Mid-Atlantic VAD and ECMO Symposium

MSPS

Welcome to the 12th Annual MAVES

3 May 2020

MAVES
Mid-Atlantic VAD and ECMO Symposium

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APRV-TCAV
&
ECMO

Maria Madden MS, RRT-ACCS

Research Coordinator
University of Maryland Medical Center
R Adams Cowley Shock Trauma Center

Respiratory Clinical Specialist
Intensive Care Online Network (ICON)

OBJECTIVES

1. Review current literature on ventilation strategies during VV-ECMO

2. Discuss the current literature in the benefits of APRV-TCAV

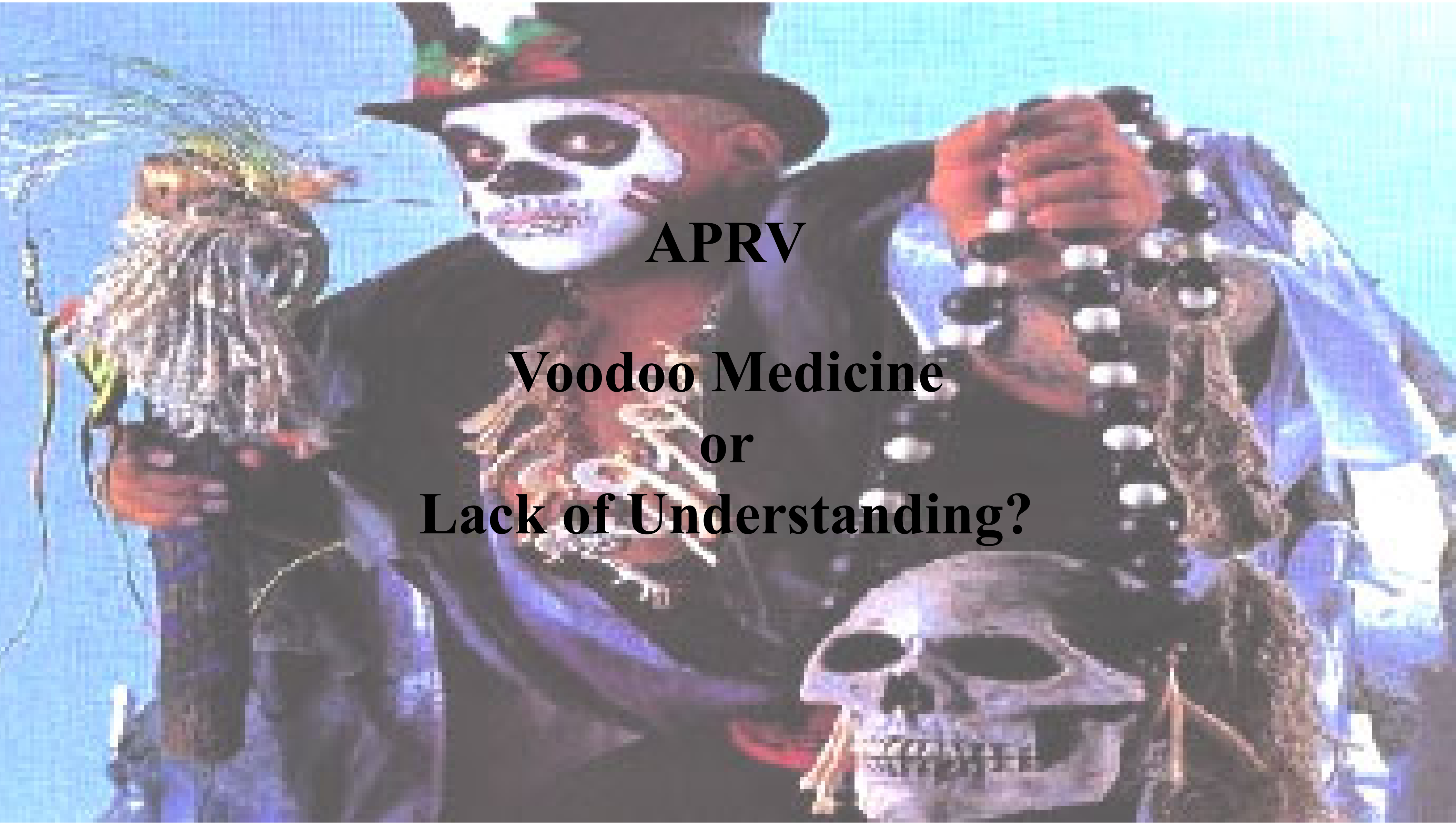
3. Review case studies using APRV-TCAV

DISCLOSURE

- Sponsored lectures and workshops
  - Intensive Care On-line Network (ICON)
  - Draeger
  - Hamilton Medical

- ICON employee

- None of the funding organizations or sponsors had any role in the design and conduct of any of the data presented;



APRV

Voodoo Medicine
or
Lack of Understanding?

Lung Protection

EAST 2012 Plenary Paper

Early stabilizing alveolar ventilation prevents acute respiratory distress syndrome: A novel timing-based ventilatory intervention to avert lung injury

Shreyas Roy, MD, CM, Benjamin Sadowitz, MD, Penny Andrews, RN, Louis A. Gatto, PhD, William Marx, DO, Lin Ge, PhD, Guirong Wang, PhD, Xin Lin, PhD, David A. Dean, PhD, Michael Kuhn, BA, Auyon Ghosh, BSc, Joshua Satalin, BA, Kathy Snyder, BA, Yoram Vodovotz, PhD, Gary Nieman, BA, *and* **Nader Habashi, MD,** *Syracuse, New York*

J Trauma Acute Care Surg.
2012 Vol. 73 No. 2

Published in final edited form as:
Shock. 2013 September ; 40(3): 210–216. doi:10.1097/SHK.0b013e31829efb06.

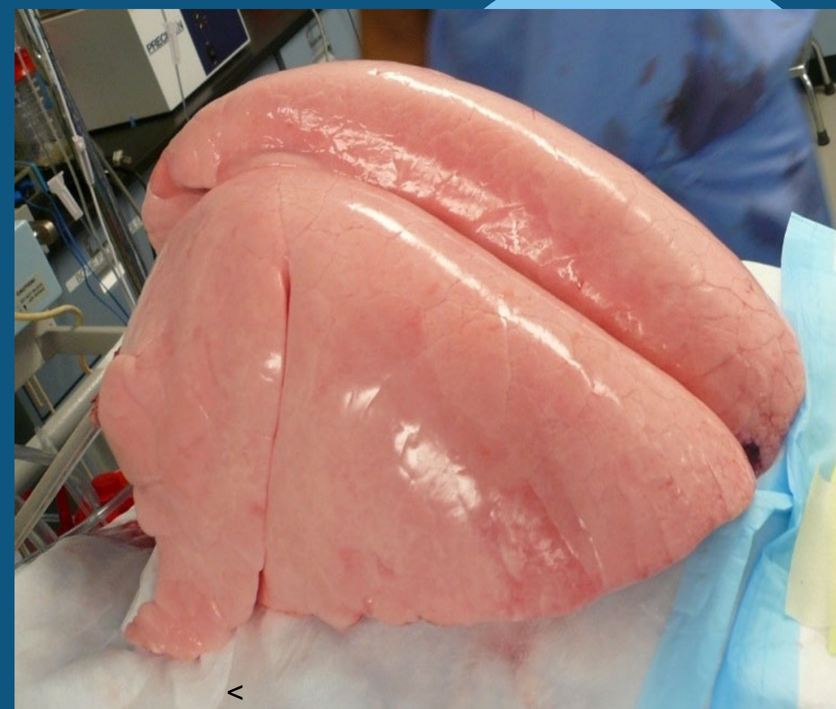
Preemptive Application of Airway Pressure Release Ventilation (APRV) Prevents Development of Acute Respiratory Distress Syndrome (ARDS) in a Rat Traumatic Hemorrhagic Shock Model

Shreyas K. Roy, M.D., C.M.[1], Bryanna Emr, M.D.[1], Benjamin Sadowitz, M.D.[1], Louis A. Gatto, Ph.D.[1,2], Auyon Ghosh, B.Sc.[1], Joshua M. Satalin, B.S.[1], Kathy P. Snyder, B.S.[1], Lin Ge, Ph.D.[1], Guirong Wang, Ph.D.[1], William Marx, D.O.[3], David Dean, Ph.D.[4], Penny Andrews, R.N.[5], Anil Singh, M.D.[1], Thomas Scalea, M.D.[5], Nader Habashi, M.D.[5], and Gary F. Nieman, B.A.[1]

APRV-TCAV when applied early reduces pulmonary edema with a constant airway pressure

(P High) for > 90% of the duration of the breath (T High).

Keeping the lungs open, minimizing atelectasis leads to decreased inflammatory mediators from being released




Review | Open Access | Published: 06 January 2020

Prevention and treatment of acute lung injury with time-controlled adaptive ventilation: physiologically informed modification of airway pressure release ventilation

Gary F. Nieman, Louis A. Gatto, Penny Andrews, Joshua Satalin, Luigi Camporota, Benjamin Daxon, Sarah J. Blair, Hassan Al-khalisy, Maria Madden, Michaela Kollisch-Singule, Hani Aiash & Nader M. Habashi

Shock 2013
39(1):28-38

Other approaches to open-lung ventilation: Airway pressure release ventilation

Nader M. Habashi, MD, FACP, FCCP

Crit Care Med 2005 Vol. 33, No. 3 (Suppl.)

