Complex Respiratory Round
April 21st , 2017

A Teaching Affiliate of Harvard Medical School

Ventilator Trouble – Recruiting Help

Ventilation Strategies Beyond ARDSnet

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MGH 1811 MASSACHUSETTS GENERAL HOSPITAL

Aims

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- Review a case of hypoxemic respiratory failure with respiratory acidosis
- Evaluate bedside techniques to determine ventilatory strategy: trans-pulmonary pressure, decremental PEEP trial, and recruitment maneuvers
- Discuss an approach in the post-operative period towards lung recruitment and PEEP titration

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Pre-Transplant
(admitted BMC 2/8/17; MGH 2/17/17)

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50F w/HCV / EtOH cirrhosis s/p ledipasvir/sofosbuvir (last drink >2yrs, G2 varices c/b UGIB in 2015, h/o hepatic encephalopathy), who transferred to MGH for liver transplant w/u after presenting to BMC w/abdominal pain, confusion, metabolic acidosis, hyperkalemia and AKI

PMHx: ESLD (MELD-NA 29), bipolar, BMI 44

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Pre-Transplant @ MGH

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- **2/18/17:** Admitted to medical floor for liver transplant evaluation
- **2/28/17:** Rectal bleeding, flexsig w/hemorrhoids
- **3/4/17:** dx paracentesis → abdominal wall hemorrhage → R inf epigastric embo (3/6/17)
- **3/7/17:** Left CFA pseudoaneurysm 3000u of thrombin injected

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Liver Transplant
(3/11/17)

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Orthotopic liver transplantation with systemic VV bypass and backbench procedure for deceased donor liver transplantation.

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Respiratory Therapy Notes
(3/12/17)

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- Appears uncomfortable. **Trialed ACVC and PCV with boluses of propofol without appearing more comfortable** and while **dyscynchronous** with vent. PSV 5/12/60%.

- Bilateral breath sounds clear. Secretions small thick tan. Patient more awake and responding appropriately to yes/no questions.

- Weaned FiO2 to 40%.

- PLAN: SBT and extubate later today

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Respiratory Therapy Notes

- 3/13/17: PSV 5 / 12 / 50%
- 3/14/17: Attempted PEEP weans – concern, due to mental status, about extubating to CPAP
- 3/15/17: Desat w/FiO2 wean, increased requirement 60-80%

March 15 -- 2224

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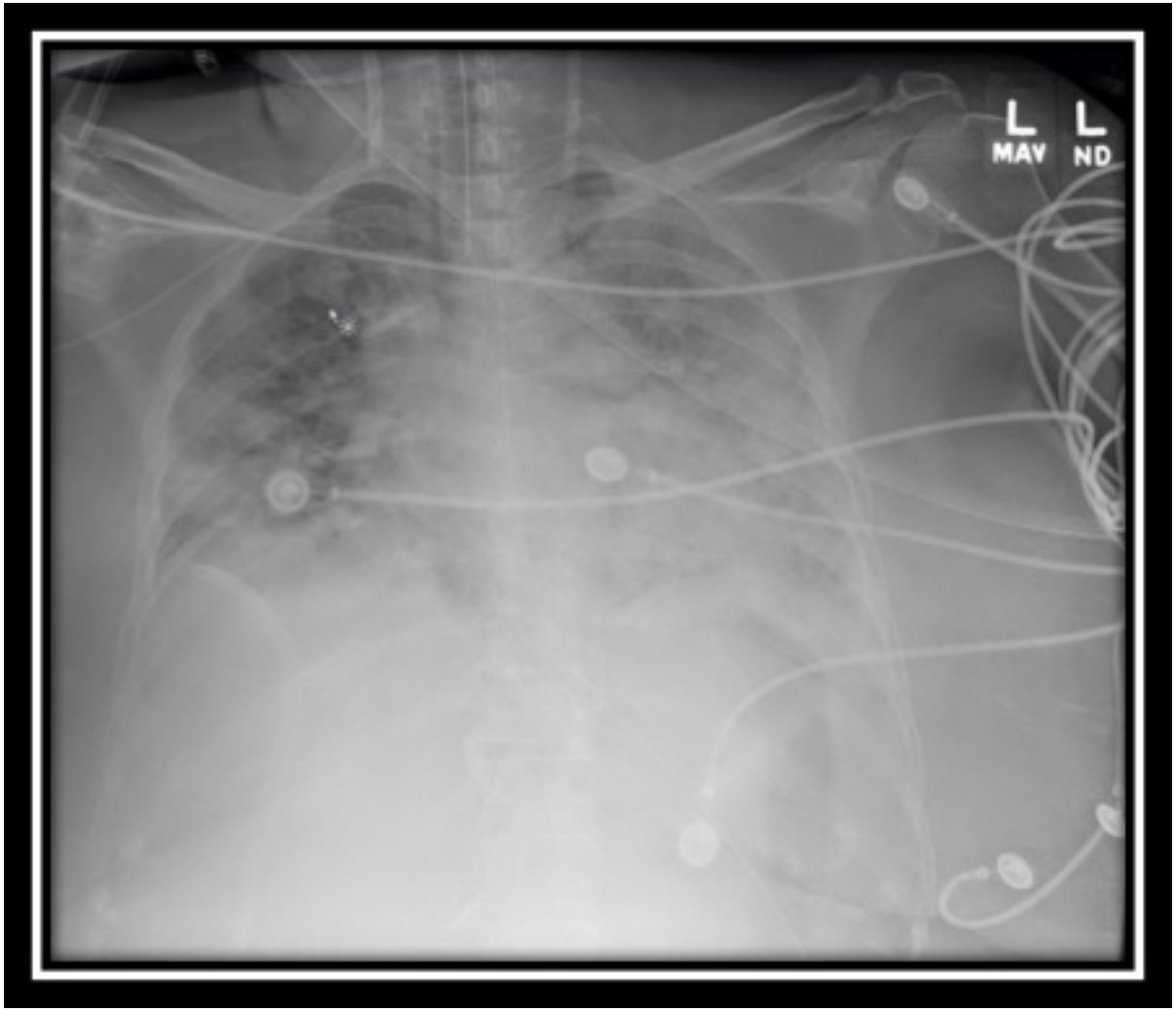

PSV 12 / 12

FiO2: 80%

Vt 600s

ABG 7.37/ 44 /133

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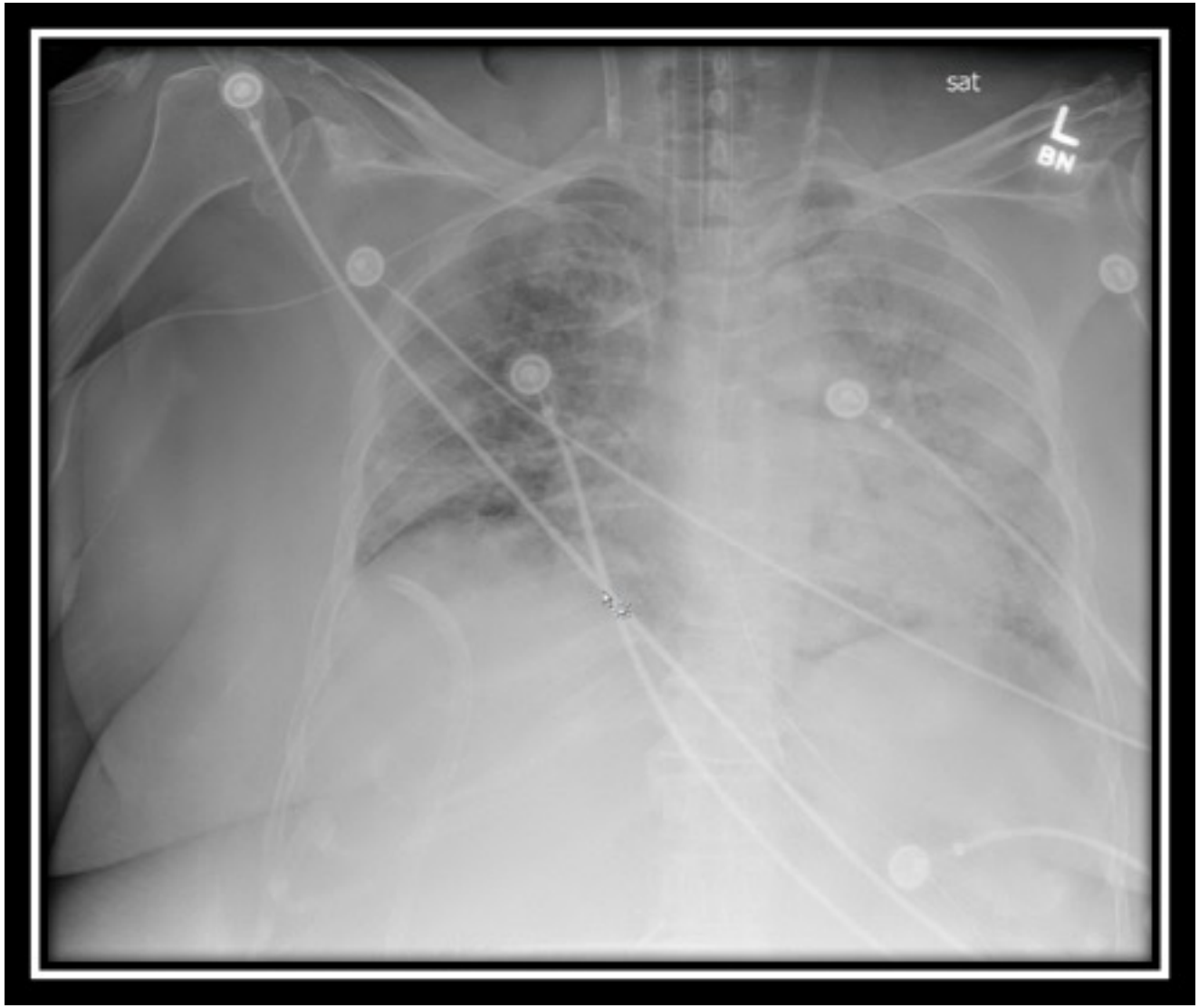
March 16, 2017

- 3/16/17 0800

Bradycardia → Asystole → CPR + Epinephrine

March 16 -- 0834

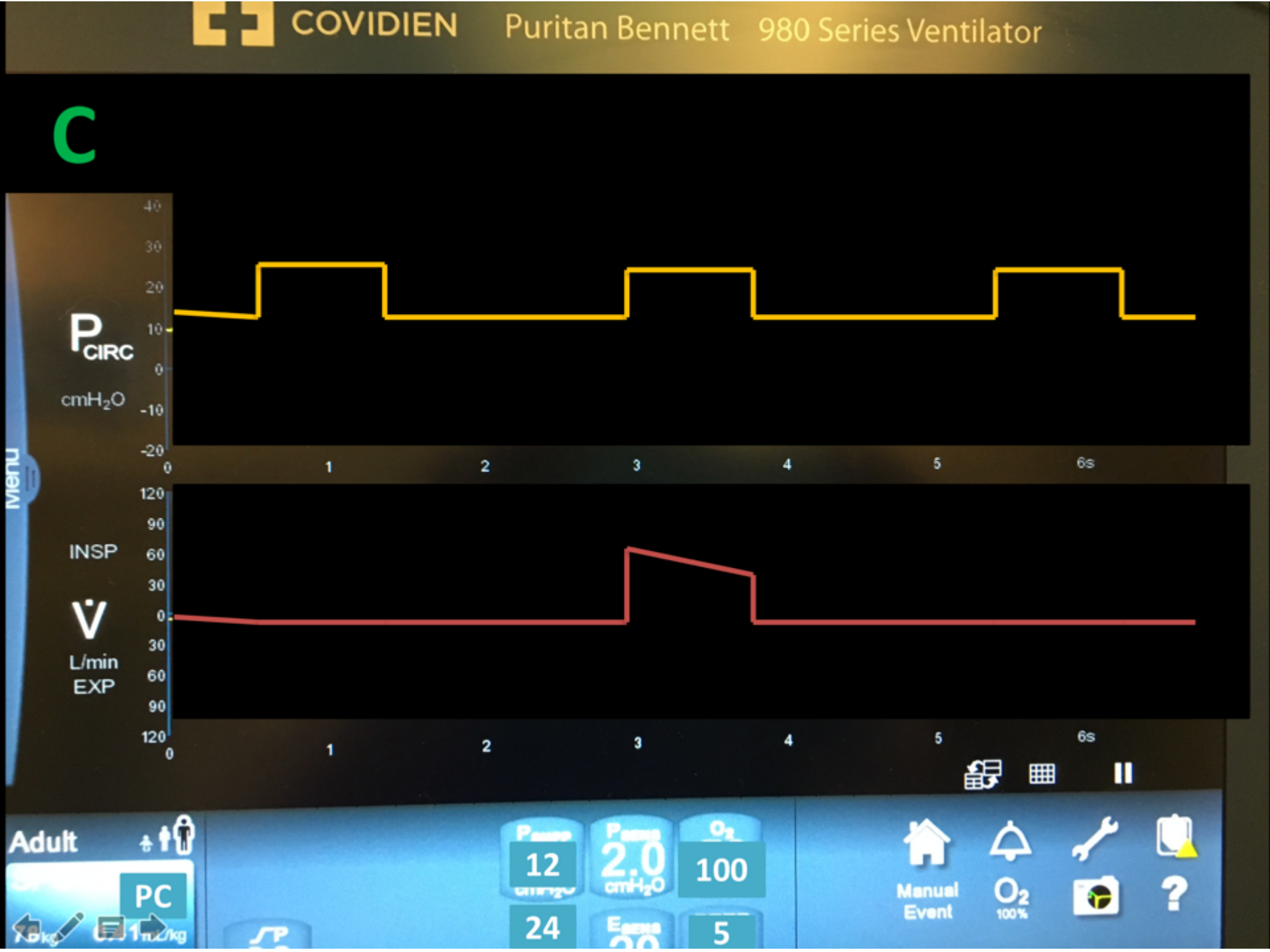


PSV 12 / 12

FiO2: 100%

Vt 600s

ABG 7.26/ 52 / 77


COVIDIEN
Puritan Bennett
980 Series Ventilator
C
P CIRC
cmH2O
40
30
20
10
0
-10
-20
0
1
2
3
4
5
6s
Menu
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V̇
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120
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60
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30
60
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120
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1
2
3
4
5
6s
Adult
PC
12
2.0
cmH2O
100
24
5
Manual
Event
O2
100%

Ventilator settings, respiratory mechanics and ABG

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Vent: PCV 12 / 5 / 100% / RR 24(8) / PIP17 / TV 0-200

