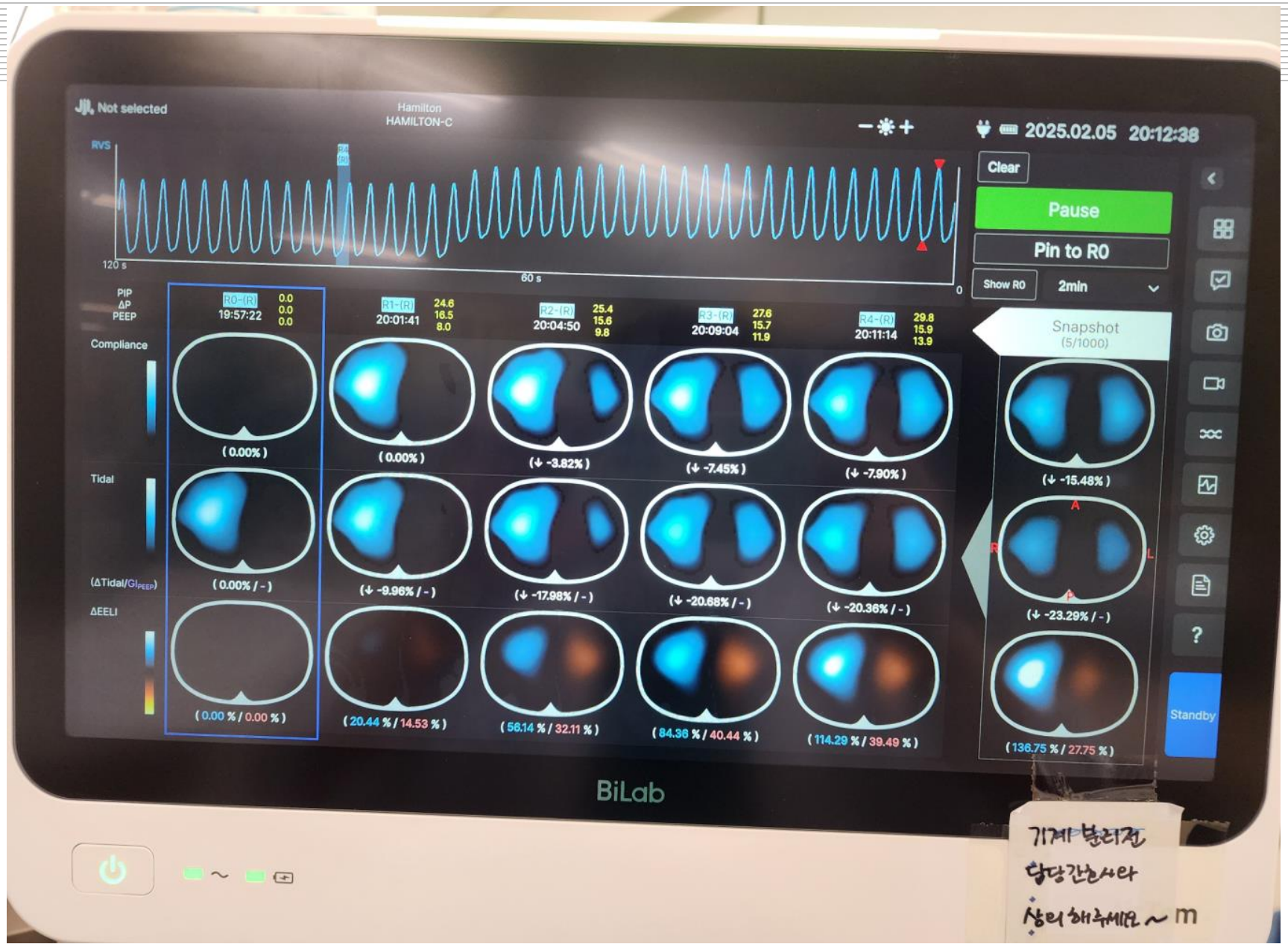
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PEEP
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Tidal
(ΔTidal/GI PEEP)
ΔEELI
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R1-(R) 20:01:41 24.6 16.5 8.0
R2-(R) 20:04:50 25.4 15.6 9.8