ORIGINAL ARTICLE

Early application of airway pressure release ventilation may reduce mortality in high-risk trauma patients: A systematic review of observational trauma ARDS literature

Penny L. Andrews, RN, BSN, Joseph R. Shiber, MD, Ewa Jaruga-Killeen, PhD, Shreyas Roy, MD, CM, Benjamin Sadowitz, MD, Robert V. O'Toole, Louis A. Gatto, PhD, Gary F. Nieman, BA, Thomas Scalea, MD, *and* **Nader M. Habashi, MD,** *Baltimore, Maryland*

BACKGROUND: Adult respiratory distress syndrome is often refractory to treatment and develops after entering the health care system. This suggests an opportunity to prevent this syndrome before it develops. The objective of this study was to demonstrate that early application of airway pressure release ventilation in high-risk trauma patients reduces hospital mortality as compared with similarly injured patients on conventional ventilation.

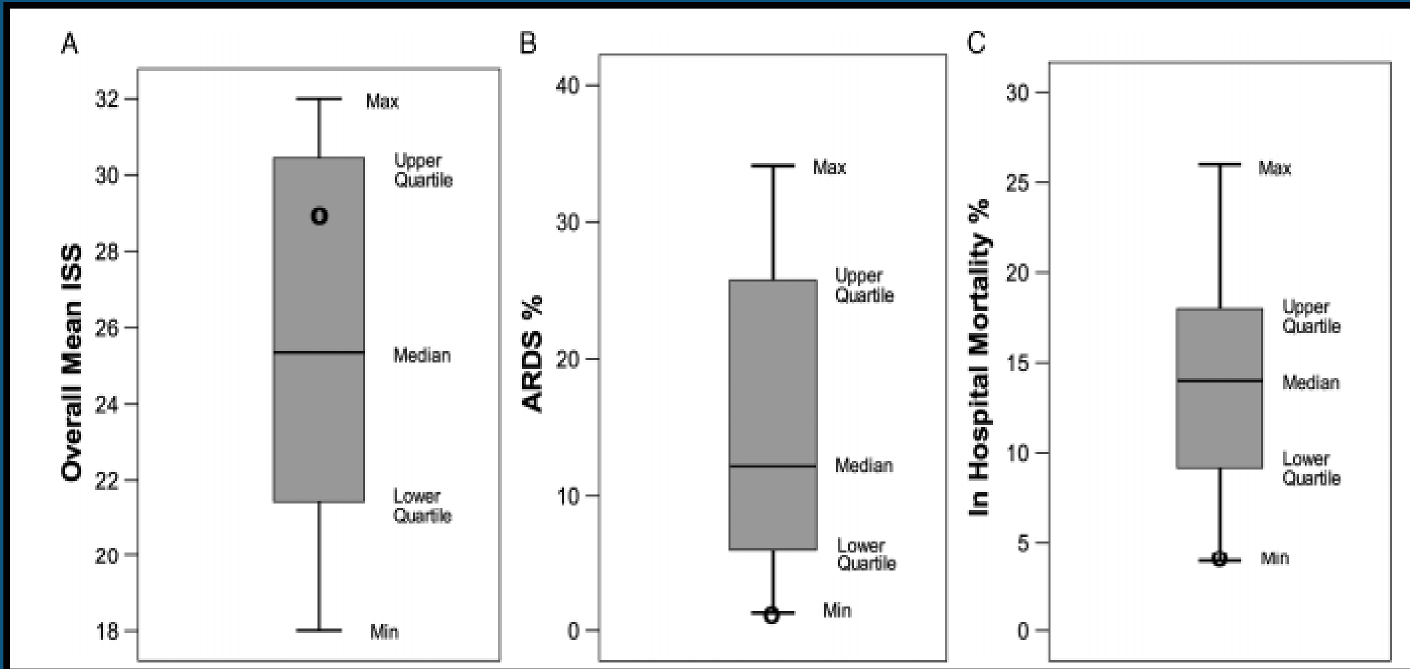
METHODS: Systematic review of observational data in patients who received conventional ventilation in other trauma centers were compared with patients treated with early airway pressure release ventilation in our trauma center. Relevant studies were identified in a PubMed and MEDLINE search from 1995 to 2012 and included prospective and retrospective observational and cohort studies enrolling 100 or more adult trauma patients with reported adult respiratory distress syndrome incidence and mortality data.

RESULTS: Early airway pressure release ventilation as compared with the other trauma centers represented lower mean adult respiratory distress syndrome incidence (14.0% vs. 1.3%) and in-hospital mortality (14.1% vs. 3.9%).

CONCLUSION: These data suggest that early airway pressure release ventilation may prevent progression of acute lung injury in high-risk trauma patients, reducing trauma-related adult respiratory distress syndrome mortality. (*J Trauma Acute Care Surg*. 2013;75: 635–641. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Systematic review, level IV.

KEY WORDS: Airway pressure release ventilation; APRV; ARDS; adult respiratory distress syndrome; ALI



CENTER	ISS	INCIDENCE %	MORTALITY %
STC ARDS	28.5	1.4	3.9
NATIONAL ARDS	26.2	13.5	14.2

J Trauma Acute Care Surg Volume 75, Number 4

J. Lim et al. / Journal of Critical Care 34 (2016) 154–159

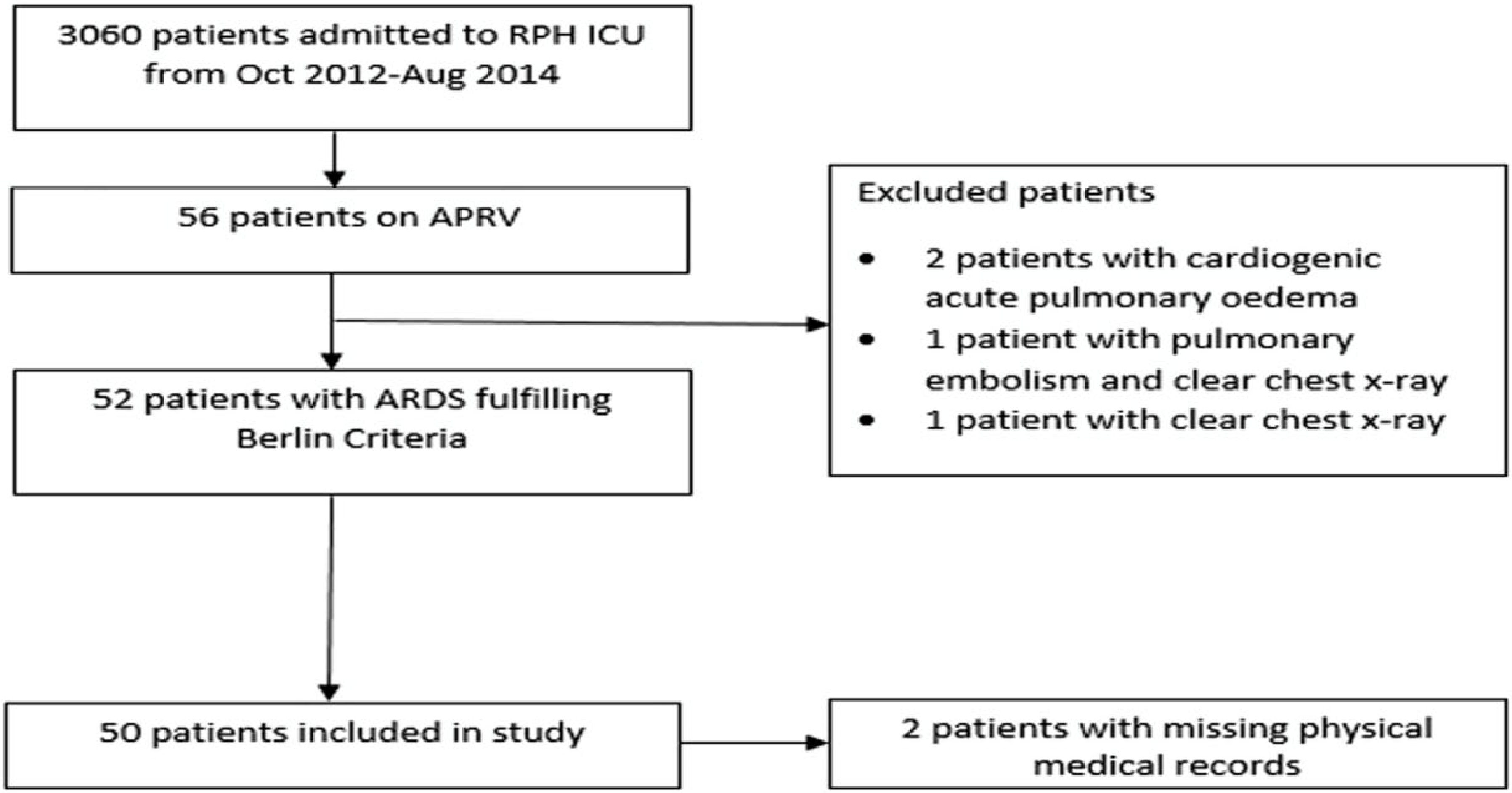


Fig. 1. Flow chart of the patients included in the study.