Resp. Mechanics: NA / Drive P. 12

ABG: 7.09 / 84 / 107

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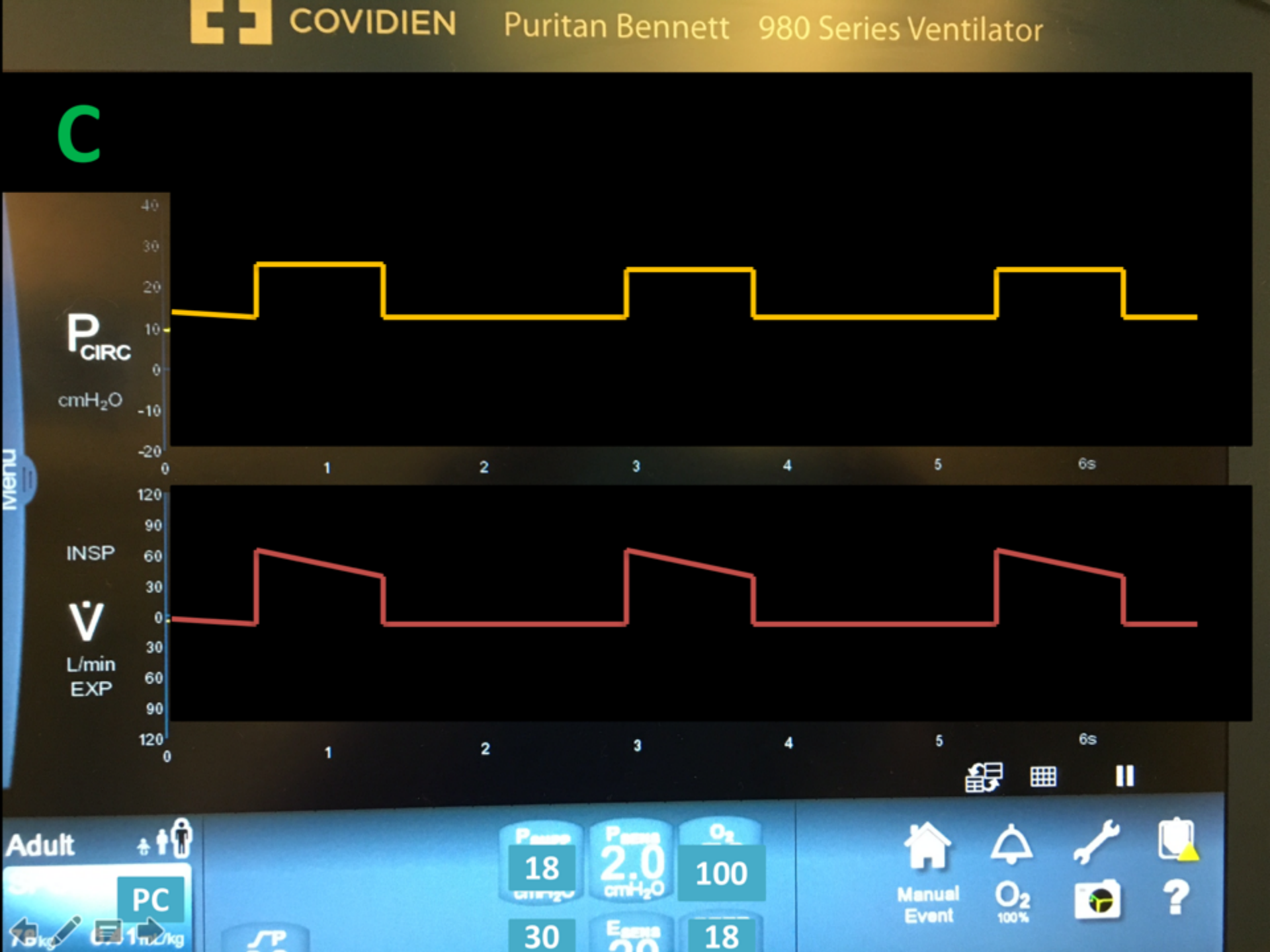
Help Recruitment

Search for leak
3-4x Respiratory Therapist
Ventilator Changed
Pulmonologist “curbside”


COVIDIEN
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Manual
Event
O2
100%

Ventilator settings, respiraxtory mechanics and ABG

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Vent: PCV 12 / 18 / 100% / RR 30 / PIP 33 / TV 230

Respiratory Mechanics: Compliance 19 / Drive P. 12

ABG: 7.06 / 92 / 95

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ECMO Consult
Berra Lab (Consult)

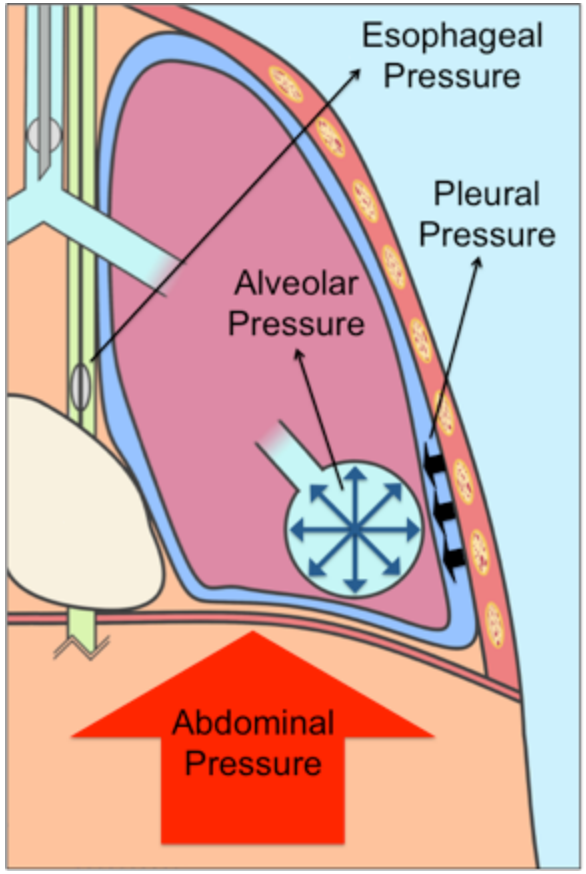
How much PEEP is enough? and, when how to recruit the lungs?

Air trapping, atelectasis → **PEEP, RM**

PEEP, RM → EFL reversal
Atelectrauma

PEEP, RM → Prevention of atelectasis
Volotrauma

PEEP, RM → Mechanics and oxygenation improvement
Hypotension



"Best PEEP" still controversial

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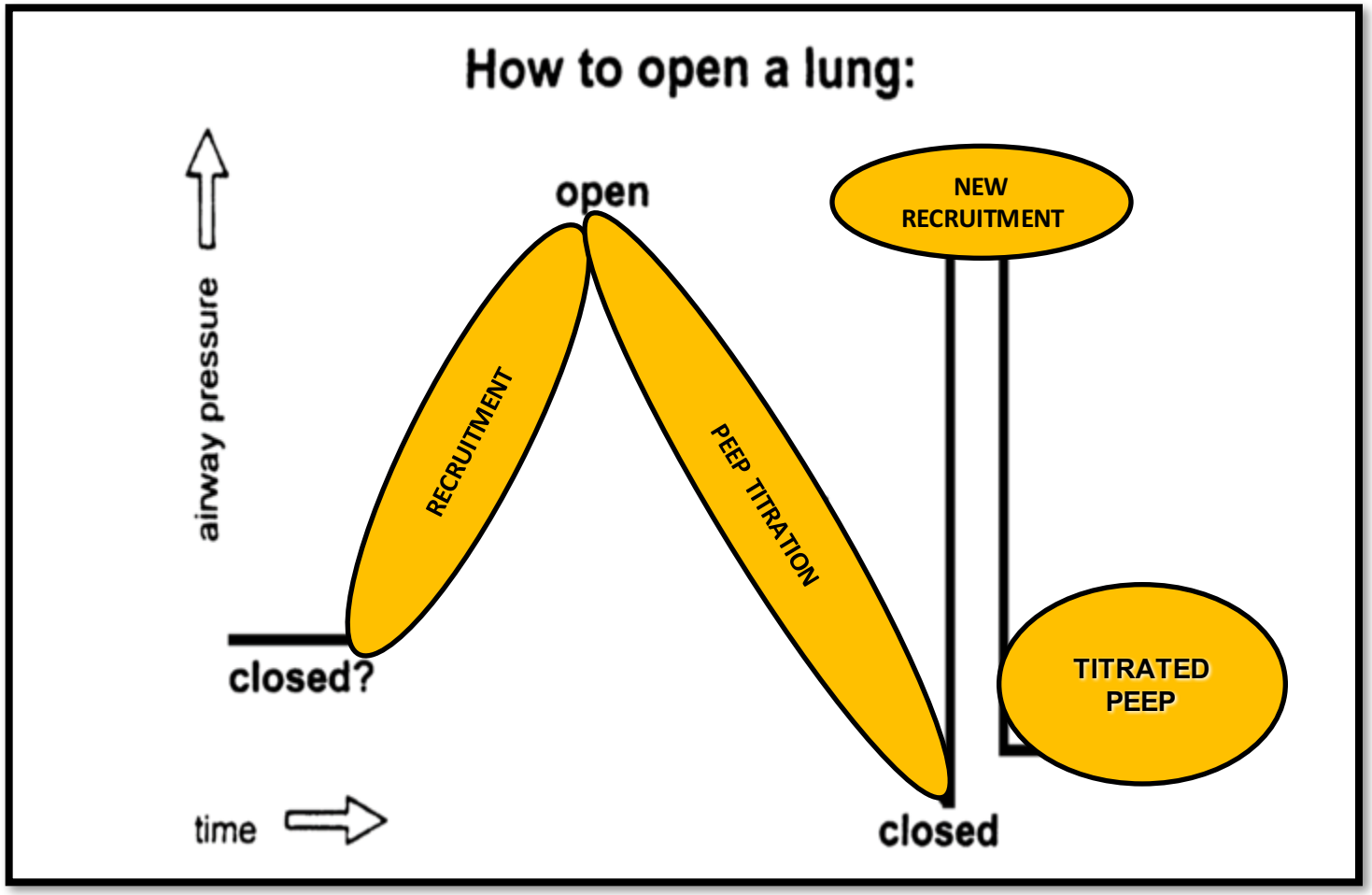
Alveolar Recruitment Rationale



(adapted Lachmann, 2002)

PEEP titration - I

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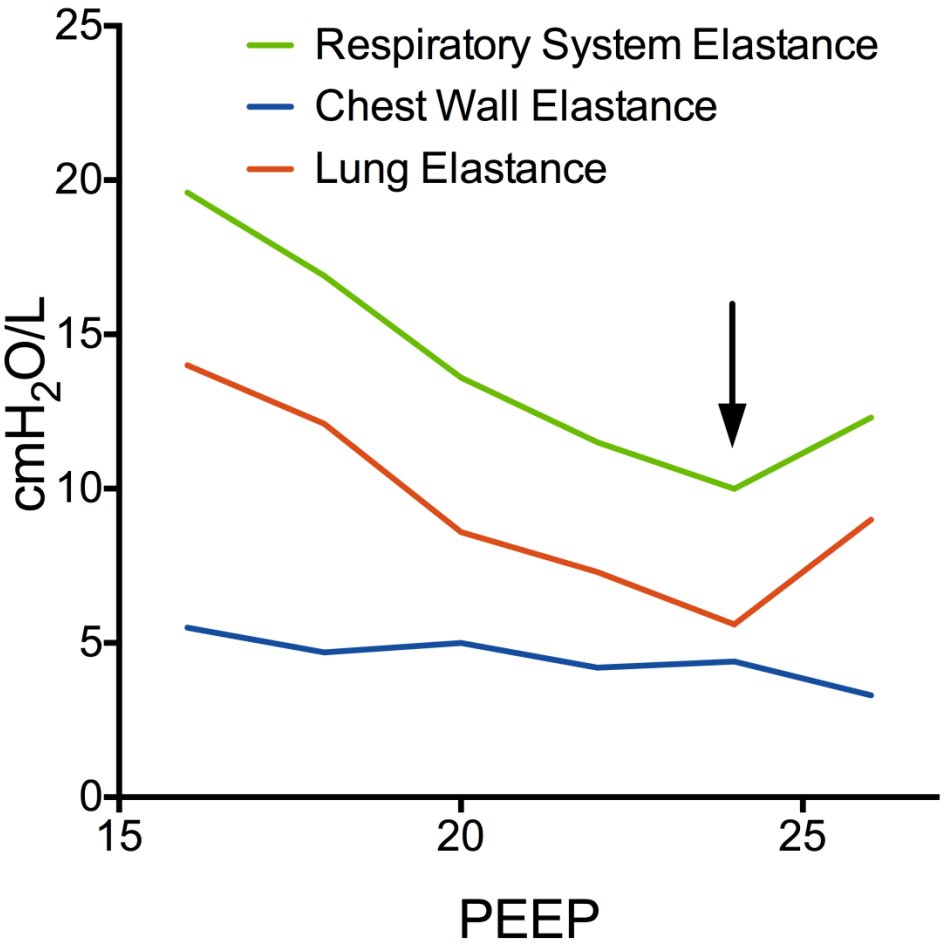
Decremental PEEP trial

Explores elastic properties by probing the respiratory system at progressively lower PEEP levels.



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Calculations

- **Dynamic Compliance:** $C_{DYN} = V_T / (PIP - PEEP)$
  - Optimal PEEP: OL-PEEP = C_{DYNMAX} + 2 cm H2O

V_T	PIP	PEEP	PIP - PEEP	C_{DYN}
360	36	20	16	22.5
360	33	18	15	24
360	29	16	13	28
360	28	14	14	26
360	26	12	14	26
360	25	10	15	24
360	24	8	16	22.5