R3-(R) 20:09:04 27.6 15.7 11.9
R4-(R) 20:11:14 29.8 15.9 13.9
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R2-(R) 20:04:50 25.4 15.6 9.8
R3-(R) 20:09:04 27.6 15.7 11.9
R4-(R) 20:11:14 29.8 15.9 13.9
R5-(R) 20:13:18 32.4 16.6 15.8
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(↓ -17.98% / -)
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(56.14 % / 32.11 %)
(84.36 % / 40.44 %)
(114.29 % / 39.49 %)
(140.80 % / 28.79 %)
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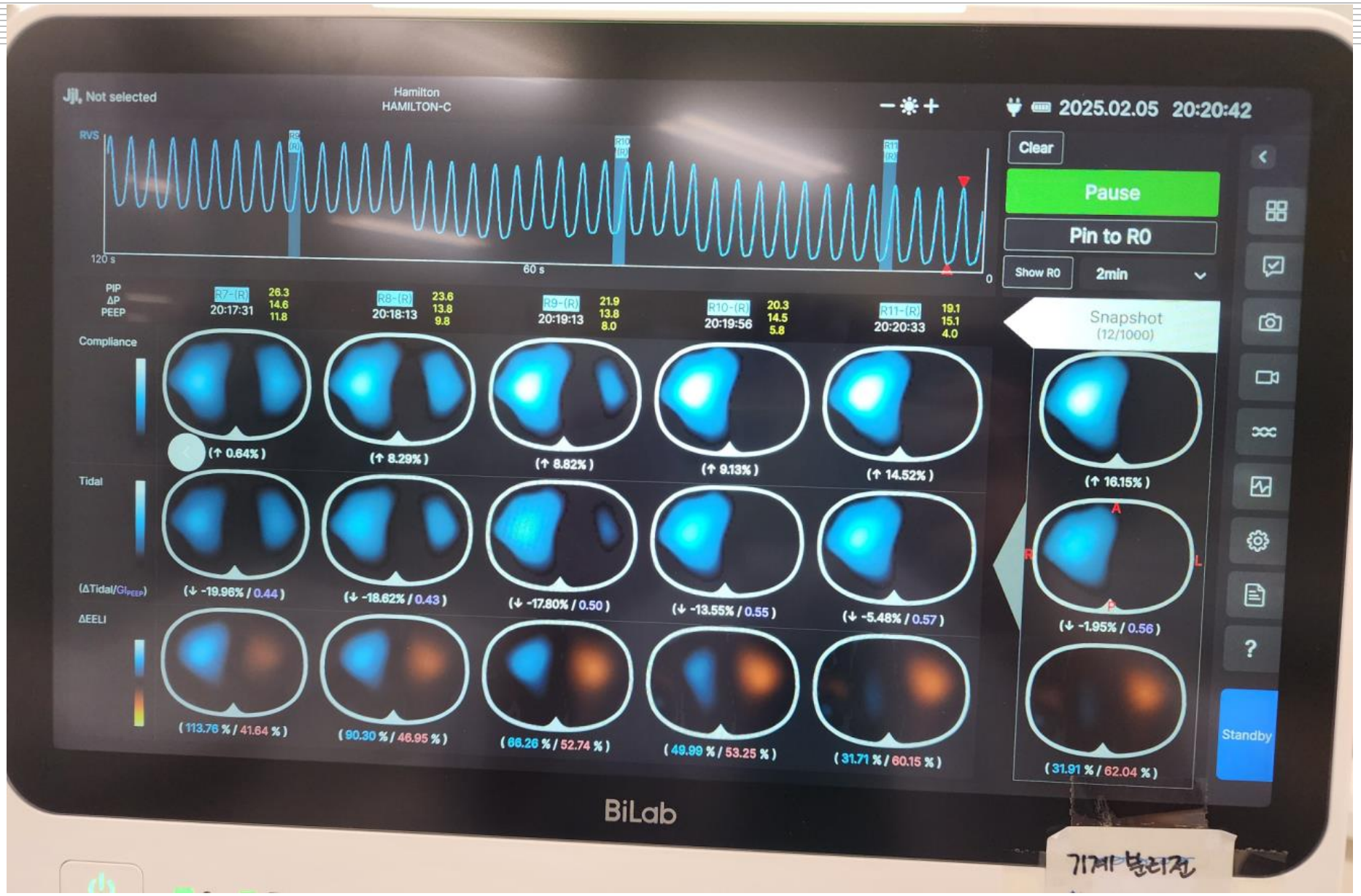

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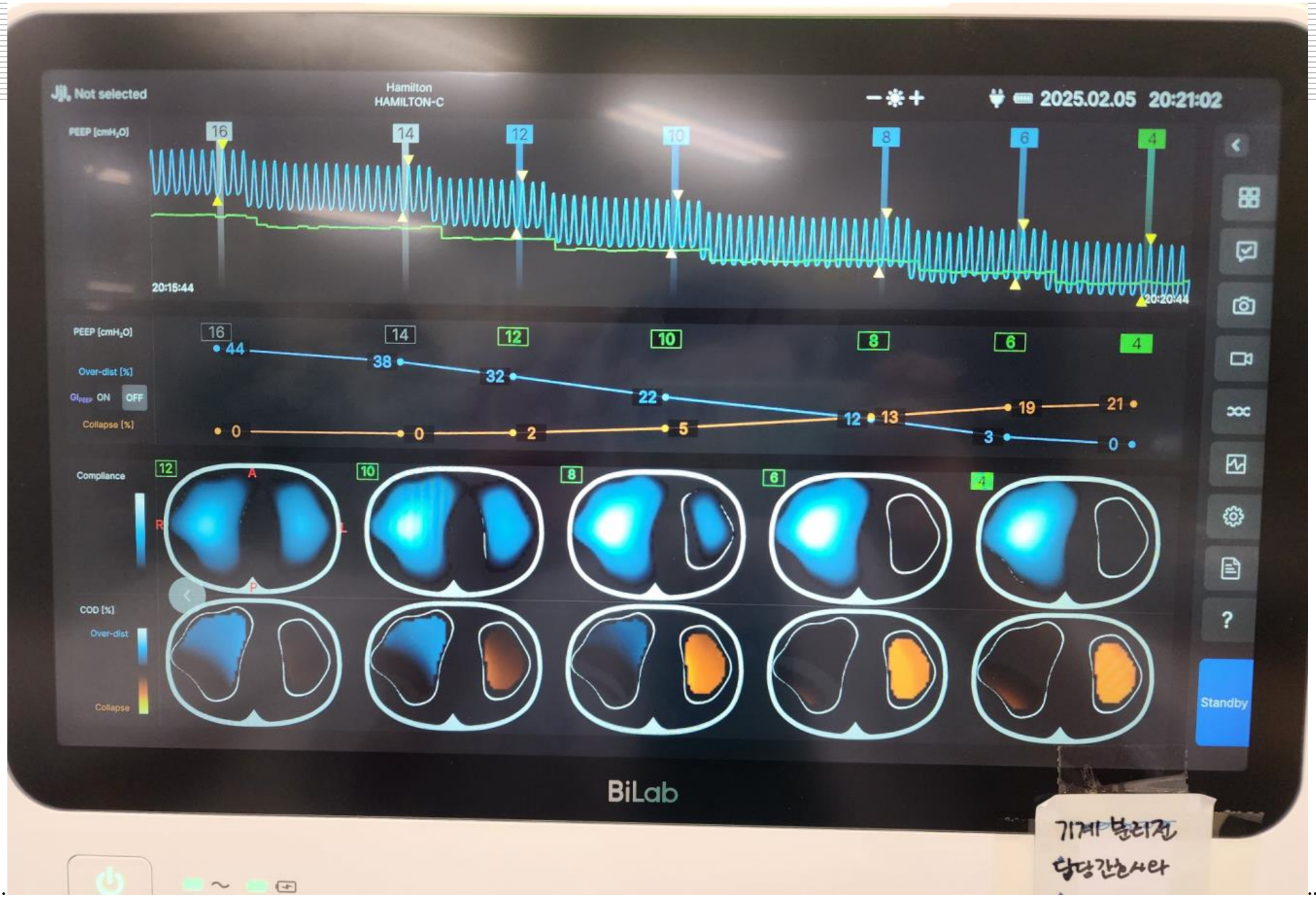