ORIGINAL

Early application of airway pressure release ventilation may reduce the duration of mechanical ventilation in acute respiratory distress syndrome

Yongfang Zhou, Xiaodong Jin, Yinxia Lv, Peng Wang, Yunqing Yang, Guopeng Liang, Bo Wang and Yan Kang*

- 138 patients with ARDS who received mechanical ventilation for <48 h
- Patients were randomly assigned to receive APRV (n = 71) or LTV (n = 67).

Day 3 of enrollment	APRV	LTV
P/F RATIO	280	180
PaCO2	40.8	42.3
PaO2	116.2	84.8

Intensive Care Med (2017) 43:1648–1659
DOI 10.1007/s00134-017-4912-z

Airway Pressure Release Ventilation in Adult Patients With Acute Hypoxemic Respiratory Failure: A Systematic Review and Meta-Analysis

Jolene Lim, MBBS (Hon), MSc (Dist)[1]; Edward Litton, MBChB, FCICM, MSc, PhD[1,2]

Crit Care Med 2019 Epub

Conclusions: In adult patients requiring mechanical ventilation for acute hypoxic respiratory failure, airway pressure release ventilation is associated with a mortality benefit and improved oxygenation when compared with conventional ventilation strategies. Given the limited number of patients enrolled in the available studies, larger multicenter studies are required to validate these findings. (*Crit Care Med* 2019; XX:00–00)

BMC Health Services Research

BioMed Central

Study protocol

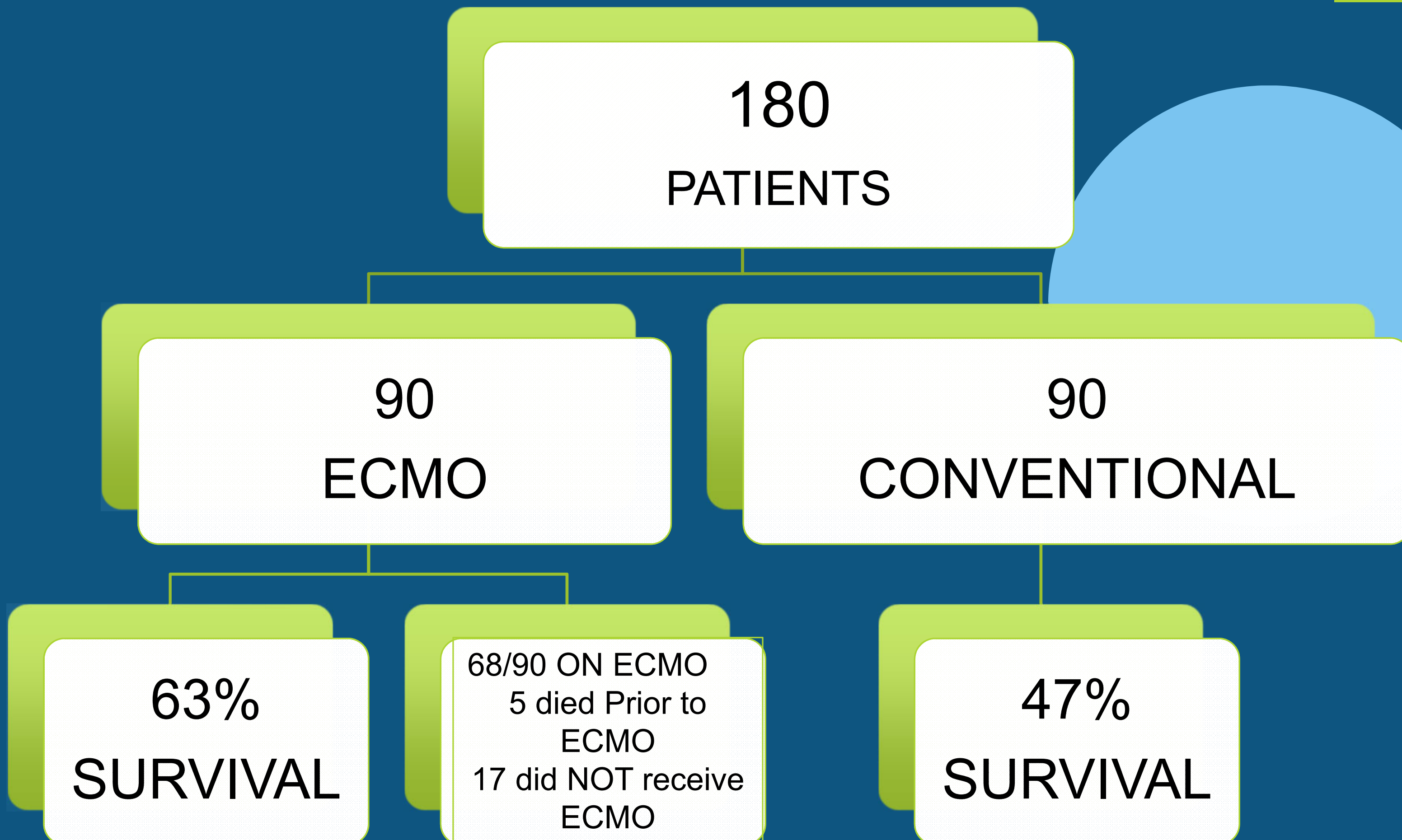
Open Access

CESAR: conventional ventilatory support vs extracorporeal membrane oxygenation for severe adult respiratory failure

Giles J Peek*[1], Felicity Clemens[2], Diana Elbourne[2], Richard Firmin[1], Pollyanna Hardy[2,3], Clare Hibbert[5], Hilliary Killer[1], Miranda Mugford[4], Mariamma Thalanany[4], Ravin Tiruvoipati[1], Ann Truesdale[2] and Andrew Wilson[6]

December 2006

CESAR TRIAL



180
PATIENTS
90
ECMO
90
CONVENTIONAL
63%
SURVIVAL
68/90 ON ECMO
5 died Prior to ECMO
17 did NOT receive ECMO
47%
SURVIVAL

CARING FOR THE
CRITICALLY ILL PATIENT

JAMA-EXPRESS

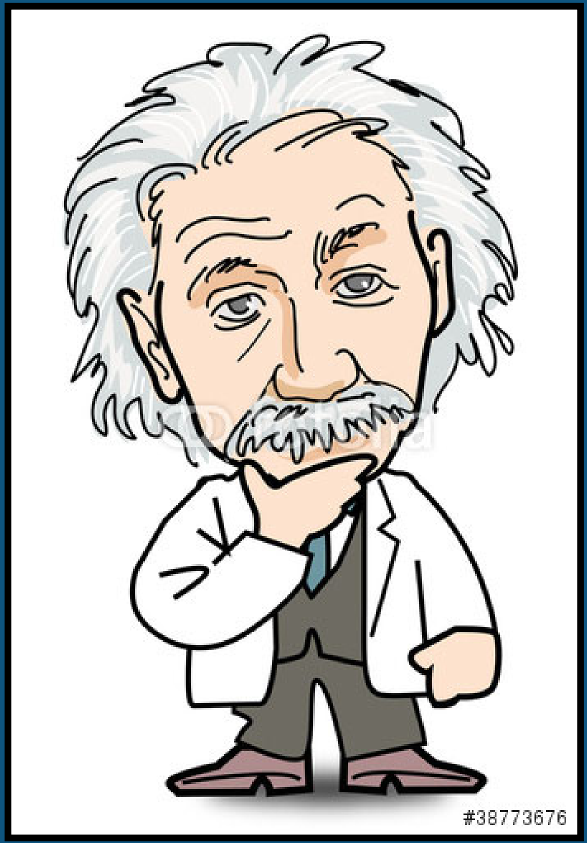
Extracorporeal Membrane Oxygenation for 2009 Influenza A(H1N1) Acute Respiratory Distress Syndrome

Conclusions:

During June to August 2009 in Australia and New Zealand, the ICUs at regional referral centers provided mechanical ventilation for many patients with 2009 influenza A(H1N1)–associated respiratory failure, one-third of whom received ECMO. **These ECMO-treated patients were often young adults with severe hypoxemia and had a 21% mortality rate at the end of the study period.**

JAMA. 2009;302(17):1888-1895

HOW SHOULD WE VENTILATE PATIENTS ON VV-ECMO



Preliminary Communication

Low-Frequency Positive-Pressure Ventilation With Extracorporeal CO_2 Removal in Severe Acute Respiratory Failure

Luciano Gattinoni, MD; Antonio Pesenti, MD; Daniele Mascheroni, MD; Roberto Marcolin, MD; Roberto Fumagalli, MD; Francesca Rossi, MD; Gaetano Iapichino, MD; Giuliano Romagnoli, MD; Lji Uziel, MD; Angelo Agostoni, MD; Theodor Kolobow, MD; Giorgio Damia, MD