PEEP titration - 2

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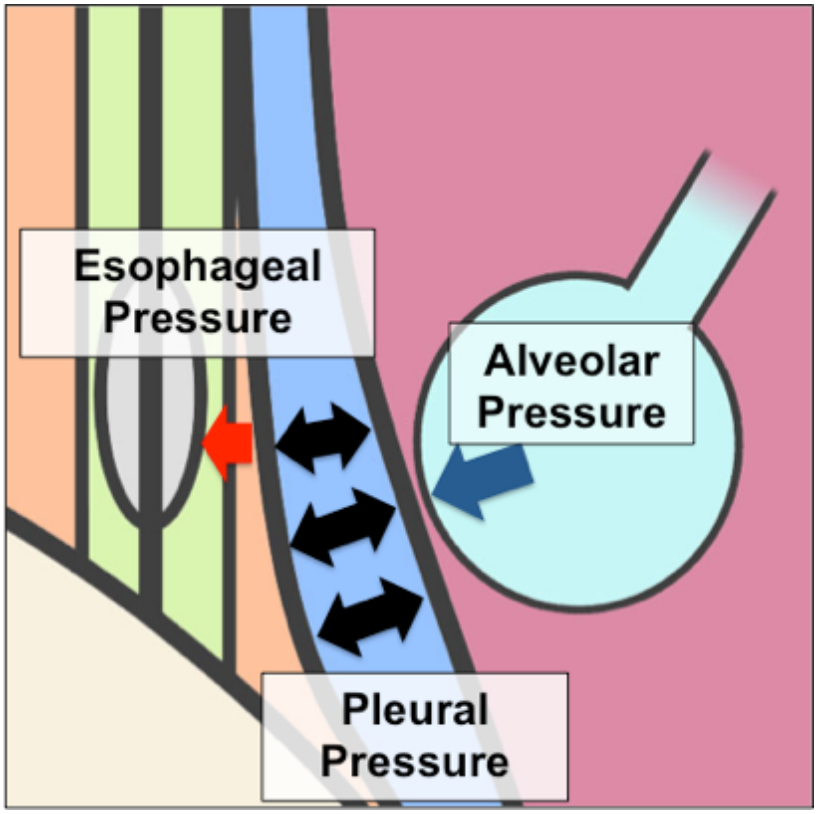
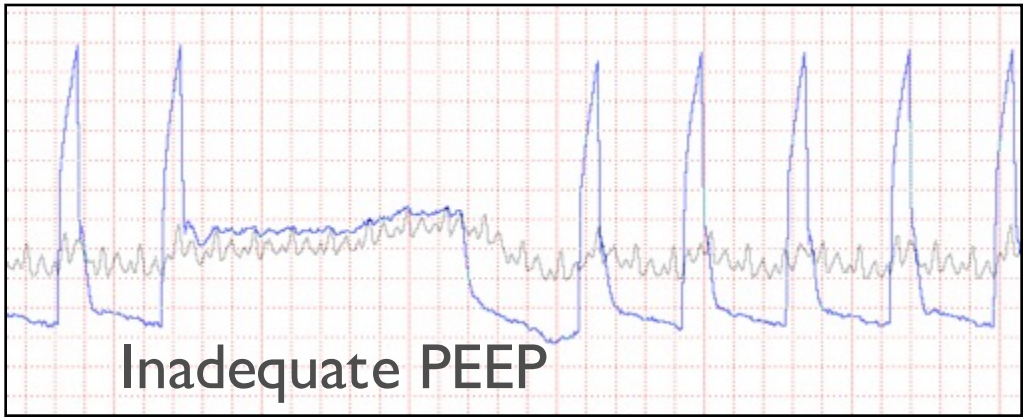
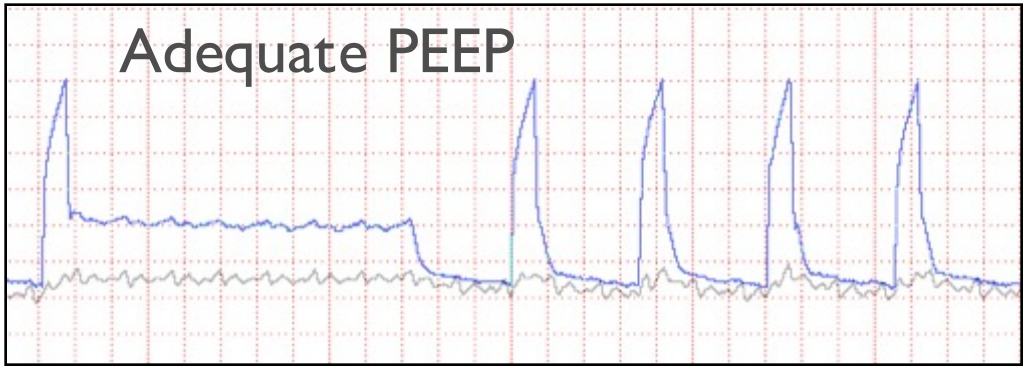
Approach with transpulmonary pressure

PEEP level is set to achieve a non-collapsing pressure at end-expiration (lowest PEEP value with positive end-exp transpulmonary pressure)







PEEP titration - 3

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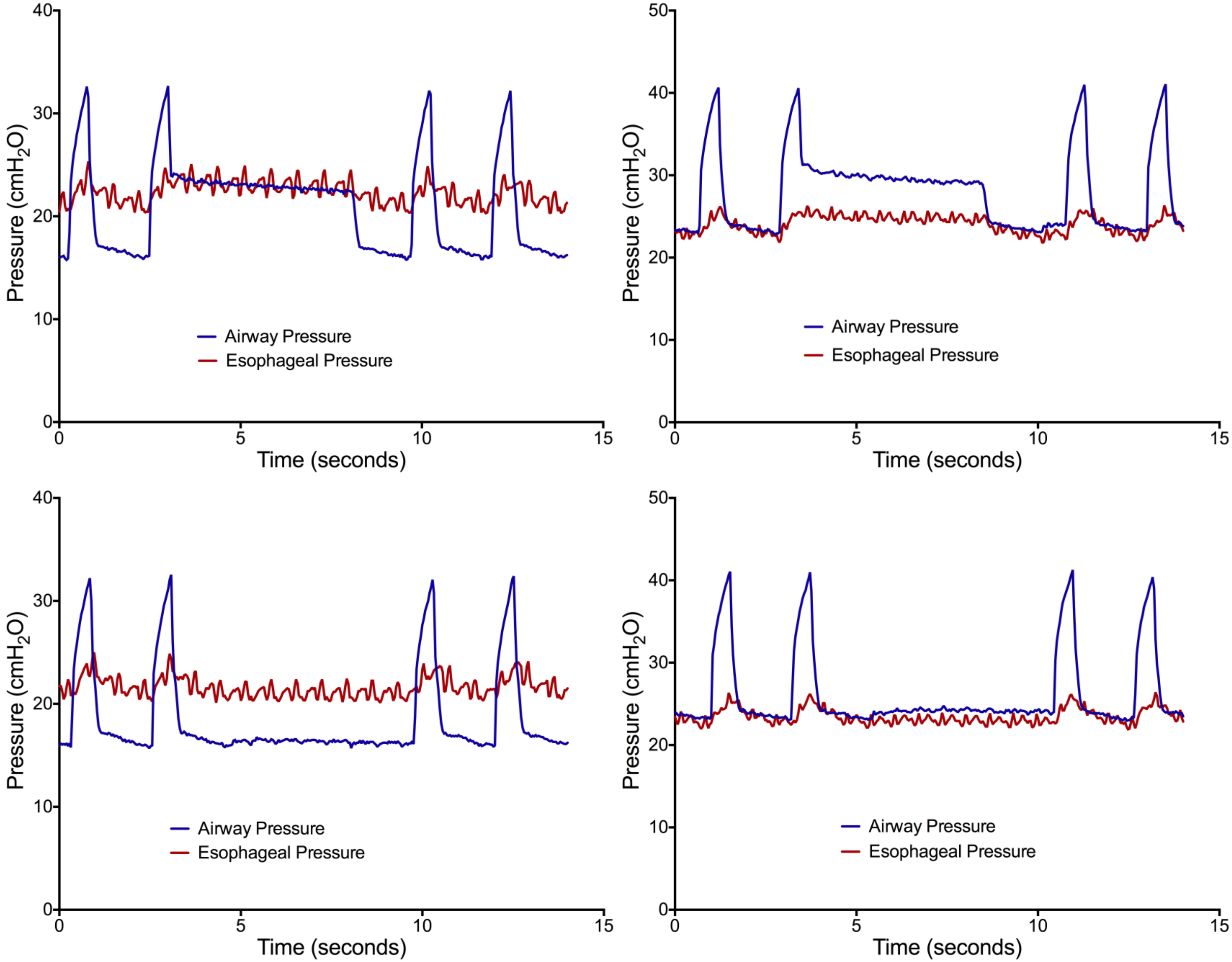

Ventilator Flowsheet

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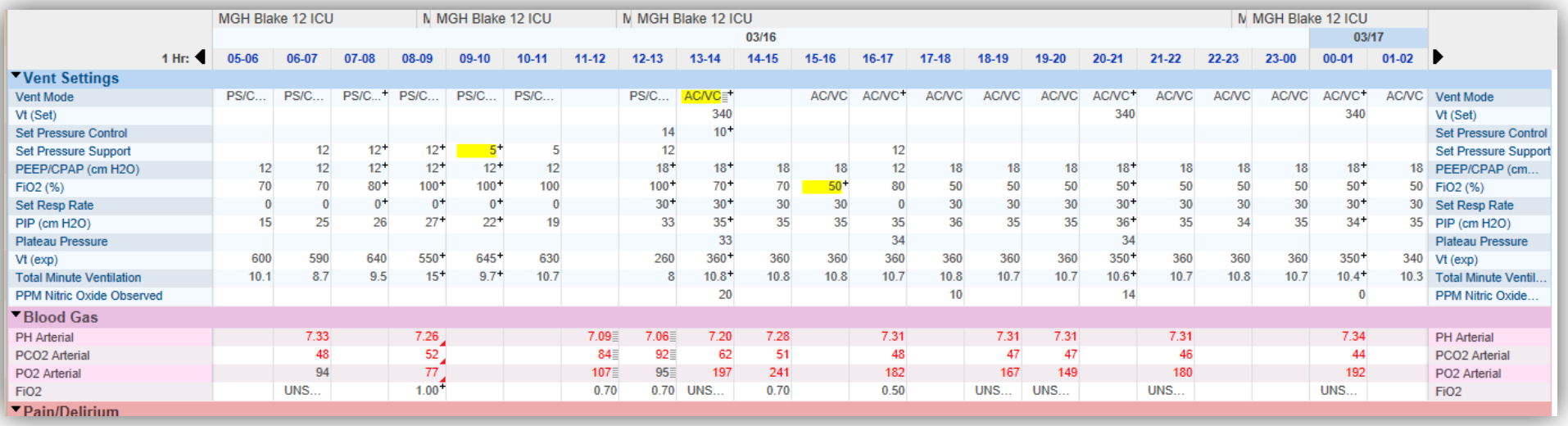

	MGH Blake 12 ICU	MGH Blake 12 ICU	MGH Blake 12 ICU	MGH Blake 12 ICU																	
								03/16												03/17	
1 Hr:	05-06	06-07	07-08	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-00	00-01	01-02
Vent Settings																					
Vent Mode	PS/C…	PS/C…	PS/C…+	PS/C…	PS/C…	PS/C…		PS/C…	AC/VC+		AC/VC	AC/VC+	AC/VC	AC/VC	AC/VC	AC/VC+	AC/VC	AC/VC	AC/VC	AC/VC+	AC/VC
Vt (Set)									340							340				340	
Set Pressure Control								14	10+												
Set Pressure Support		12	12+	12+	5+	5		12				12									
PEEP/CPAP (cm H2O)	12	12	12+	12+	12+	12		18+	18+	18	18	12	18	18	18	18+	18	18	18	18+	18
FiO2 (%)	70	70	80+	100+	100+	100		100+	70+	70	50+	80	50	50	50	50+	50	50	50	50+	50
Set Resp Rate	0	0	0+	0+	0+	0		30+	30+	30	30	0	30	30	30	30+	30	30	30	30+	30
PIP (cm H2O)	15	25	26	27+	22+	19		33	35+	35	35	35	36	35	35	36+	35	34	35	34+	35
Plateau Pressure									33			34				34					
Vt (exp)	600	590	640	550+	645+	630		260	360+	360	360	360	360	360	360	350+	360	360	360	350+	340
Total Minute Ventilation	10.1	8.7	9.5	15+	9.7+	10.7		8	10.8+	10.8	10.8	10.7	10.8	10.7	10.7	10.6+	10.7	10.8	10.7	10.4+	10.3
PPM Nitric Oxide Observed									20				10			14				0	
Blood Gas																					
PH Arterial		7.33		7.26			7.09	7.06	7.20	7.28		7.31		7.31	7.31		7.31			7.34	
PCO2 Arterial		48		52			84	92	62	51		48		47	47		46			44	
PO2 Arterial		94		77			107	95	197	241		182		167	149		180			192	
FiO2		UNS…		1.00+			0.70	0.70	UNS…	0.70		0.50		UNS…	UNS…		UNS…			UNS…	
Pain/Delirium																					

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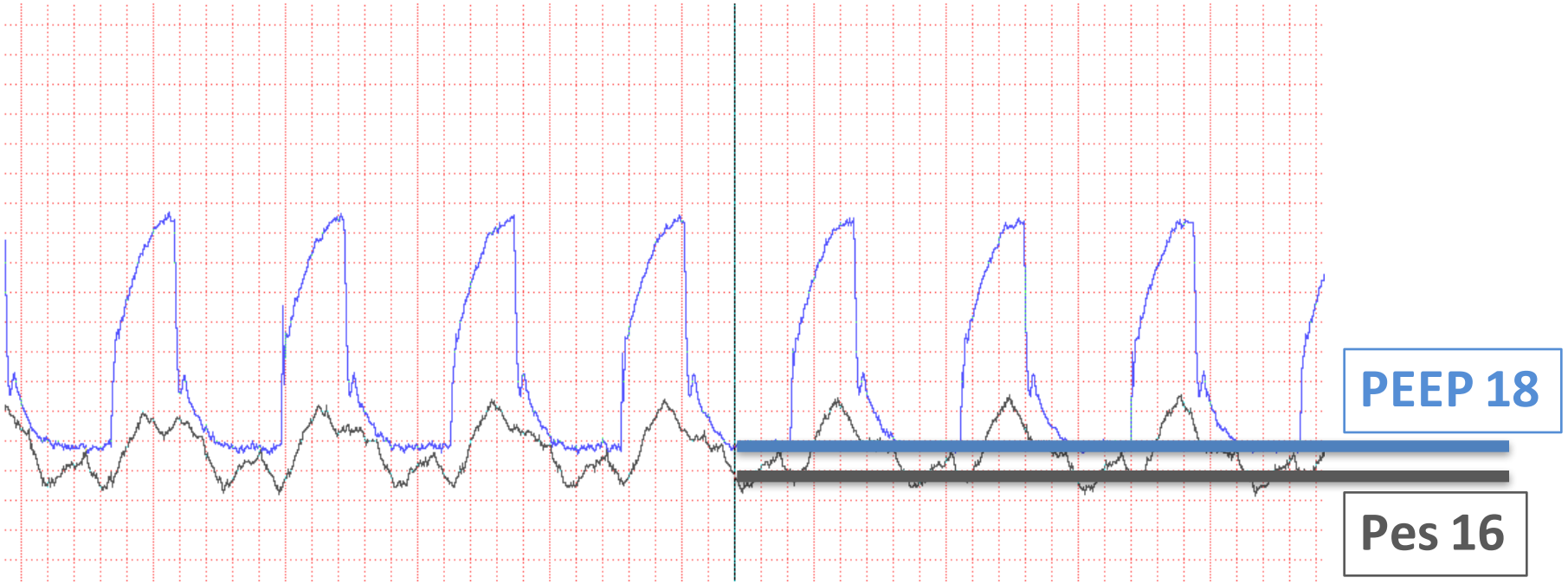
Transpulmonary