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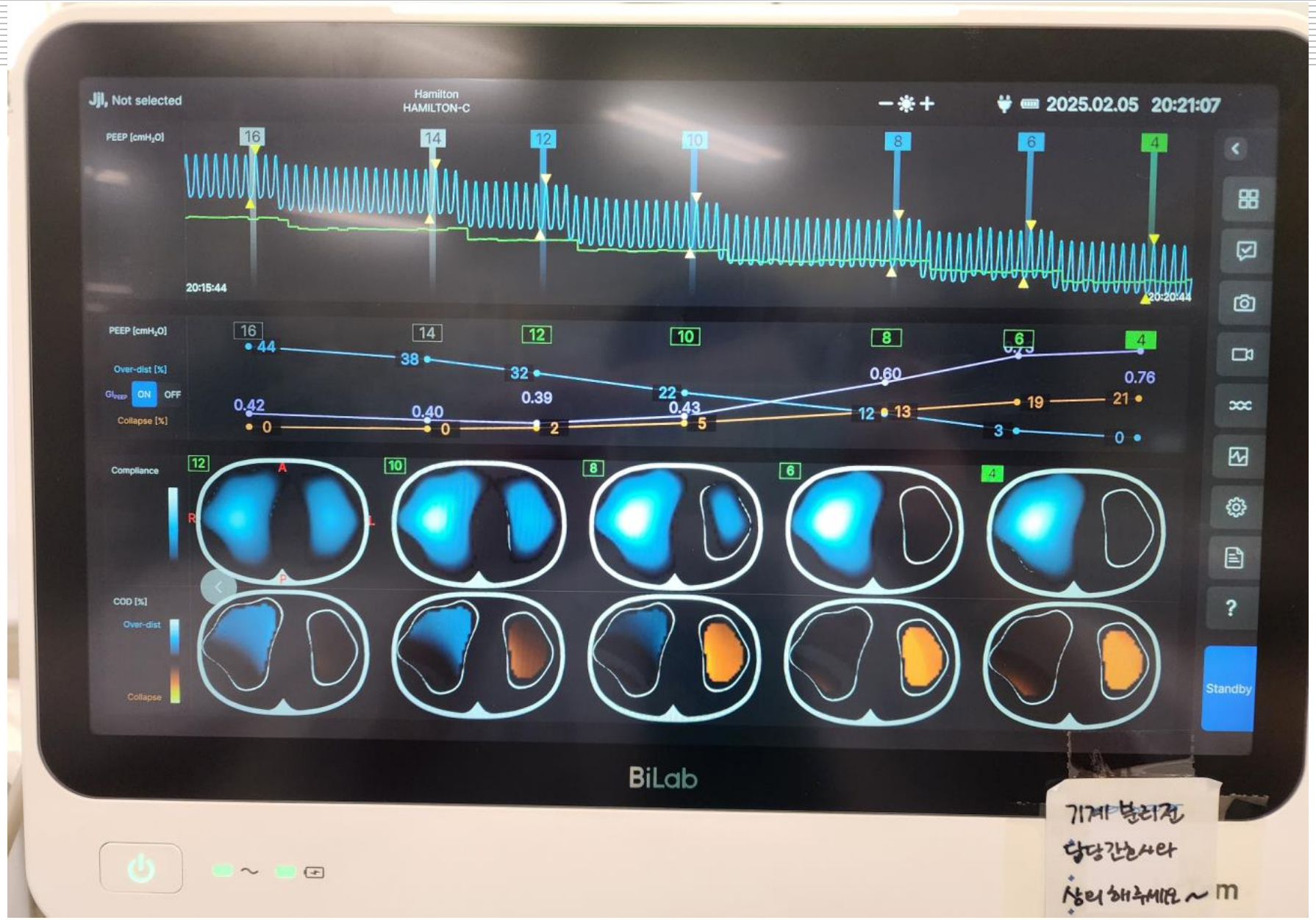
울산대학교



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좋아
하세요?
EIT


정말
좋아합니다.
10
이번엔
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아니라구요.
슬램덩크 30 끝

경청 해주셔서 감사합니다 !