- "Lung Rest" was first described with ECMO patients by Dr. Gattinoni in 1986.
- "Prevent further damage to diseased lung by reducing their motion (pulmonary rest)"
- 3-5 breaths per minute as a "sigh" breath calling it "Low frequency positive pressure ventilation" LFPPV

Preliminary Communication

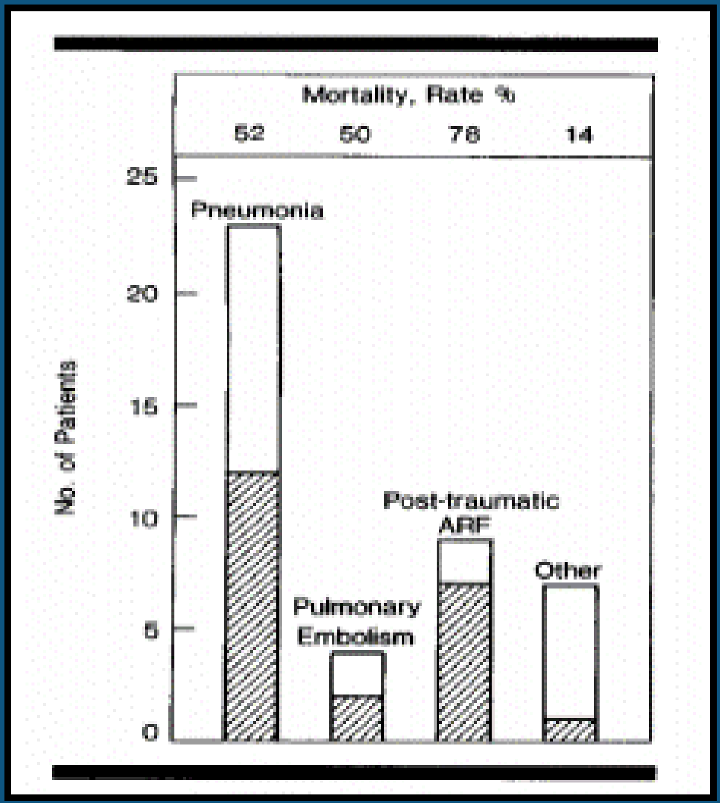
Low-Frequency Positive-Pressure Ventilation With Extracorporeal CO_2 Removal in Severe Acute Respiratory Failure

Luciano Gattinoni, MD; Antonio Pesenti, MD; Daniele Mascheroni, MD; Roberto Marcolin, MD; Roberto Fumagalli, MD; Francesca Rossi, MD; Gaetano Iapichino, MD; Giuliano Romagnoli, MD; Ljli Uziel, MD; Angelo Agostoni, MD; Theodor Kolobow, MD; Giorgio Damia, MD

LFPPV

- PEEP ranging from 15 to 25 cm H2O.
- Frequency 3 -5 breaths per minutes
- Peak airway pressure limited to 35 to 45 cm H2O
- 1 to 2 L/min of oxygen during long expiration

LFPPV



- 43 Patients were enrolled
- Lung function improved in thirty-one patients (72.8%), and 21 patients (48.8%) eventually survived

JAMA. 1986;256(7):881–886

Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial

Giles J Peek, Miranda Mugford, Ravindranath Tiruvoipati, Andrew Wilson, Elizabeth Allen, Mariamma M Thalanany, Clare L Hibbert, Ann Truesdale, Felicity Clemens, Nicola Cooper, Richard K Firmin, Diana Elbourne, for the CESAR trial collaboration

During ECMO, ventilator settings are gradually reduced to allow lung rest

- Peak inspiratory Pressure 20 cm H2O (PC of 10cm H2O above PEEP)
- PEEP 10 cm H2O
- Respiratory Rate 19 breaths per minute
- FIO2 30%

Nieman *et al. Critical Care* (2018) 22:136
https://doi.org/10.1186/s13054-018-2051-8

Critical Care

VIEWPOINT Open Access

CrossMark

Acute lung injury: how to stabilize a broken lung

Gary F. Nieman[1], Penny Andrews[2], Joshua Satalin[1*], Kailyn Wilcox[1], Michaela Kollisch-Singule[1], Maria Madden[2], Hani Aiash[1], Sarah J. Blair[1], Louis A. Gatto[1,3] and Nader M. Habashi[2]

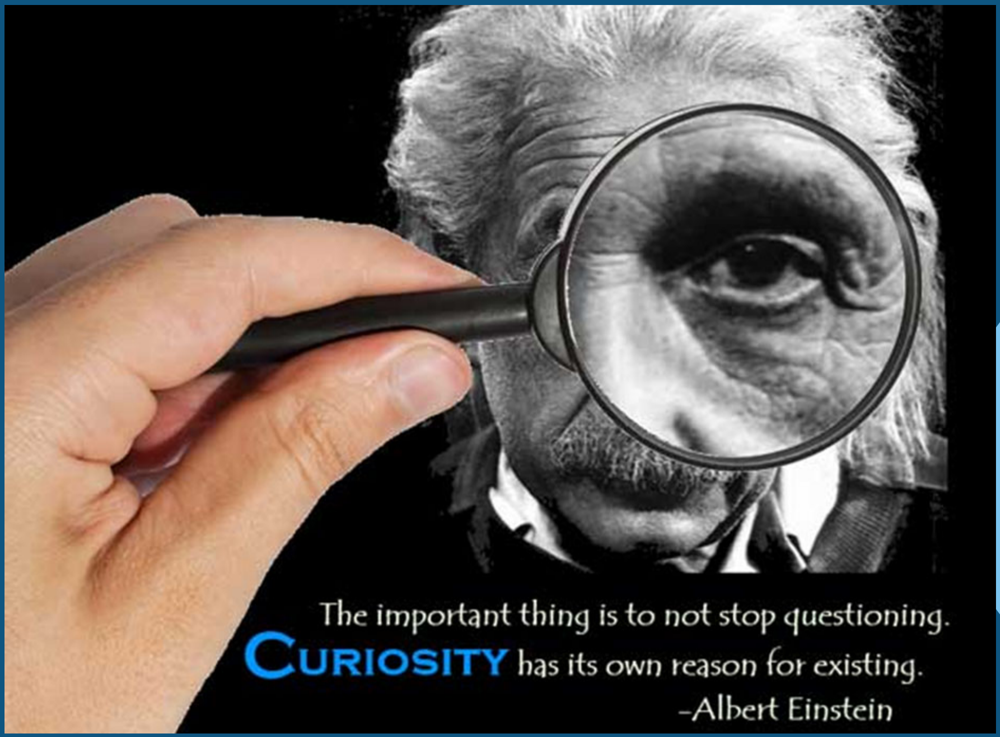

L
hbl



Should Patients With Acute Respiratory Distress Syndrome on Venovenous Extracorporeal Membrane Oxygenation Have Ventilatory Support Reduced to the Lowest Tolerable Settings? No

- Respiratory Rate of 1-2 BPM or apneic ventilation
- Minimal tidal volume < 4ml/kg/IBW (1-2ml/kg/IBW)
- High PEEP
- Results
  - Increase in atelectasis with small tidal volumes and despite High PEEP
  - High PEEP levels may cause further over distension in the "baby lung"
  - Reabsorption atelectasis

Crit Care Med. 2019 Aug;47(8):1143-1146



How Are We Ventilating ECMO Patients

Ann Am Thorac Soc. 2014 Jul;11(6):956-61. doi: 10.1513/AnnalsATS.201403-100BC.

Mechanical ventilation during extracorporeal membrane oxygenation. An international survey.

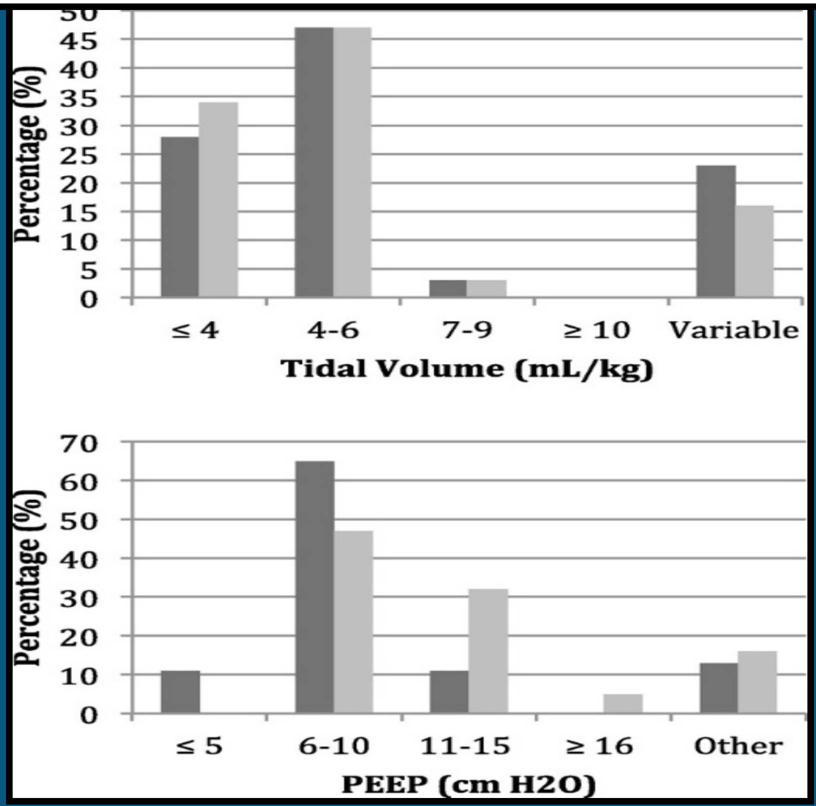
Marhong JD[1], Telesnicki T, Munshi L, Del Sorbo L, Detsky M, Fan E.