Before and after PEEP titration
Transpulmonary pressures were equal



March 16 -- 2238

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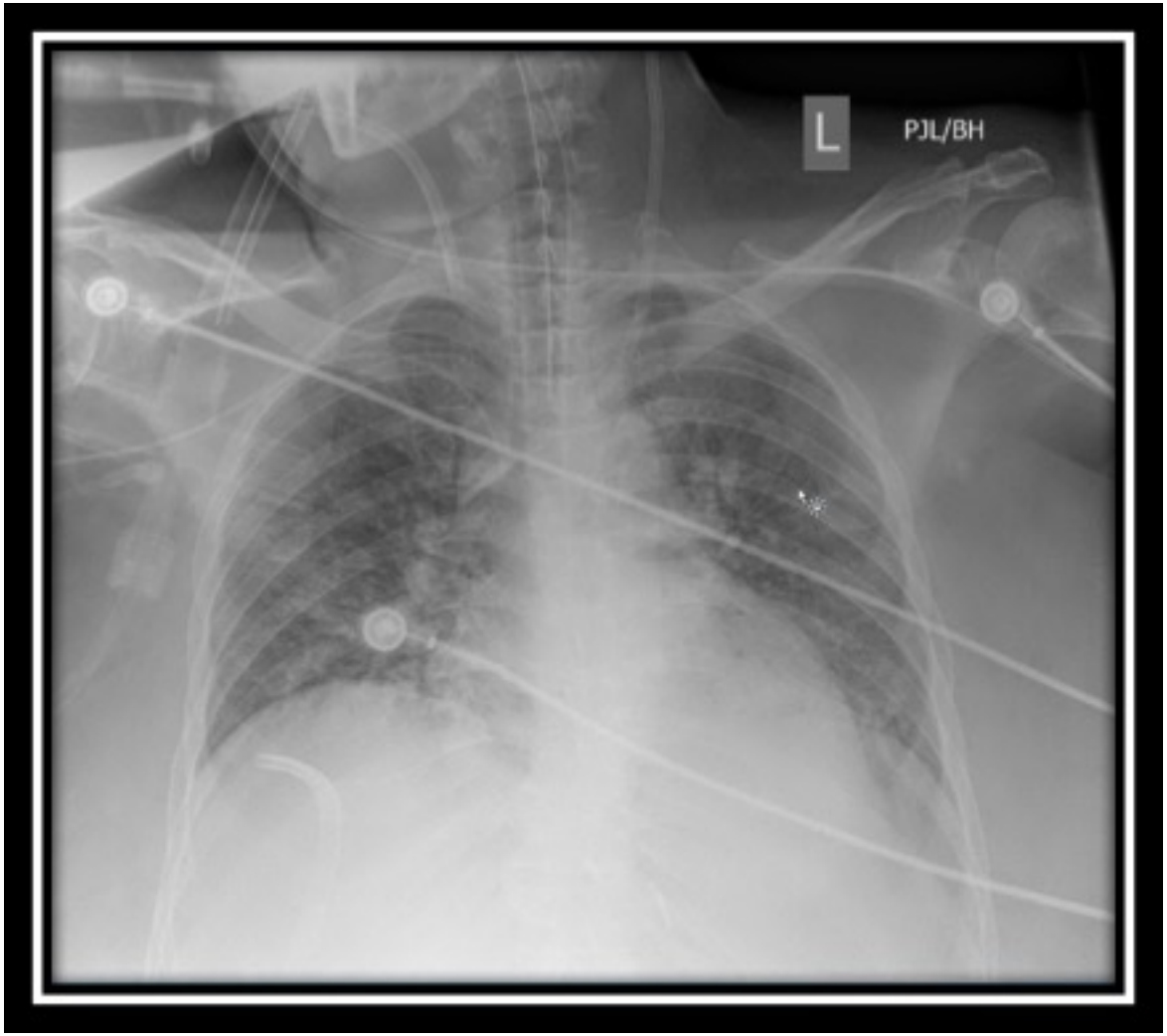

VCV 350 / 18 / 50%
PIP 34

ABG 7.34 / 44 / 192

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Recruitment + 8 hours

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Vent: PCV 12 / 18 / 100%, RR 30, PIP 33, TV 230

Resp. Mech: **Resp. Cpl 19**, Drive P 12, Pleu P = 16

ABG: 7.06 / 92 / 95 (P/F 95)

VCV 350 / 18 / 50% RR 30, PIP 32

Resp. Cpl 25, Drive P 14, Pleu P = 16

ABG 7.34 / 44 / 192 (P/F 384)

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Post-Event

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- 3/16/17 – 4/10/17: multiple bradycardia / asystole events / NSTEMI
- 3/23/17: Tracheostomy
- 4/12/17: Transferred to floor
- 4/21/17: Plan for rehab

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Complex Respiratory Rounds
April 21st , 2017

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Roberta De Santis Santiago (research fellow)

Effect of Intensive vs Moderate Alveolar Recruitment Strategies Added to Lung-Protective Ventilation on Postoperative Pulmonary Complications

A Randomized Clinical Trial

Costa Leme A, Hajjar LA, Volpe MS, Fukushima JT, De Santis Santiago RR, Osawa EA, Pinheiro de Almeida J, Gerent AM, Franco RA, Zanetti Feltrim MI, Nozawa E, de Moraes Coimbra VR, de Moraes Ianotti R, Hashizume CS, Kalil Filho R, Auler JOC, Jatene FB, Gomes Galas FRB, Amato MBP.

JAMA. 2017;317(14):1422-1432. (published online March 21)

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Background

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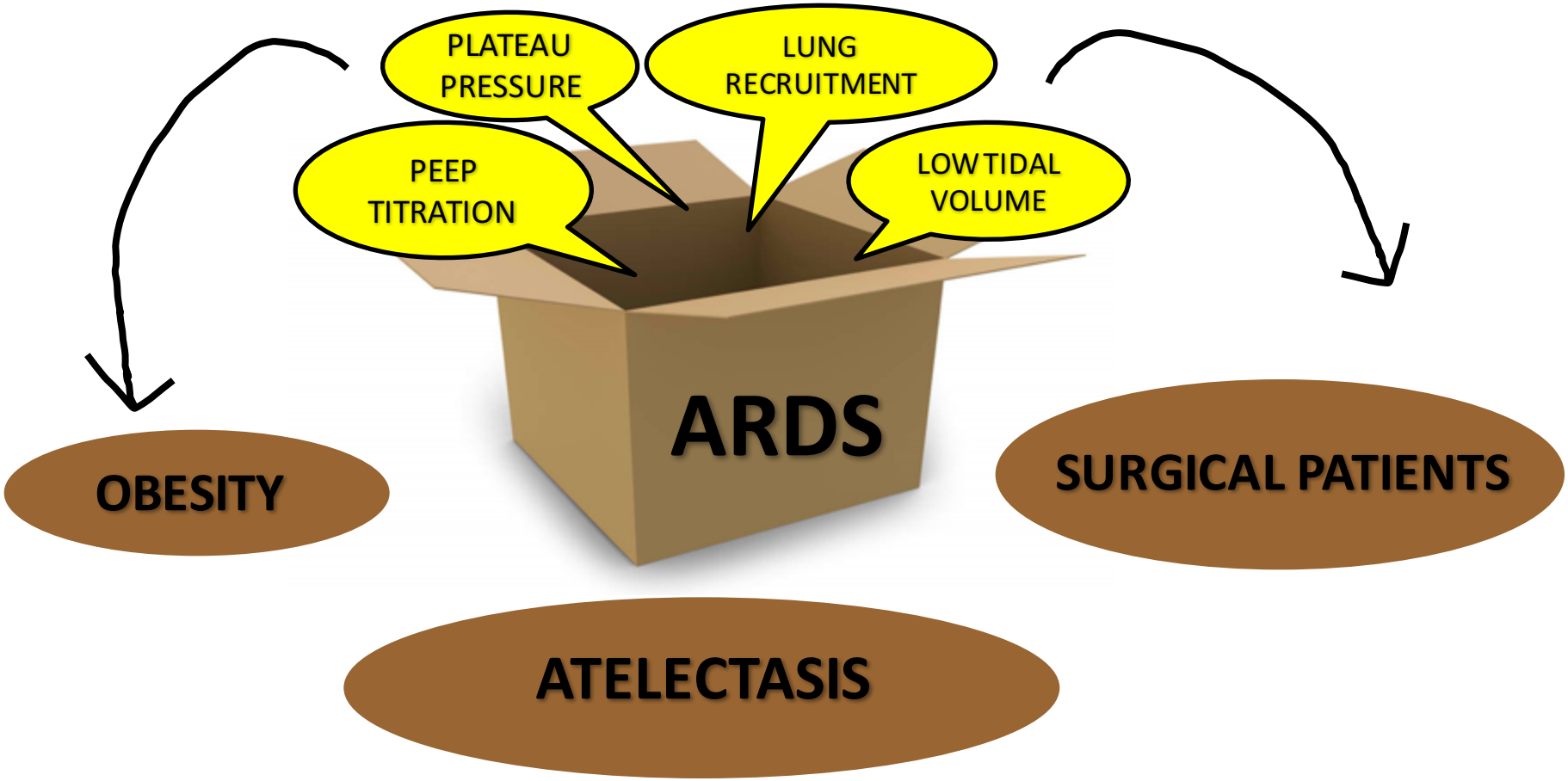

HOW TO VENTILATING OUTSIDE THE BOX ?

Background

- Pulmonary complication after cardiac surgery
  - Open chest / cardiopulmonary bypass (CPB)
  - Hypoxemia , pneumonia, VILI, ARDS
    - NIV
    - Delayed mobilization
    - Prolonged supp O2

Question

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Is there any extra benefit of applying more intensive alveolar recruitment strategies for high-risk surgical patients already receiving protective lung ventilation?

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Methods

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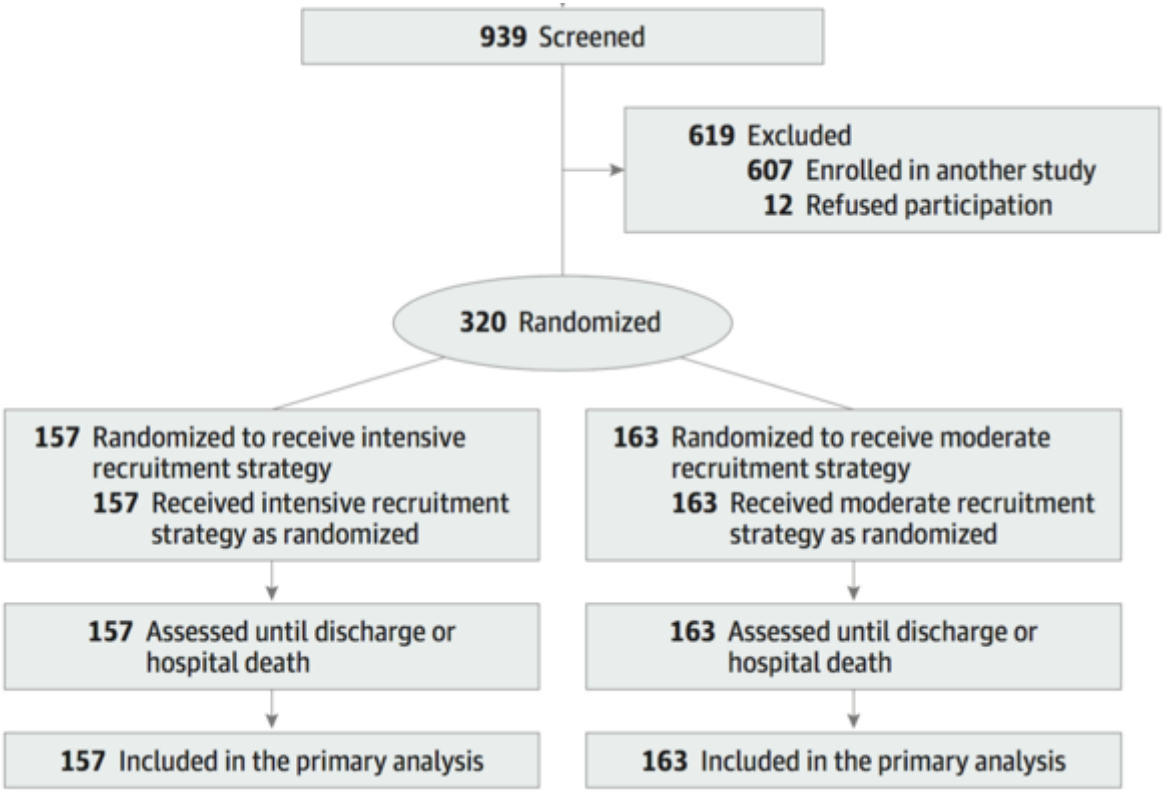
Single-center, prospective trial, University of São Paulo, Brazil (2011 to 2014)

Eligibility

1)Elective cardiac surgery:
CABG and/or valve surgery
(with or without CPB)

2)Hypoxemia at ICU admission:
PaO_2/FiO_2 <250 mmHg and
PEEP ≥5 cmH_2O



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Arm I
(Moderate recruitment strategy)

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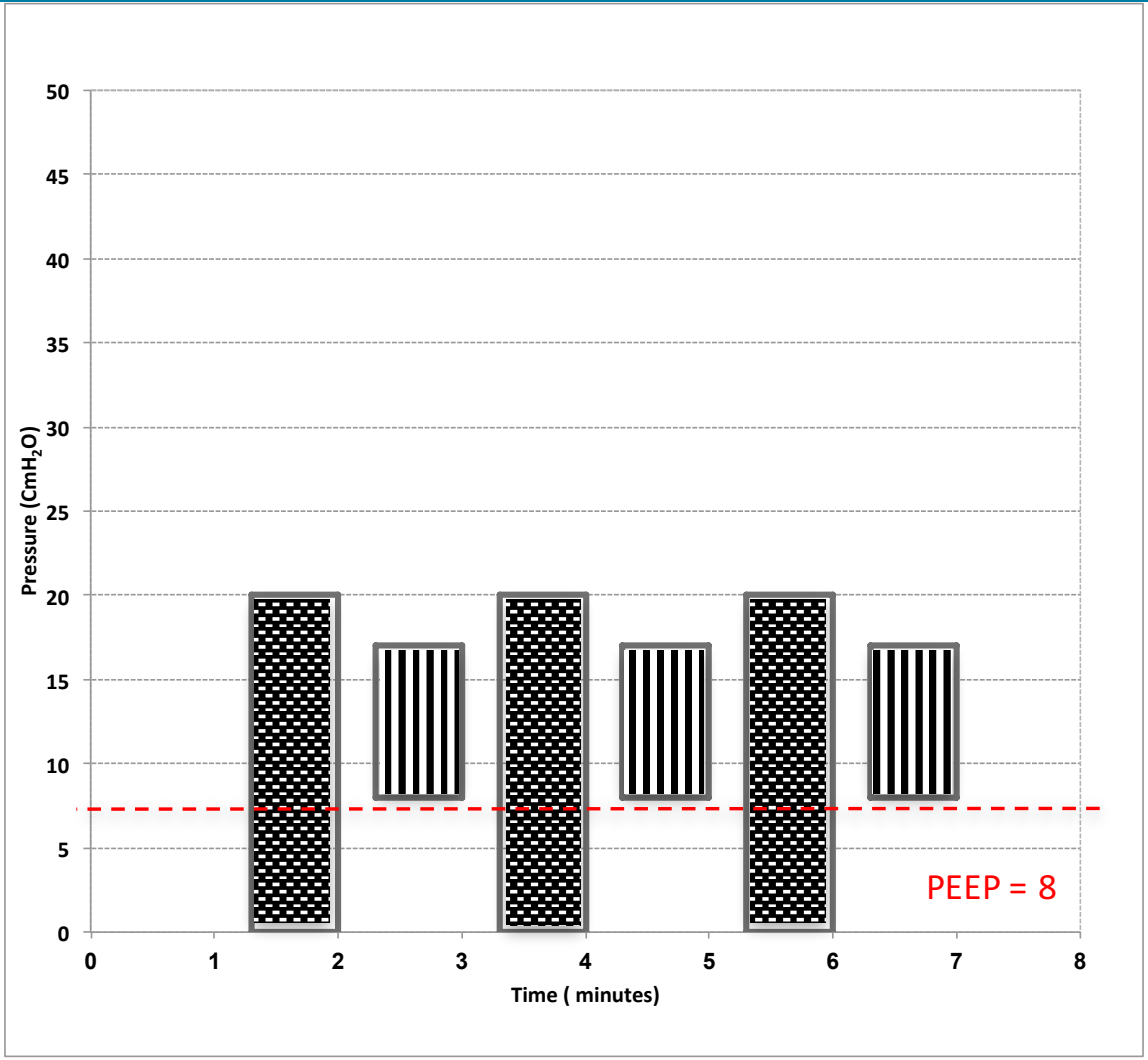
Baseline:
VCV (6mL/Kg $_{PBW}$)
FiO_2 60% PEEP 5

Moderate-RS:
CPAP 20 (30 sec)
FiO2 60%

Maintenance:
VCV
6 mL/kg $_{PBW}$
PEEP 8



AFTER 4H :RECRUITMENT WAS REPEATED

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Arm II
(Intensive recruitment strategy)

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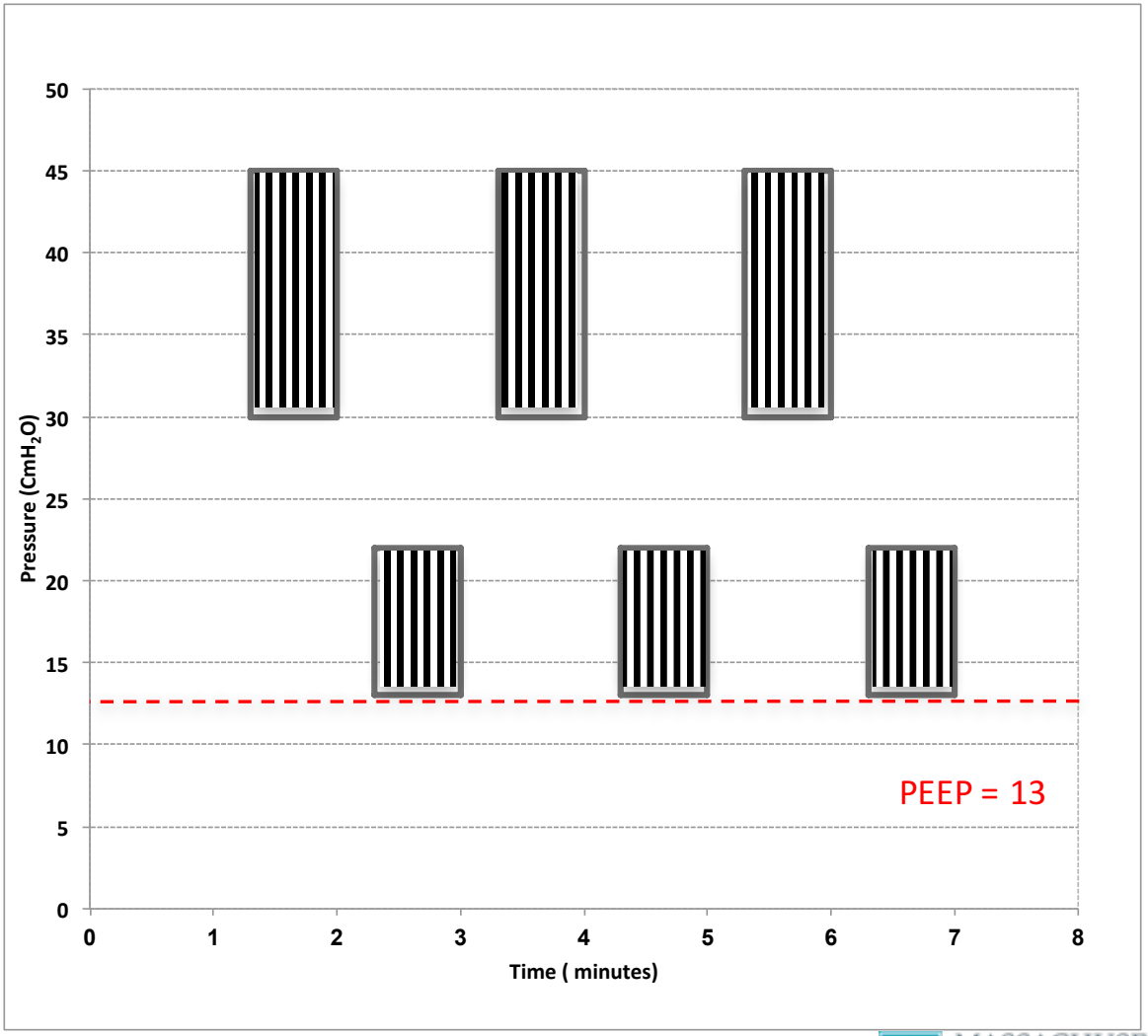
Baseline:
VCV (6mL/Kg $_{PBW}$)
FiO_2 60% PEEP 5

Intensive-RS:
PEEP 30 (60 sec)
Delta P 15
RR 15 / Tinsp 1,5 sec
FiO_2 40%

Maintenance:
PCV
Delta P → 6 ml/kg PBW
PEEP 13



AFTER 4H :RECRUITMENT WAS REPEATED

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Recruitment strategies

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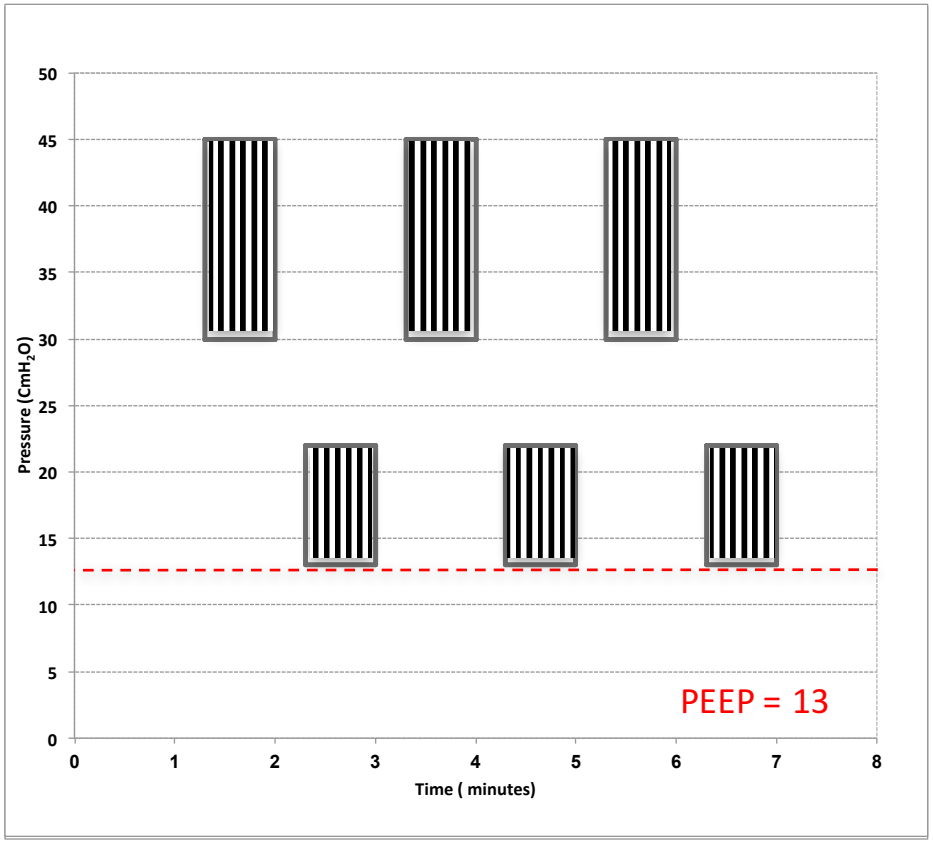
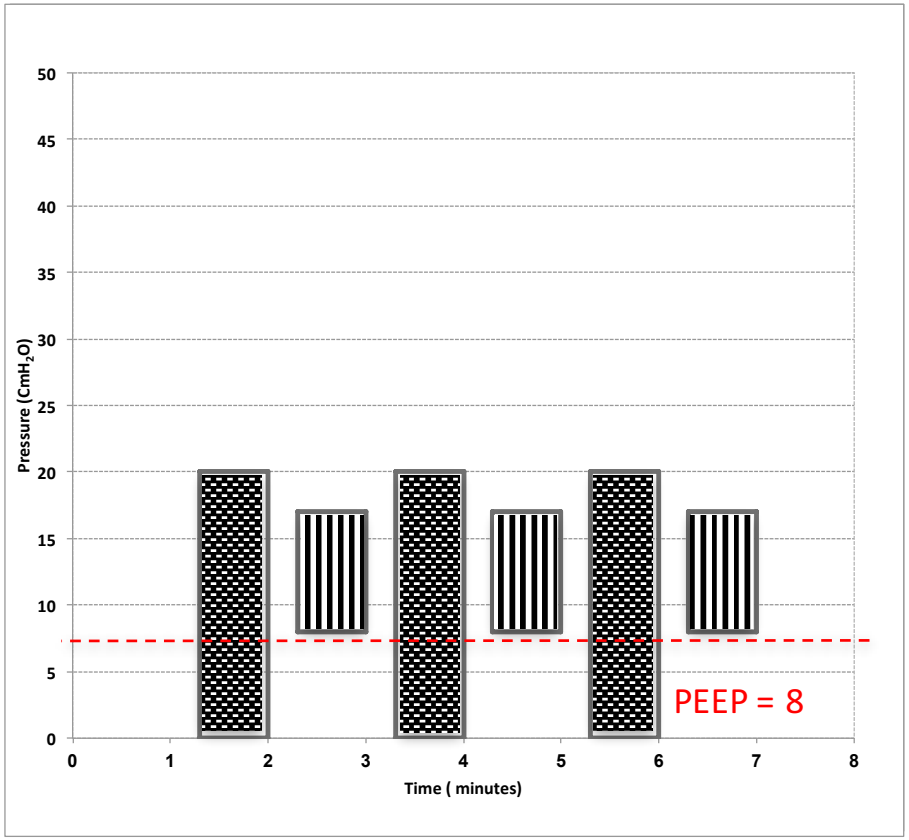
INTENSIVE



MODERATE



After the second recruitment , weaned and extubated at arm's PEEP

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Outcomes

PRIMARY OUTCOME

Post surgical pulmonary complication

Scale 0-5

0: no symptoms / signals

4: MV ≥ 48h (invasive)

5: death

SECUNDARY OUTCOMES

Hospital and ICU (length of stay)

Hospital mortality

Cardiovascular complications

Daily (5) post surgical pulmonary complications

Results

Table 2. Intraoperative Characteristics

Variables	Recruitment Strategy, No. (%) of Patients	
	Intensive (n = 157)	Moderate (n = 163)
Type of surgery		
CABG	116 (74)	119 (73)
Valvular repair	35 (22)	36 (22)
Combined	6 (4)	8 (5)
Duration of surgery, median (IQR), min	390 (340-450)	390 (335-450)
Use of CPB	134 (85)	135 (83)
Length of CPB, median (IQR), min	91 (78-104)	90 (75-107)

Lung Pressure-volume curve

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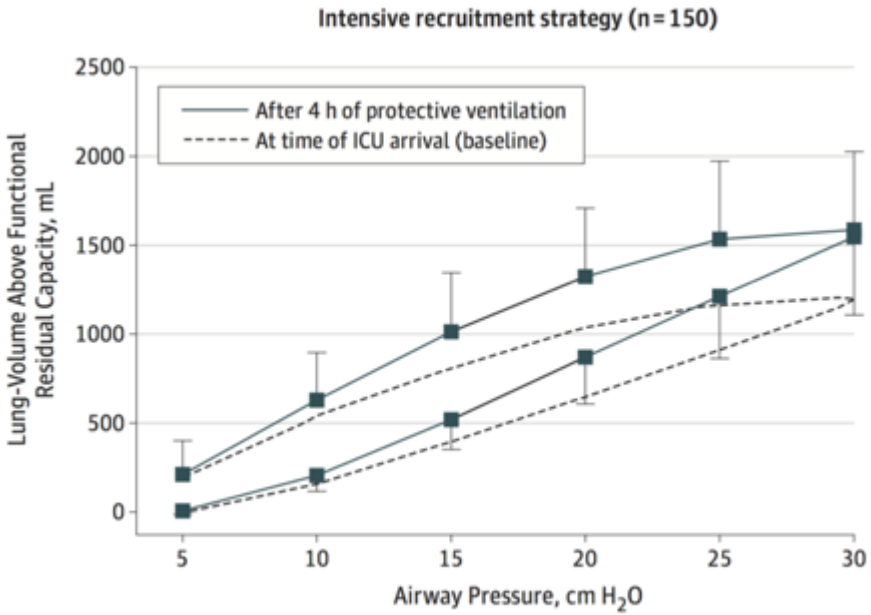

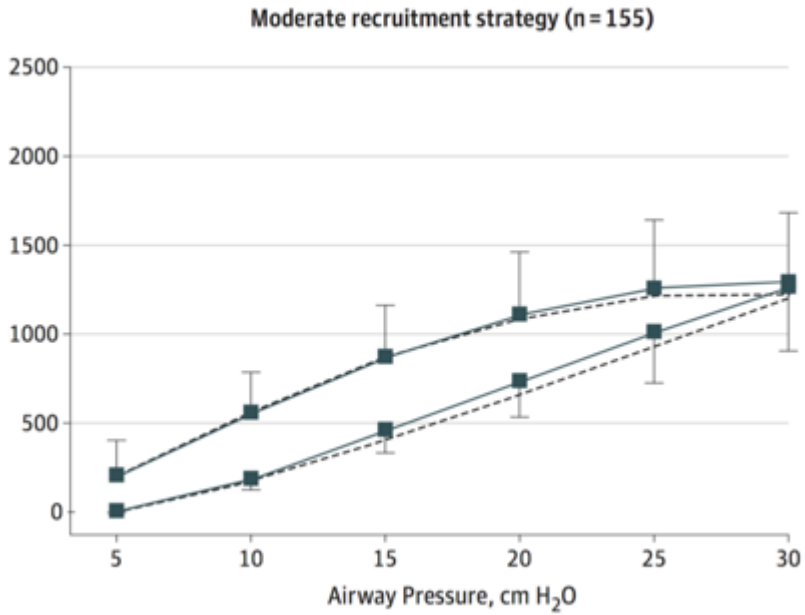

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Lung Mechanics

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	First recruitment		Second recruitment			
Variables	Baseline	15 min after 1° RM	4 hours	15 min after 2° RM	P-Value between-factor	P-Value interaction-factor
V_T (mL/PBW)						
Moderate-RS (N=155)	6.0 (0.9)	6.1 (1.0)	6.0 (1.0)	6.1 (1.1)	0.387	0.520
Intensive-RS (N=144)	6.1 (1.4)	6.1 (1.3)	6.1 (1.4)	6.2 (1.4)		
C_{RS} (mL/cmH_2O)						
Moderate-RS (N=155)	42.3 (12.8)	50.0 (15.5)	47.9 (14.5)	52.6 (17.8)	<0.001	<0.001
Intensive-RS (N=144)	41.6 (12.7)	64.6 (19.4)	54.9 (17.1)	68.4 (19.0)		

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Arterial blood gas

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First recruitment | Second recruitment

Variables	Baseline	15 min after 1° RM	4 hours	15 min after 2° RM	P-Value between-factor	P-Value interaction-factor
$PaCO_2$, mmHg						
Moderate-RS (N=151)	42.8 (5.9)	49.7 (9.0)	43.9 (8.0)	47.3 (9.0)	< 0.001	< 0.001
Intensive-RS (N=142)	43.3 (6.2)	45.4 (7.3)	41.6 (6.2)	41.9 (7.4)		
PaO_2/FiO_2						
Moderate-RS (N=151)	183 (37)	236 (68)	231 (74)	239 (74)	< 0.001	< 0.001
Intensive-RS (N=142)	181 (35)	344 (74)	348 (69)	362 (67)		