Question	Neonatal/Pediatric: n = 75 [n (%)]	Adult: n = 38 [n (%)]	Protocol MV: n = 38 [n (%)]	Overall: n = 141 [n (%)]
None	[illegible]	[illegible]	[illegible]	[illegible]
Tidal volume (per predicted body weight)				
≤4 ml/kg	21 (28)	13 (34)	17 (45)	44 (31)
4–6 ml/kg	35 (47)	18 (47)	11 (29)	64 (45)
7–9 ml/kg	2 (3)	1 (3)	0 (0)	3 (2)
≥10 ml/kg	0 (0)	0 (0)	0 (0)	0 (0)
Not strictly controlled	17 (23)	6 (16)	10 (26)	30 (21)
PEEP (during VV-ECMO)				
≤5 cm H_2O	8 (11)	0 (0)	3 (8)	10 (7)
6–10 cm H_2O	49 (65)	18 (47)	19 (50)	82 (58)
11–15 cm H_2O	8 (11)	12 (32)	11 (29)	30 (21)
≥16 cm H_2O	0 (0)	2 (5)	0 (0)	2 (1)
Other	10 (13)	6 (16)	5 (13)	17 (12)

Ann Am Thorac Soc. 2014 Jul;11(6):956-61. doi: 10.1513/AnnalsATS.201403-100BC.

Mechanical ventilation during extracorporeal membrane oxygenation. An international survey.

Marhong JD[1], Telesnicki T, Munshi L, Del Sorbo L, Detsky M, Fan E.



Mechanical Ventilation during Extracorporeal Membrane Oxygenation
An International Survey

Jonathan D. Marhong*, Teagan Telesnicki*, Laveena Munshi, Lorenzo Del Sorbo, Michael Detsky, and Eddy Fan

Interdepartmental Division of Critical Care Medicine, and Department of Medicine, University of Toronto, University Health Network and Mount Sinai Hospital, Toronto, Ontario, Canada

ATS Volume 11 Number 6| July 2014

- **27% of centers reported having an explicit mechanical ventilation protocol for ECMO patients.**
- **77% reported "lung rest" to be the primary goal of mechanical ventilation**
- **9% reported "lung recruitment" to be their ventilation strategy.**
- **A tidal volume of 6 ml/kg or less was targeted by 76% of respondents, and 58% targeted a positive end-expiratory pressure of 6–10 cm H2O while ventilating patients on VV-ECMO.**

Minerva Anestesiol. 2015 Nov;81(11):1170-83, 77 p following 1183. Epub 2015 Jun 30.

International survey on the management of mechanical ventilation during ECMO in adults with severe respiratory failure.

Camporota L[1], Nicoletti E, Malafronte M, De Neef M, Mongelli V, Calderazzo MA, Caricola E, Glover G, Meadows C, Langrish C, Ioannou N, Wyncoll D, Beale R, Shankar-Hari M, Barrett N.

CONCLUSION:

We found large variability in ventilatory practices during ECMO. The clinicians' training background and the 173 centers' experience had no influence on the approach to ventilation. This survey shows that well conducted studies are necessary to determine the best practice of mechanical ventilation during ECMO and its impact on patient outcome.

REVIEW

Mechanical ventilation in patients subjected to extracorporeal membrane oxygenation (ECMO)☆

M. López Sanchez

Servicio de Medicina Intensiva, Hospital Universitario Marqués de Valdecilla, Santander, Cantabria, Spain

Received 7 November 2016; accepted 14 December 2016
Available online 21 September 2017

Table 1 Mechanical ventilation in VV ECMO according to the opinion of different expert sources.

Source	MV objective	MV mode	Vt	Pp	PEEP (cmH_2O)	RF (rpm)	FiO_2
ELSO guides 2013[35]	Lung rest	PCV	-	<25	10–15	5	<0.4
European Network of MV (REVA)[37]	Lung rest	VCV	-	≤20–25	≥10	6–20	0.3–0.5
Consensus Conference ECMO[36]	Lung rest	-	-	Minimize Pp	Minimum PEEP	-	-

PEEP: positive end-expiratory pressure; Pp: plateau pressure; FiO_2: inspired fraction of oxygen; RF: respiratory frequency; REVA: *Réseau Europeen de Recherche en Ventilation Artificielle*; PCV: pressure control ventilation; VCV: volume control ventilation; MV: mechanical ventilation; Vt: tidal volume.

ARDSnet

- Volume Control-Assist Control
- 4 – 6 ml/Kg IBW
- high PEEP, low $P_{PLAT < 30\ cm}$ H2O
- oxygenation 88 – 95%
- pH 7.30 – 7.40 (permissive hypercapnia)

ARDSnet

NIH NHLBI ARDS Clinical Network
Mechanical Ventilation Protocol Summary

INCLUSION CRITERIA: Acute onset of

1. $PaO_2/FiO_2 \leq 300$ (corrected for altitude)
2. Bilateral (patchy, diffuse, or homogeneous) infiltrates consistent with pulmonary edema
3. No clinical evidence of left atrial hypertension

OXYGENATION GOAL: PaO_2 55-80 mmHg or SpO_2 88-95%

Use a minimum PEEP of 5 cm H_2O. Consider use of incremental FiO_2/PEEP combinations such as shown below (not required) to achieve goal.

Lower PEEP/higher FiO2

FiO_2	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_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

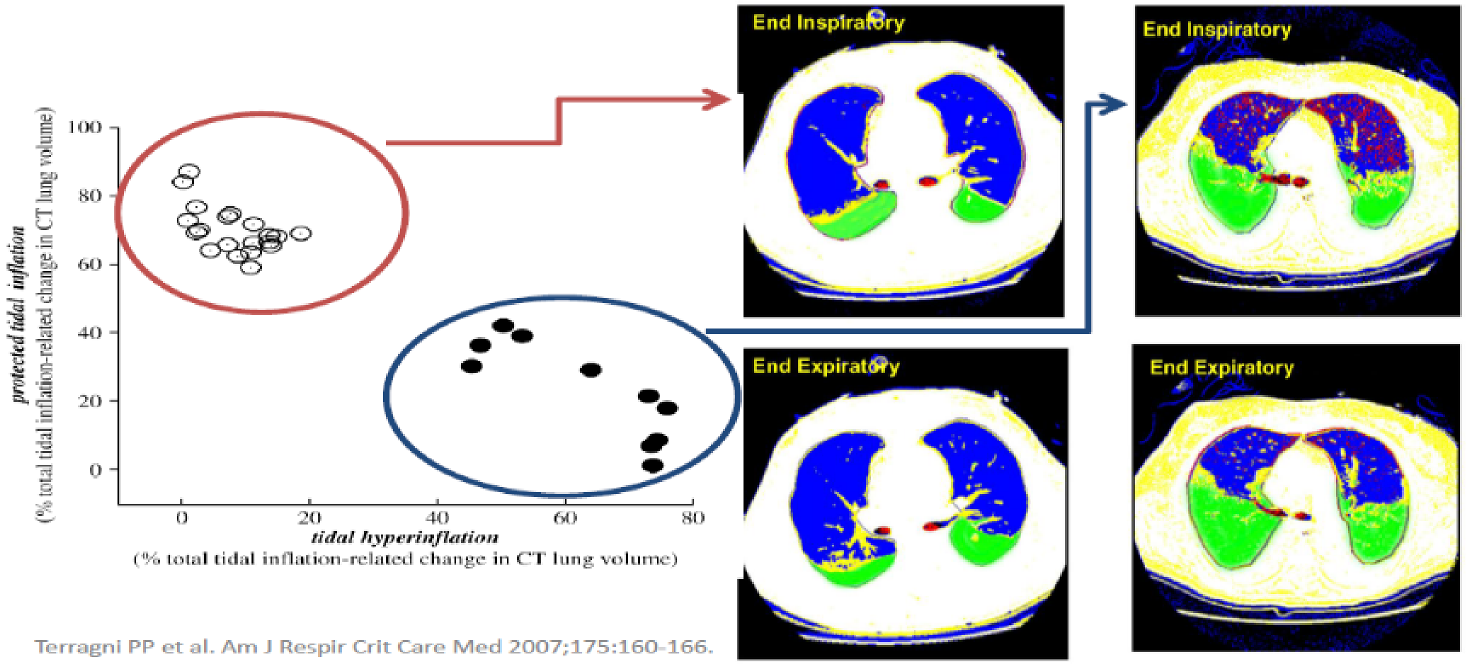
Higher PEEP/lower FiO2

FiO_2	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_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

Tidal Hyperinflation during Low Tidal Volume Ventilation in Acute Respiratory Distress Syndrome

Pier Paolo Terragni, Giulio Rosboch, Andrea Tealdi, Eleonora Corno, Eleonora Menaldo, Ottavio Davini, Giovanni Gandini, Peter Herrmann, Luciana Mascia, Michel Quintel, Arthur S. Slutsky, Luciano Gattinoni, and V. Marco Ranieri



Terragni PP et al. Am J Respir Crit Care Med 2007;175:160-166.