IMPROVED VENTILATION

DECREASED ATELECTASIS

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Pulmonary complications

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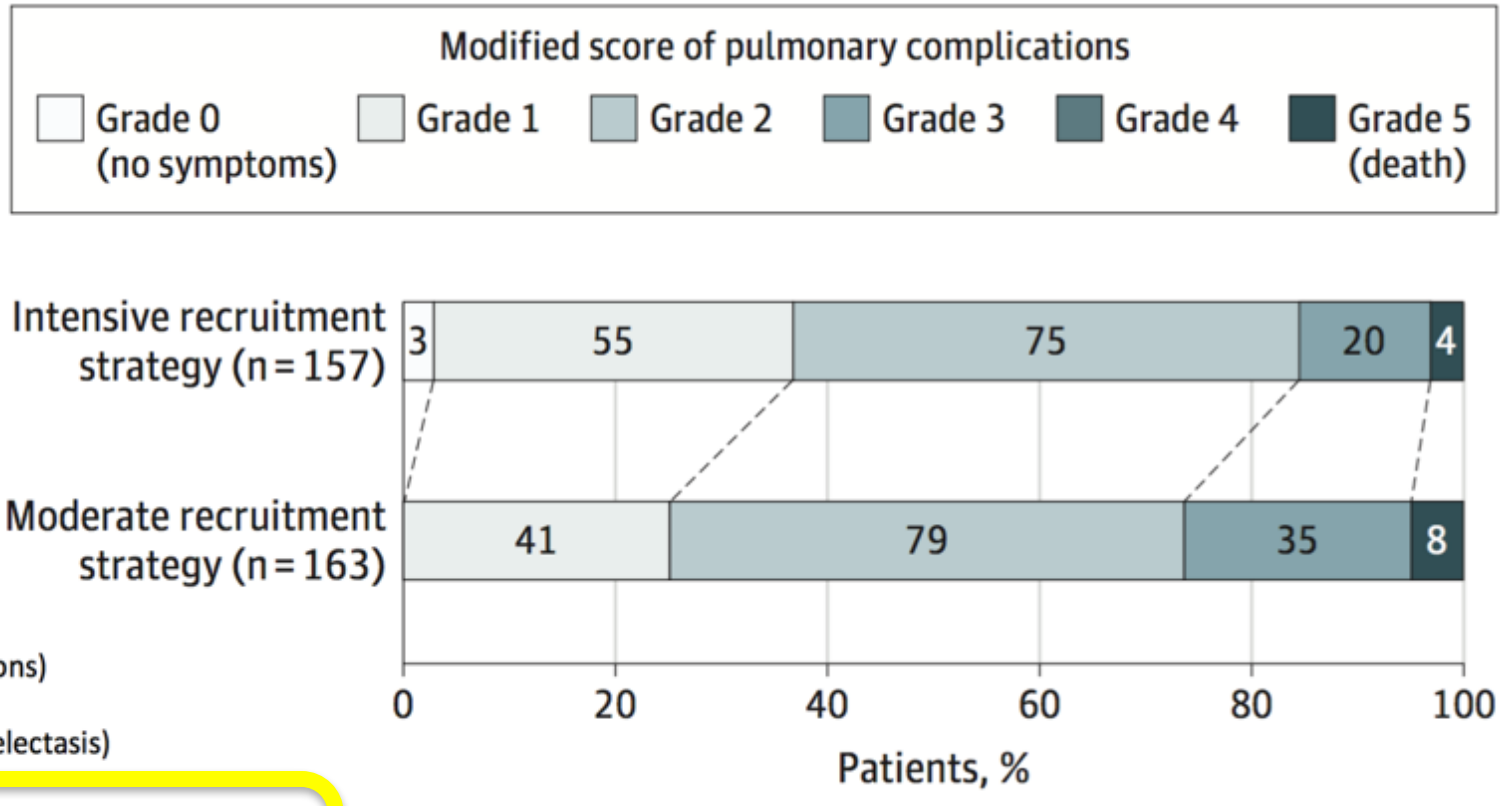

grade 0 (no complications)

grade 1 (e.g. simple atelectasis)

grade 2 (e.g. hypoxemia plus abnormal lung findings)

grade 3 (e.g. pneumonia, intense NIV need)

grade 4 (e.g. intubation > 48hs)

grade 5 (death)

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Daily pulmonary complications

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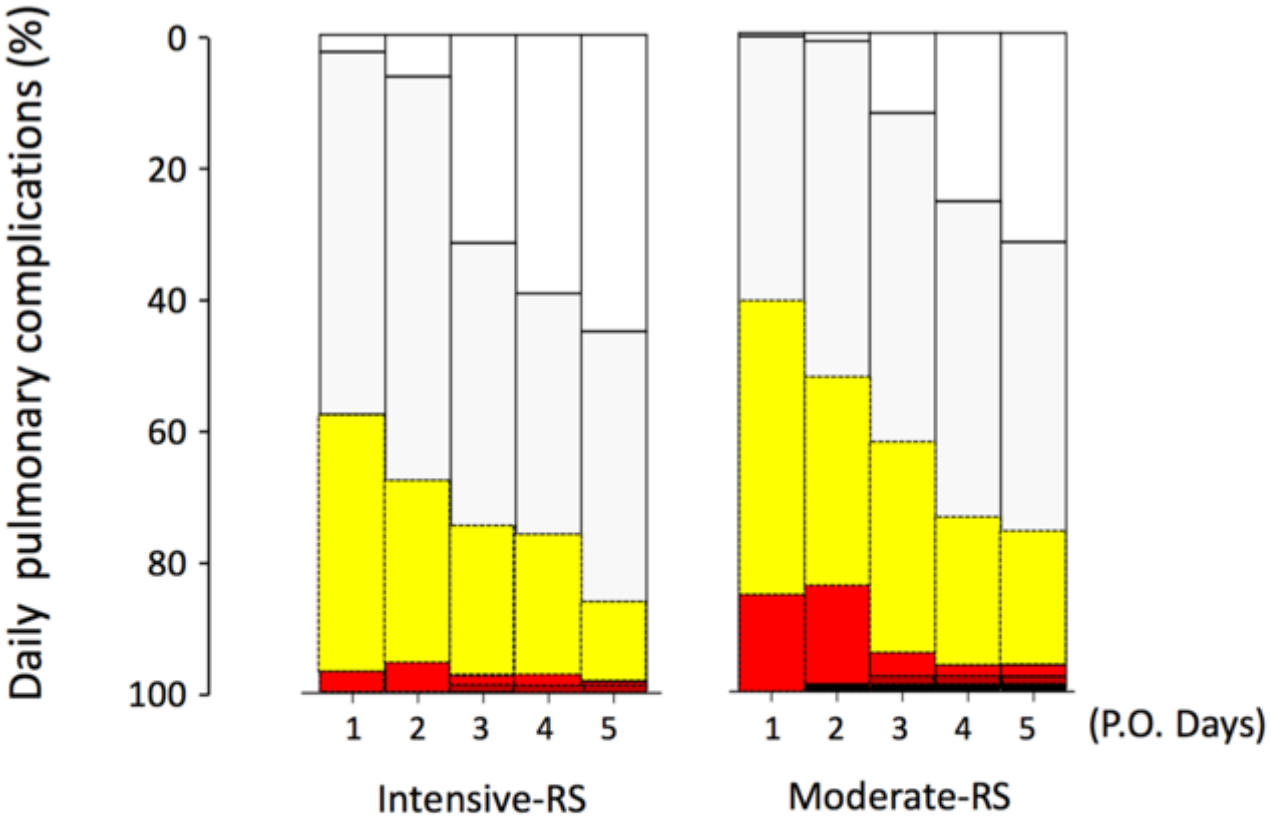

grade 0 (no complications)

grade 1 (e.g. simple atelectasis)

grade 2 (e.g. hypoxemia plus abnormal lung findings)

grade 3 (e.g. pneumonia, intense NIV need)

grade 4 (e.g. intubation > 48hs)

grade 5 (death)

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Hypoxemia

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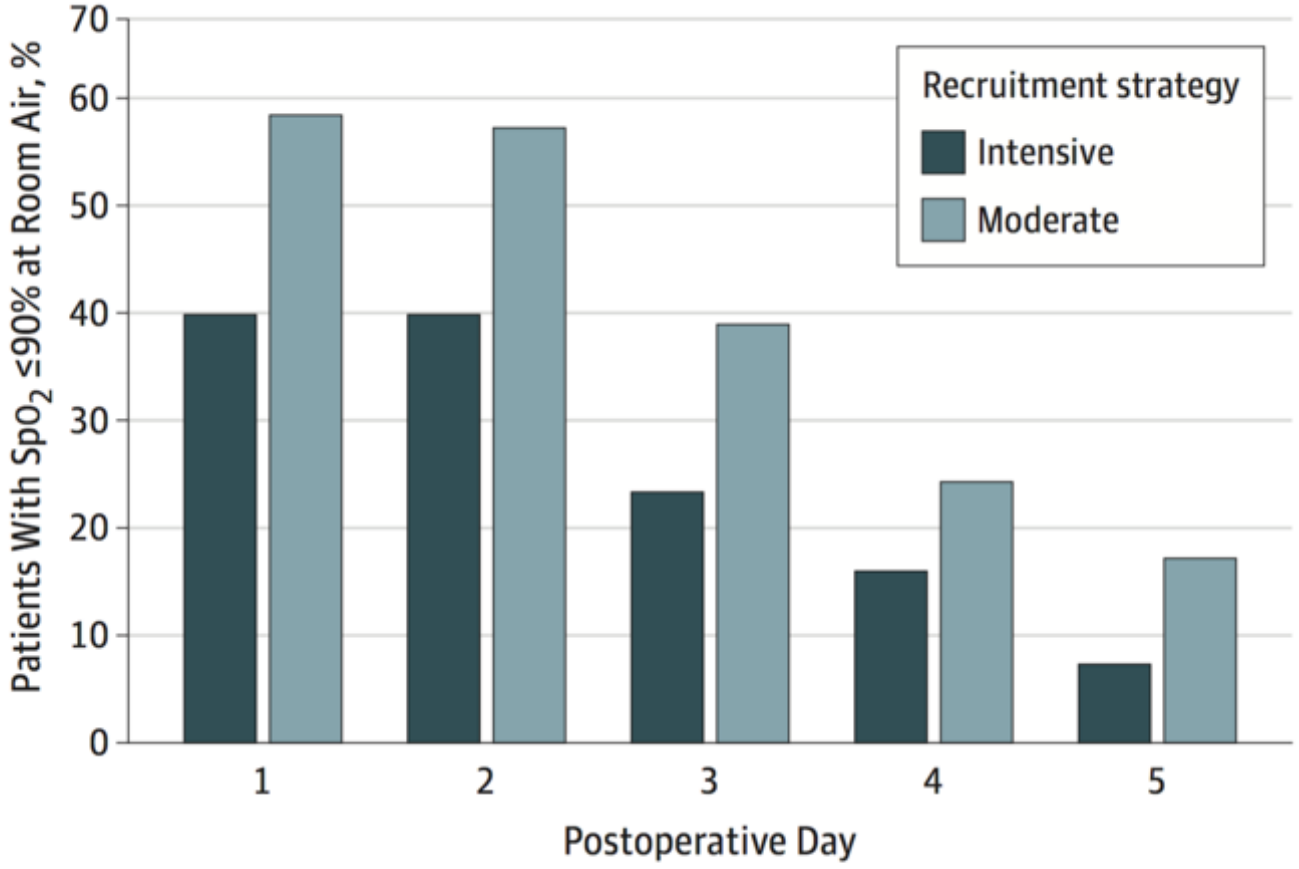

No. of patients by recruitment strategy

Intensive	154	154	154	154	154
Moderate	158	158	158	158	157

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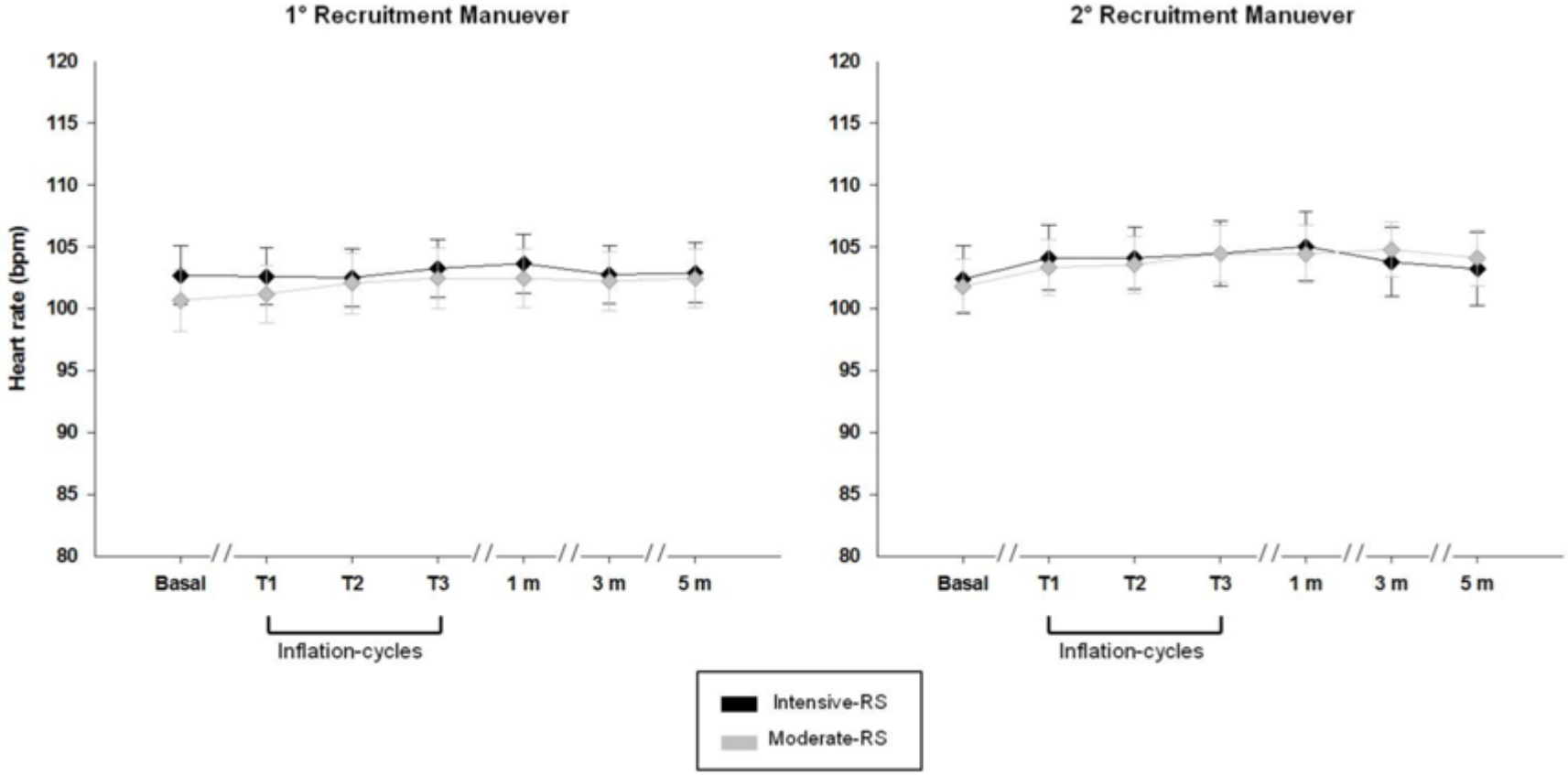
Heart rate