Original Investigation | ASSOCIATION OF VA SURGEONS

Mechanical Breath Profile of Airway Pressure Release Ventilation

The Effect on Alveolar Recruitment and Microstrain in Acute Lung Injury

Michaela Kollisch-Singule, MD; Bryanna Emr, MD; Bradford Smith, PhD; Shreyas Roy, MD; Sumeet Jain, MD; Joshua Satalin, BS; Kathy Snyder; Penny Andrews, RN; Nader Habashi, MD; Jason Bates, PhD; William Marx, DO; Gary Nieman, BA; Louis A. Gatto, PhD

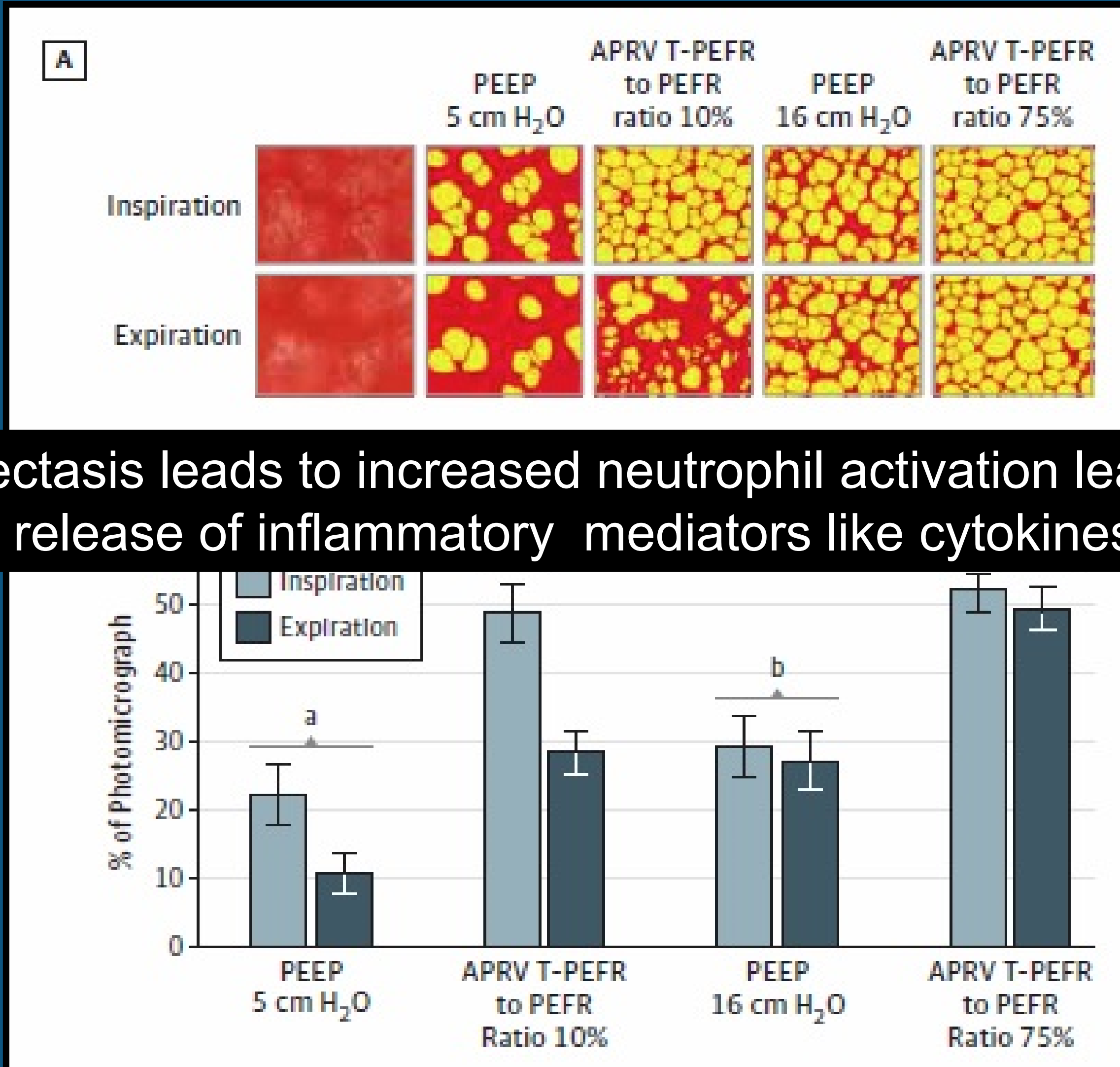
ARDS net - CMV VT 6 ml/kg

PEEP – 5, 10, 16, 20 and 24 cmH_2O

APRV P High – 35 – 40 cmH_2O

T-PEFR/PEFR – 10, 25, 50 and 75%

JAMA Surg. doi:10.1001/jamasurg.2014.1829
Published online September 17, 2014.



Atelectasis leads to increased neutrophil activation leads to release of inflammatory mediators like cytokines

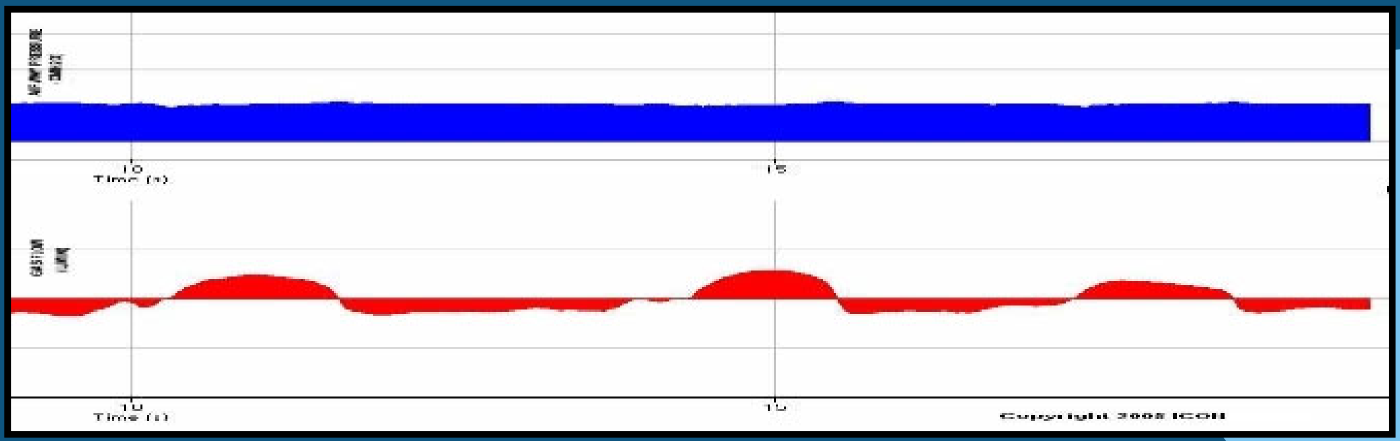
JAMA Surg. doi:10.1001/jamasurg.2014.1829
Published online September 17, 2014.