	1 hour	2 hours	3 hours	4 hours	P between factor	P interaction factor
Heart rate, bpm						
Moderate-RS (N=156)	101 (16)	103 (15)	104 (16)	105 (15)	0.959	0.538
Intensive-RS (N=148)	101 (14)	104 (15)	104 (17)	105 (17)		

Mean arterial pressure

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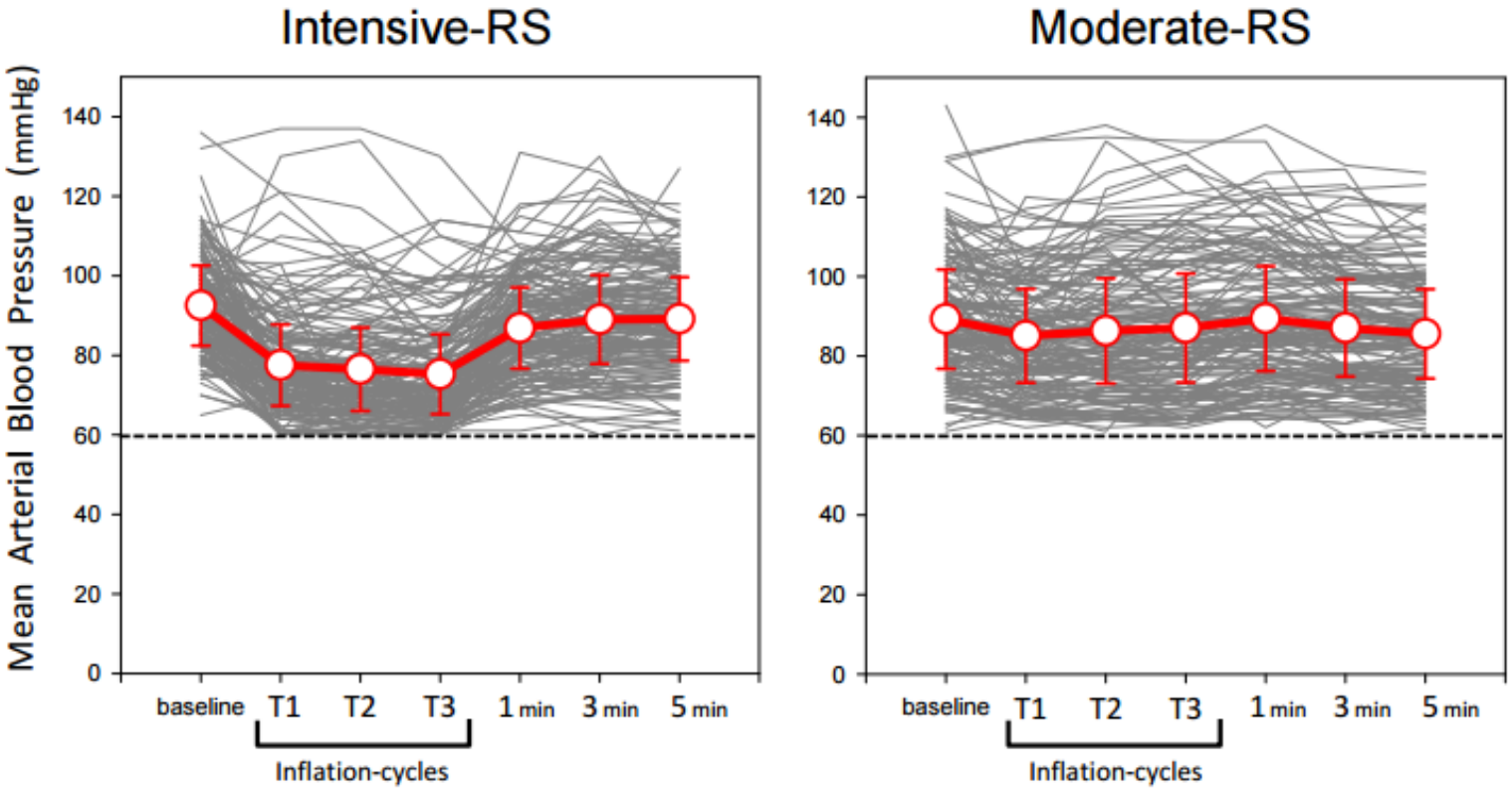

	1 hour	2 hours	3 hours	4 hours	P between factor	P interaction factor
MAP[¶], mmHg						
Moderate-RS (N=156)	91 (16)	88 (14)	86 (13)	86 (15)	0.667	0.588
Intensive-RS (N=148)	89 (16)	88 (14)	86 (13)	87 (12)		

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Intensive-RS decreased the needs of supp O2 and use of NIV

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Variables	Recruitment Strategy: Intensive (n = 157)	Recruitment Strategy: Moderate (n = 163)	Odds Ratio (95% CI) or Absolute Difference, % (95% CI)	*P* Value Unadjusted
Primary outcome				
Pulmonary complication severity score	1.7 (1 to 2)	2 (1.5 to 3)	1.86 (1.22 to 2.83)[a]	.003[b]
Dichotomized as grade, No. (%)[c]				
≥2	99 (63)	122 (75)	−11.8 (−21.6 to −1.7)	
≥3	24 (15)	43 (26)	−11.1 (−19.8 to −2.2)	
≥4	4 (2.5)	8 (4.9)	−2.4 (−7.1 to 2.2)	
Other outcomes				
Need of supplemental O_2>24 h within first 5 d, No. (%)[g]	93 (59)	125 (77)	−17.5 (−27.2 to −7.2)	.001[h]
Mechanical ventilation in ICU, mean (95% CI), h[g]	10.6 (9.6-11.3)	11.7 (10.8-12.5)	1.1 (−1.7 to −0.3)	.02[i]
Extended use of NIV, No. (%)[g,j]	6 (4)	25 (15)	−11.5 (−17.2 to −5.2)	<.001[h]

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Kaplan-Meier (discharges)

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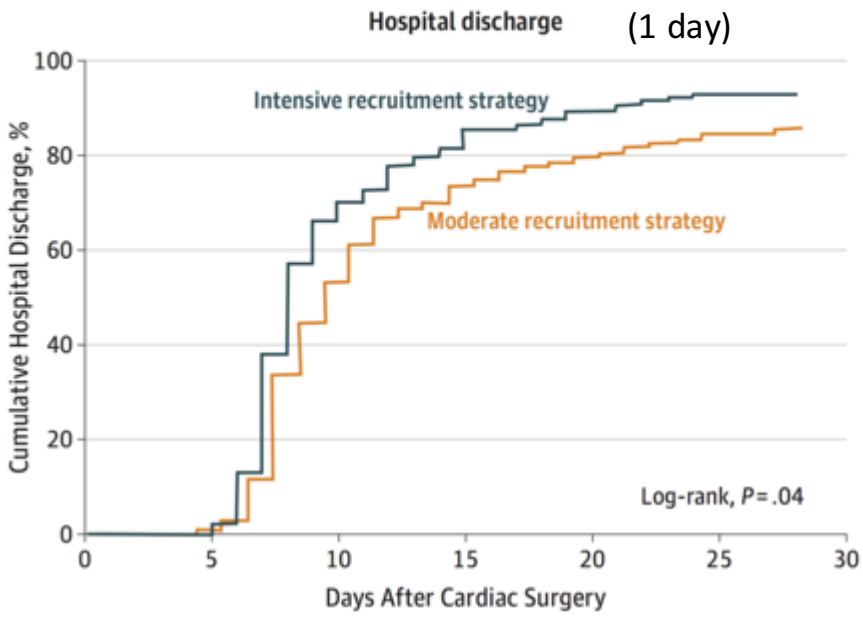
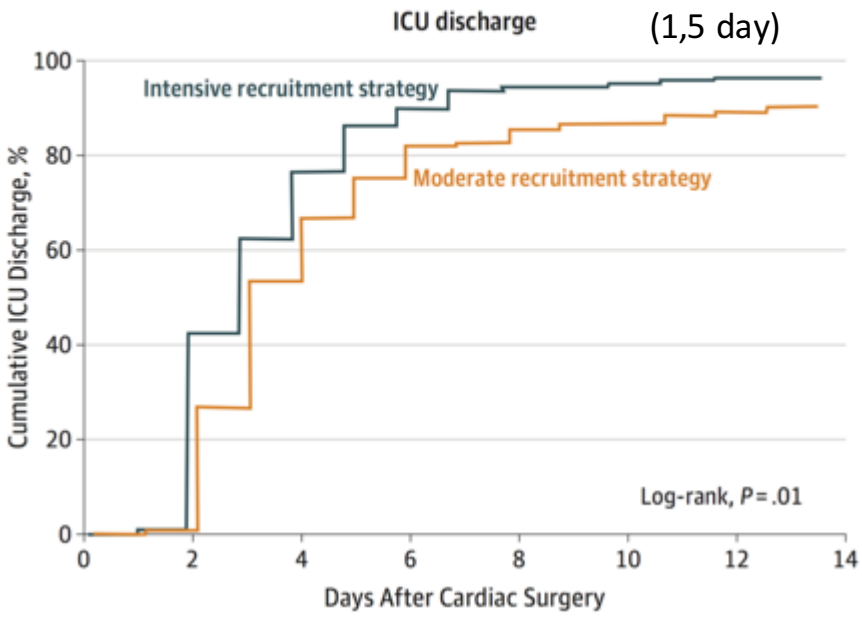
Figure 3. Kaplan-Meier Survival Analysis for Time to Hospital Discharge and Intensive Care Unit Discharge





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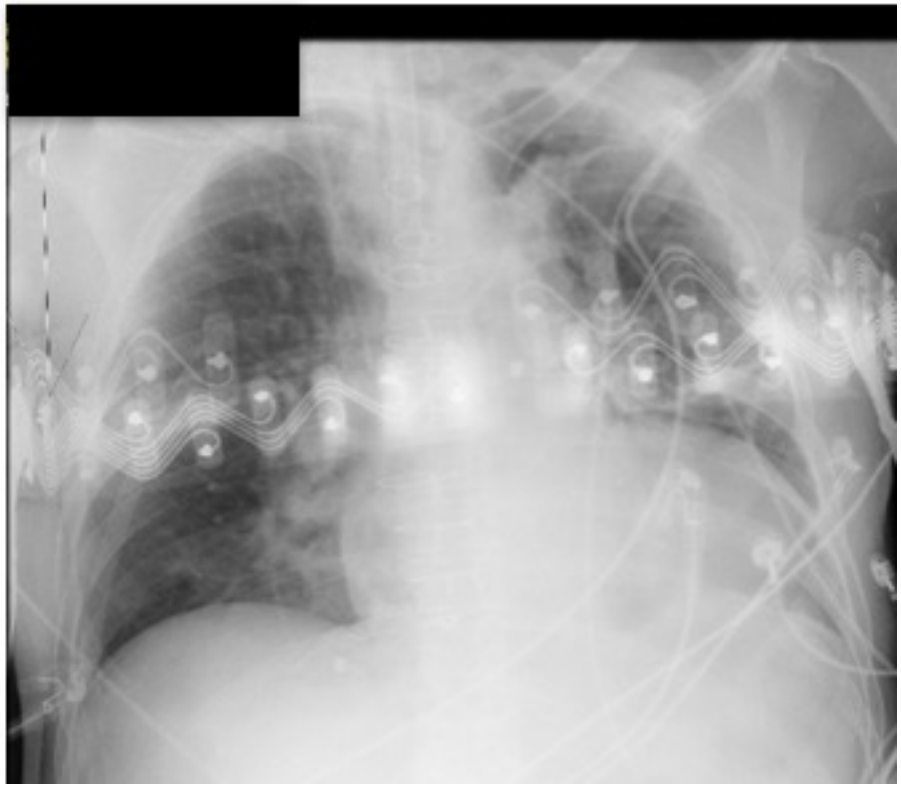
Electrical Impedance Tomography (EIT)



(33 patients)

EIT imaging

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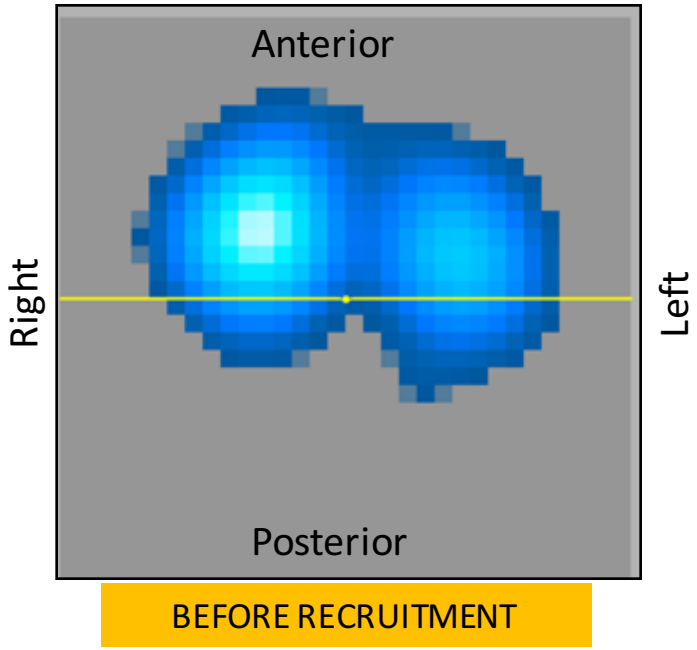
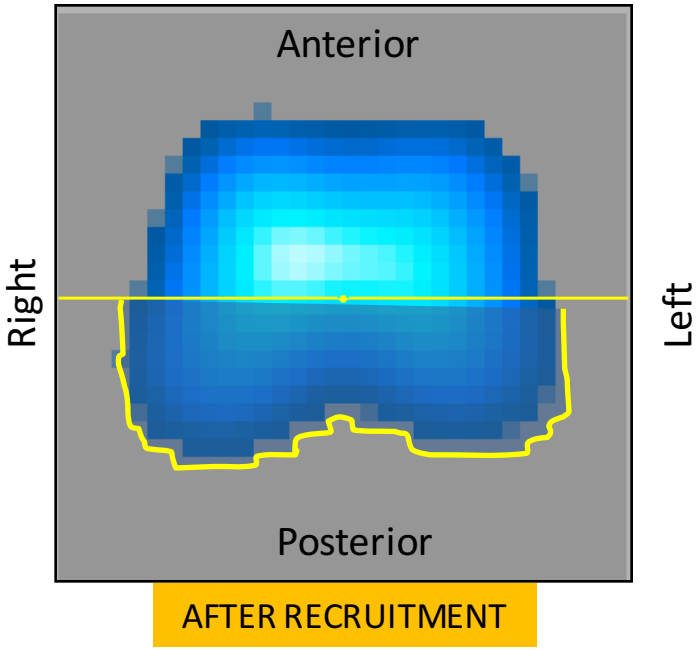
Impact on distribution of increased gas volume