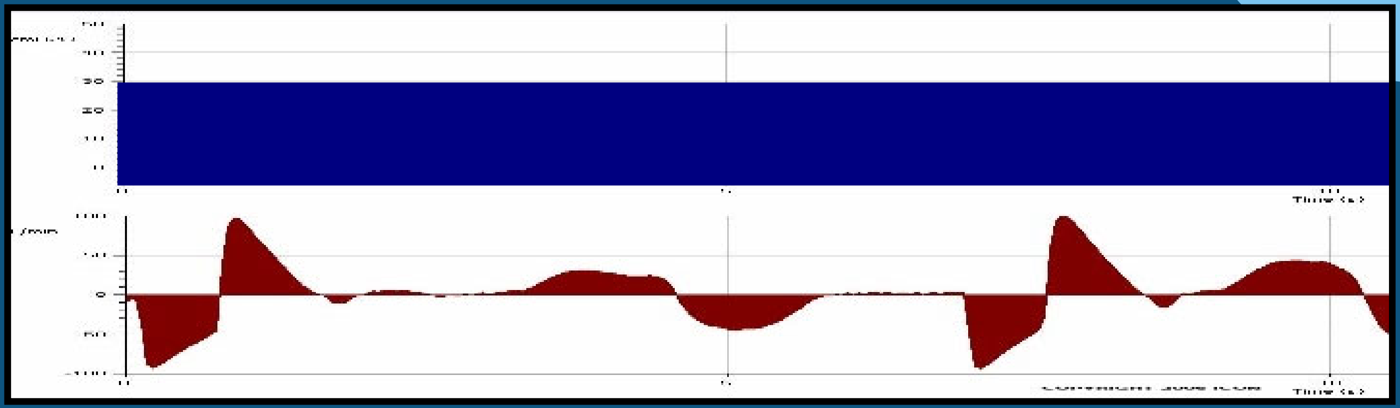
APRV

TCAV

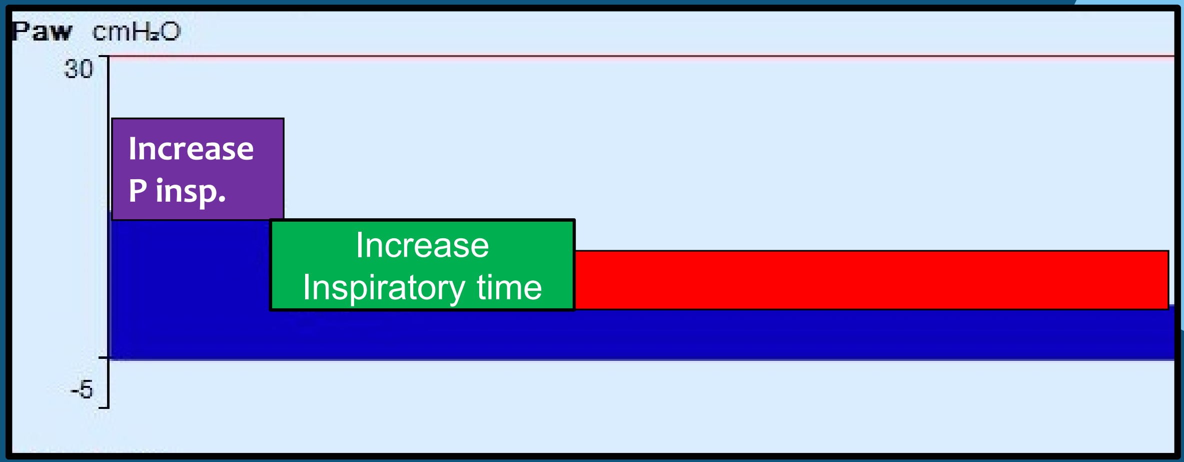
Time Constant Adaptive Ventilation

APRV-TCAV



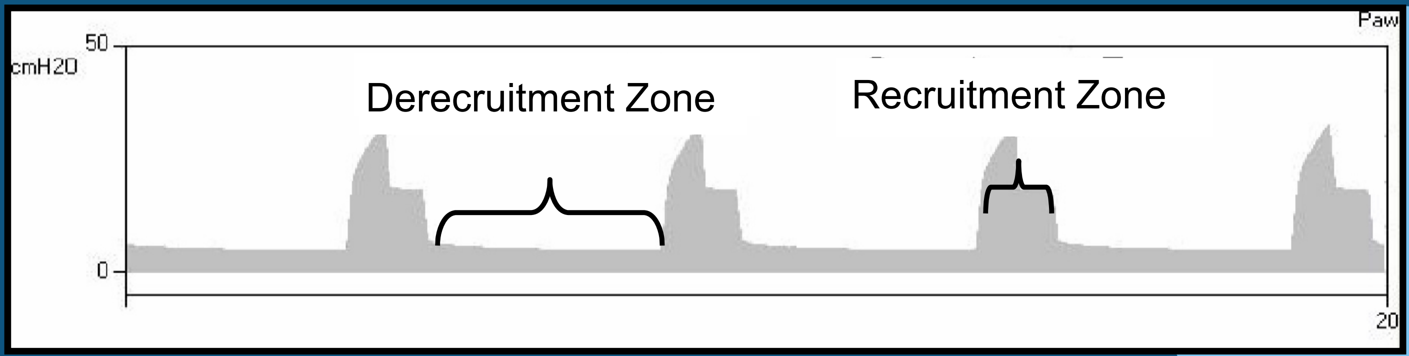


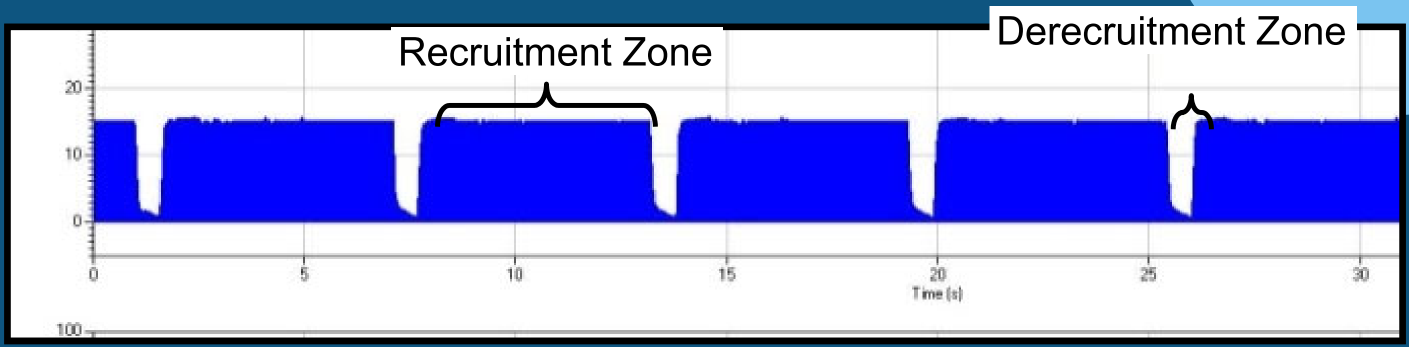
MEAN AIRWAY PRESSURE



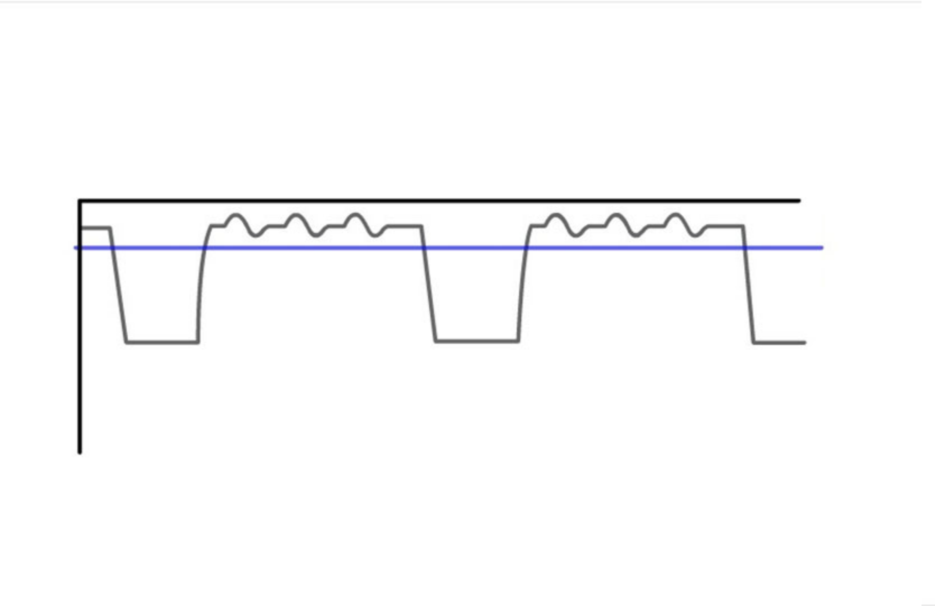
- The P_{aw} is the average pressure over time
- It is the area in the pressure time waveform