BEFORE RECRUITMENT



AFTER RECRUITMENT

EIT traces

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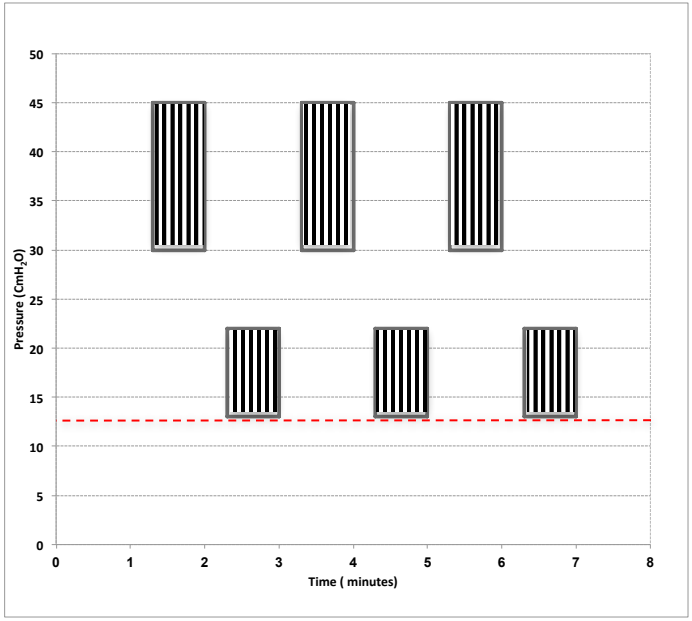
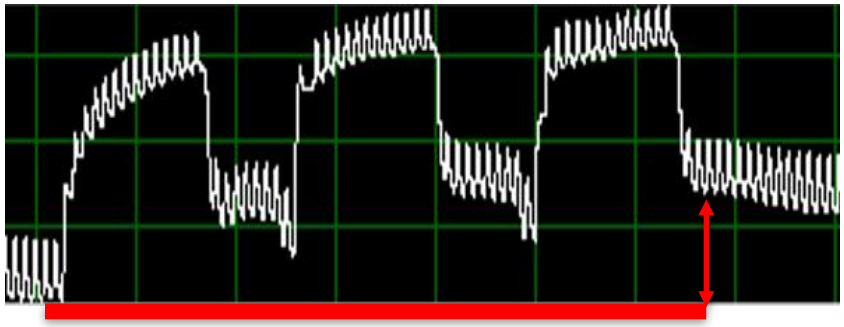
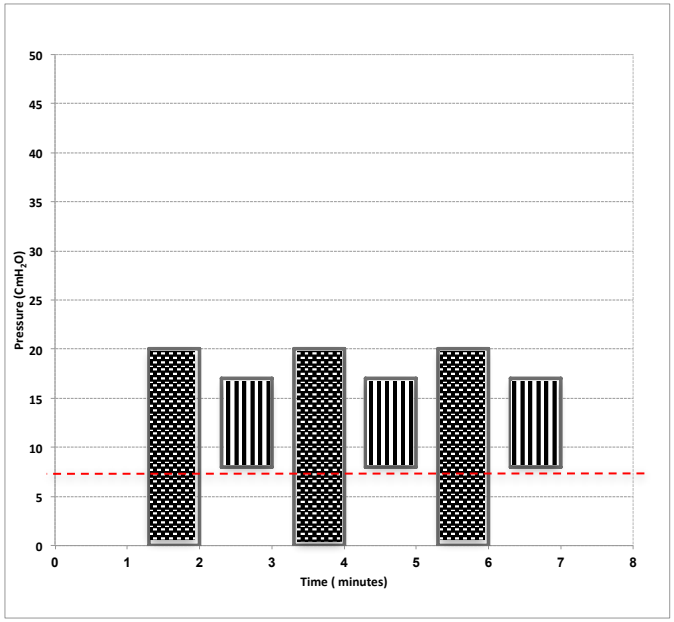
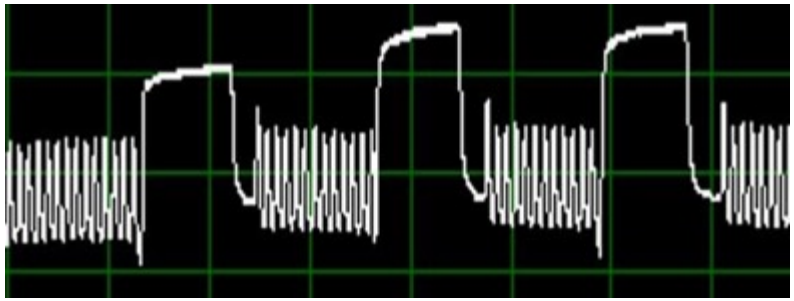
INTENSIVE –RS





MODERATE –RS





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Redistribution of ventilation (EIT)

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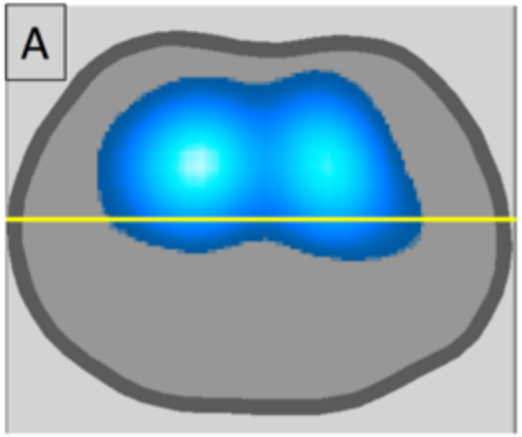
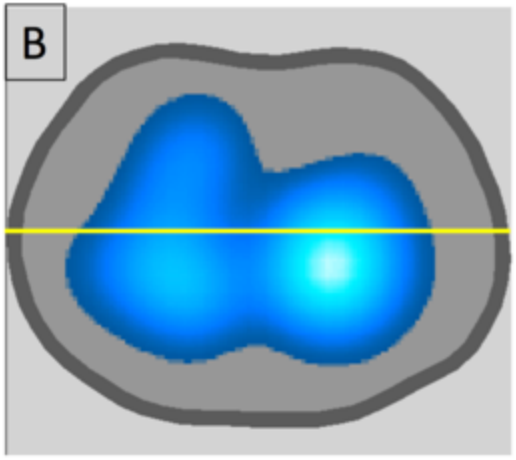
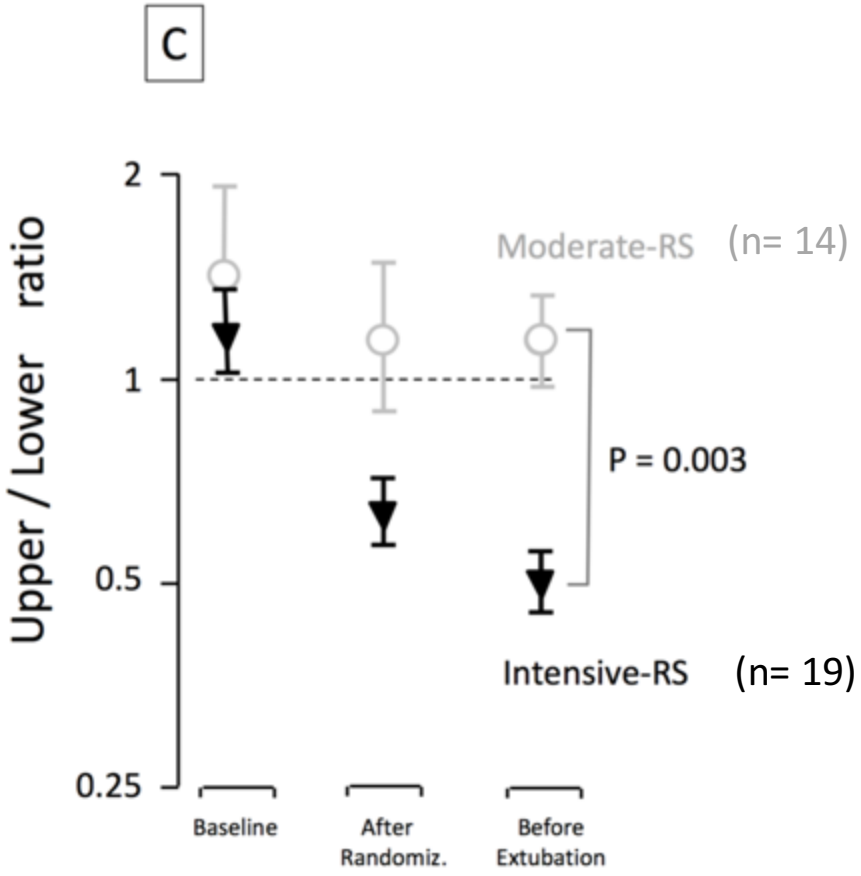


U/L ratio = 4.7 (Moderate-RS)



U/L ratio = 0.5 (Intensive-RS)



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Regional P-V curves

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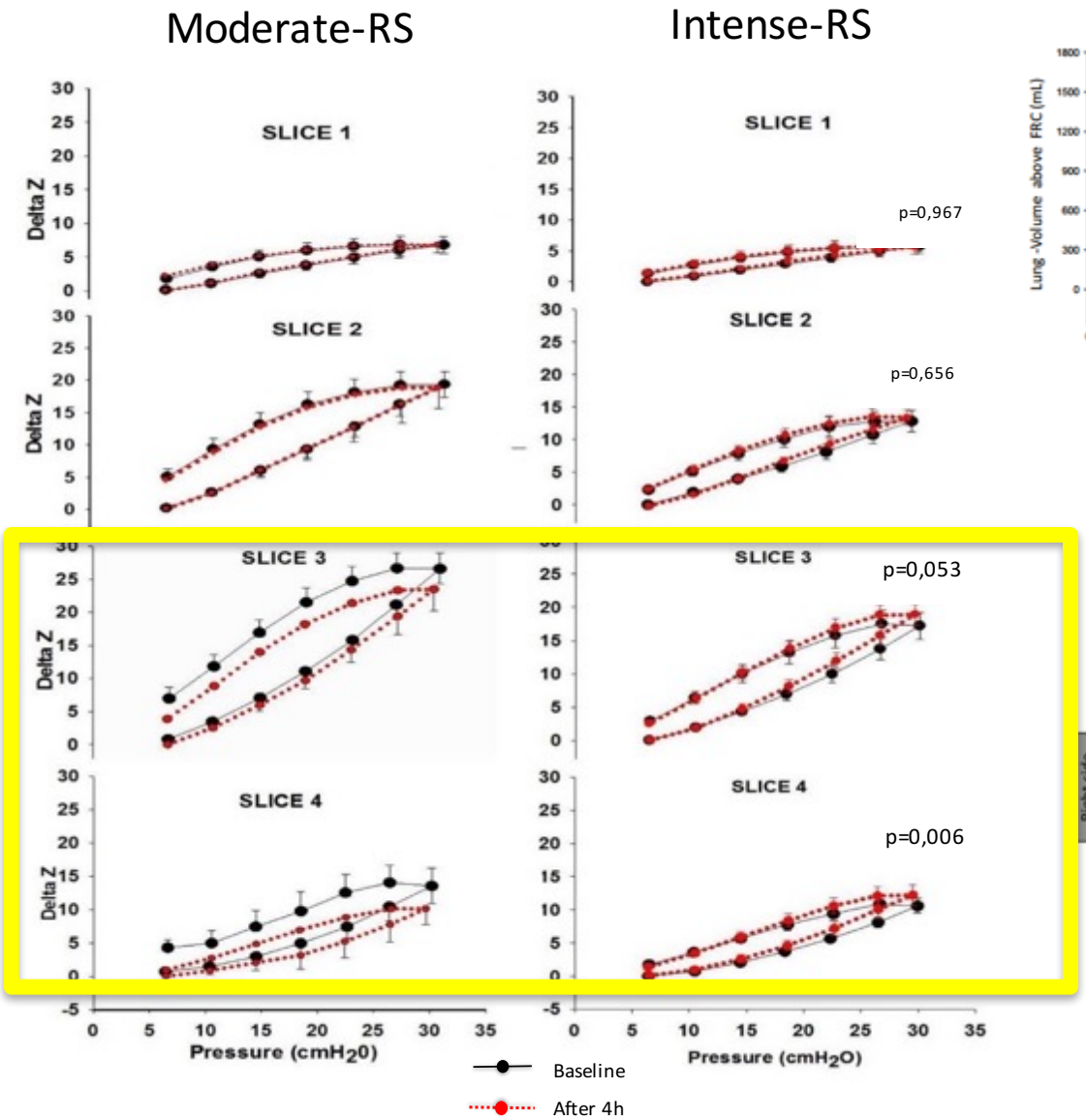

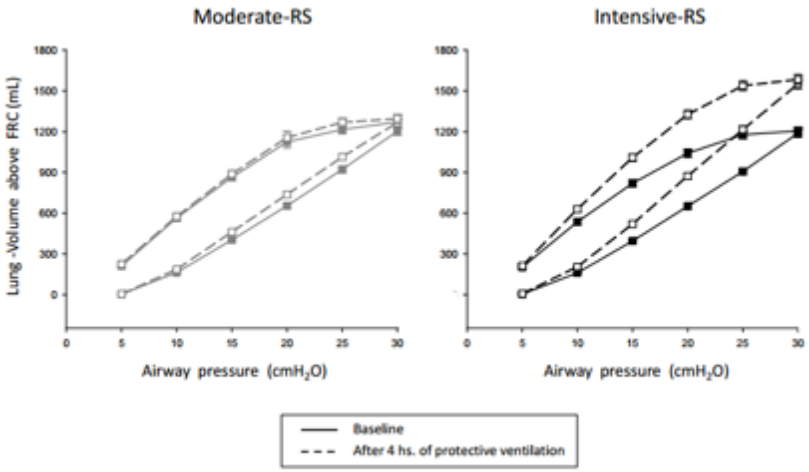

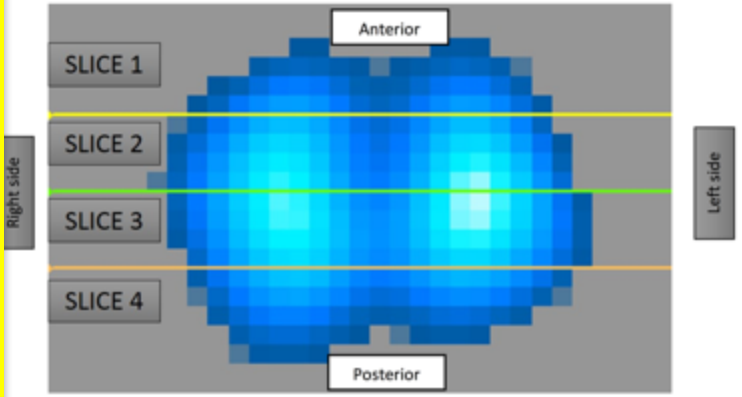

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Conclusion

Among patients with hypoxemia after cardiac surgery, the use of an intensive alveolar recruitment strategy compared with a moderate recruitment strategy, maintaining 6 mL/Kg PBW in both groups, resulted in less severe pulmonary complications during the hospital stay

Final remarks

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- We became aggressive in treating hypoxemic surgical patient with early implementation of ARDS ventilation (low Vt and low plateau pressure), however to improve outcomes in our patients, we now need to address the following clinical gaps:

1. To recruit lung as early as possible by appropriate lung recruitment maneuvers

2. To titrate PEEP by lung mechanics : measuring compliance, driving pressures, transpulmonary pressure

3. To monitor hemodynamics during lung recruitment and PEEP titration is mandatory (at least a-line and TTE, ideally PA catheter)

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