Recruitment vs Derecruitment Zones





Turning Ventilation Upside Down

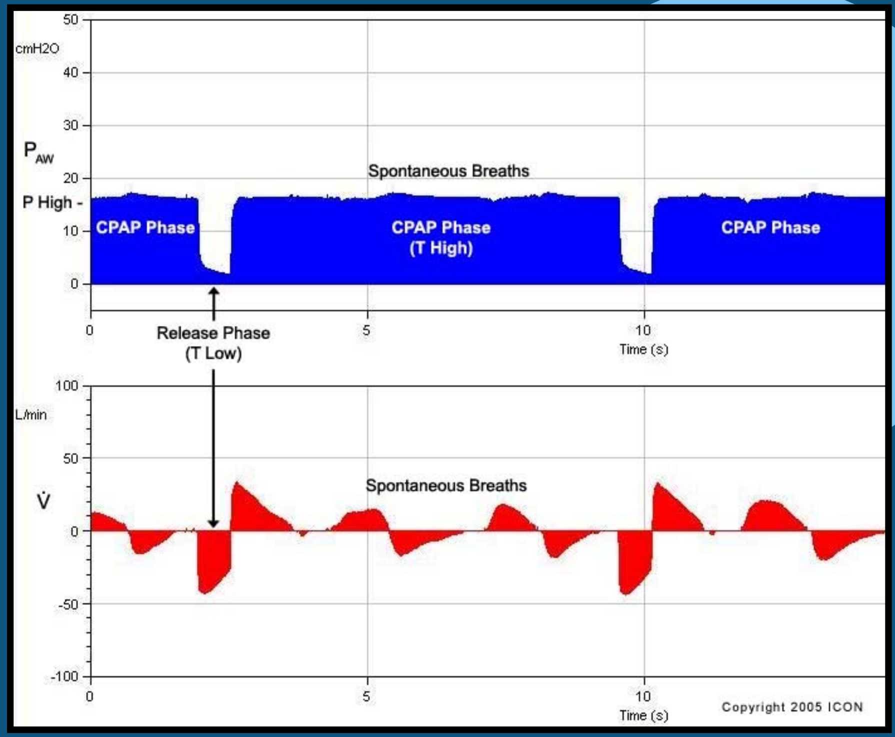


10:27:52
PC-AC
Paw cmH₂O
Flow L/min
Volume mL
EIP cmH₂O
20
Pmean cmH₂O
12
RR /min
10
24
VT mL
406
1040
1
MVe L/min
4.75
12.50
0.02
VTspon mL
0
% leak %
0
I:E
1.0:5.0
Views...
Day/Night
Freeze waveforms
Export screenshot
Trends/Data...
Trends table
Values
Special maneuvers...
Nebulization
O₂ suction
Man. insp./hold
Manual disconnection
Alarms...
Ventilation settings...
Trigger
Apnea Ventilation
Sensors/ Parameters...
System setup...
Help...
Start/ Standby...
PC-AC
21
FiO₂
20.0
Pinsp
1.00
Ti
10.0
RR
10.0
PEEP
0.10
Slope

10:28:55
PC-APRV
ATC Ø
8.0 mm
Paw cmH₂O
Flow L/min
Volume mL
EIP cmH₂O
20
Pmean cmH₂O
19
RR /min
10
24
VT mL
434
1040
1
MVe L/min
4.34
12.50
0.02
VTspon mL
0
% leak %
5
I:E
11.0:1.0
Views...
Day/Night
Freeze waveforms
Export screenshot
Trends/Data...
Trends table
Values
Special maneuvers...
Nebulization
O₂ suction
Man. insp./hold
Manual disconnection
Alarms...
Ventilation settings...
Trigger
Apnea Ventilation
Sensors/ Parameters...
System setup...
Help...
Start/ Standby...
PC-APRV
Apn. Vent. On
VTapn 520
RRapn 12.0
21
FiO₂
0.00
Slope
20.0
Phigh
0.0
Plow
5.50
Thigh
0.50
Tlow

APRV SETTINGS

- P High
- P Low – PEEP
- T High
- T Low
- FiO_2

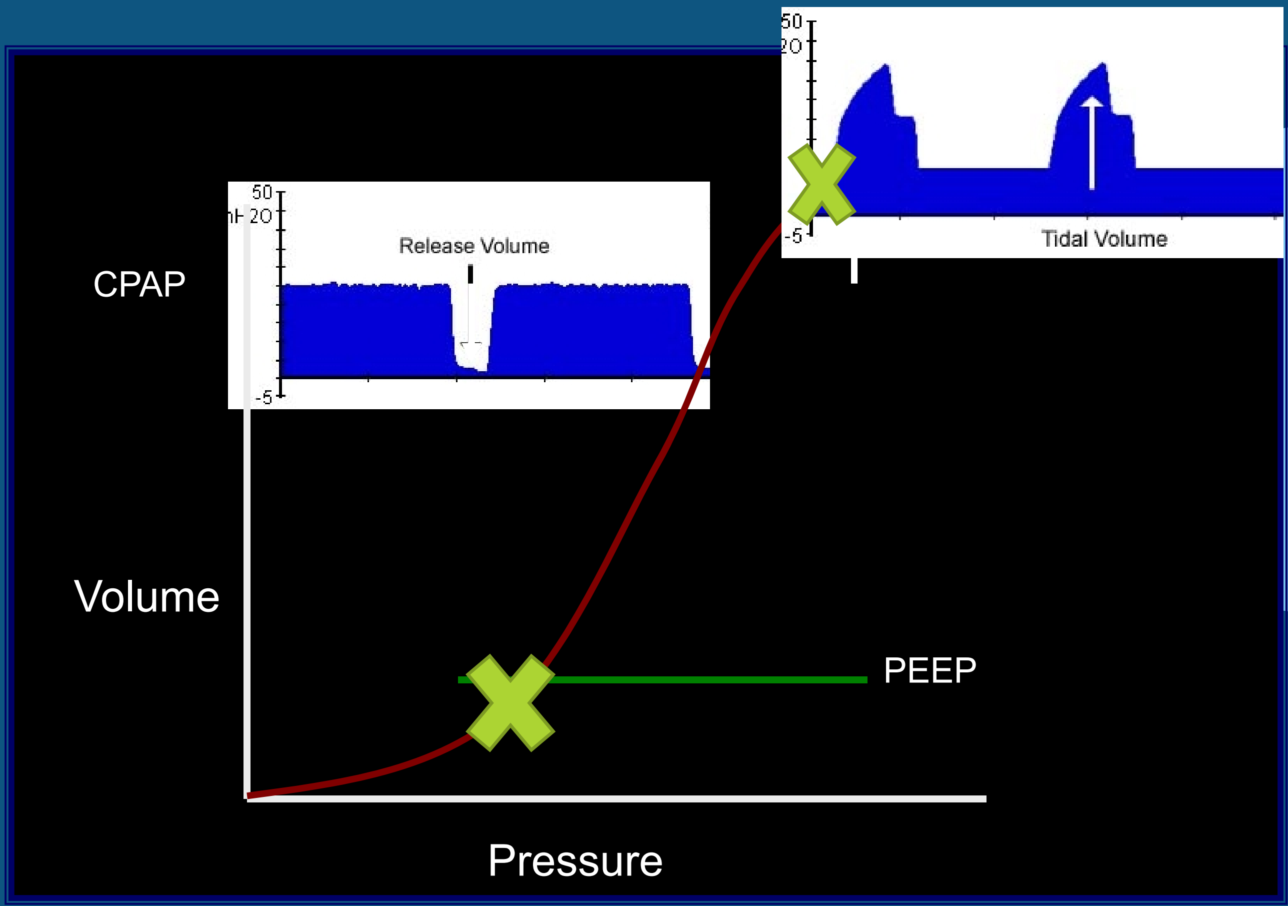


P High

- Using as Initial Mode Upon Intubation
  - Typically 21-24 cmH_2O
  - Adjust as necessary based on oxygenation and ventilation
  - Assess your settings

- Transitioning from a [Pure] Volume Mode
  - Set at current plateau pressure
  - (not mean airway pressure)

- Transitioning from a Pressure or Dual Targeted Mode
  - Set at current total pressure from pressure mode

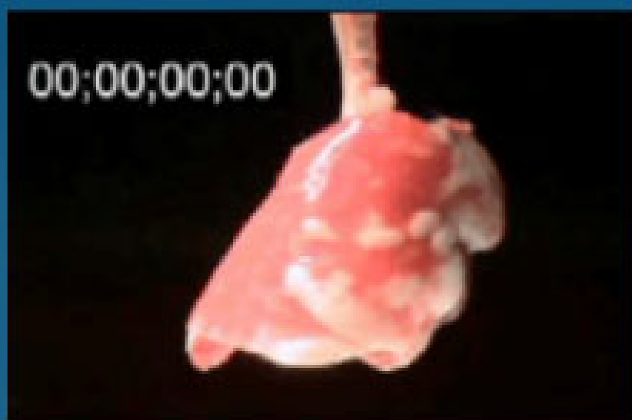

CPAP
Release Volume
Tidal Volume
Volume
PEEP
Pressure

T High

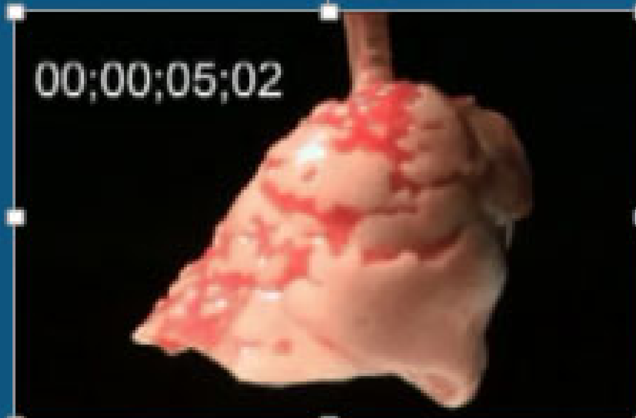
- 4 - 6 seconds for Adults APRV-TCAV as a standard of care mode of ventilation
- APRV-TCAV as a rescue, initially match the RR
- APRV-TCAV with ECMO, eventually increase T High to assist with recruitment

- Recruitment takes ***time***

Use of Time to Recruit Collateral ventilation



Inspiratory Time ~ 1.0 second



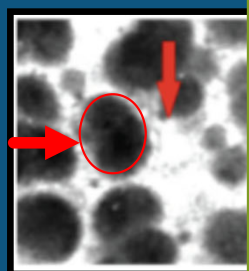
Inspiratory Time ~ 5.0 seconds

Courtesy of Gary Nieman SUNY

Alveolar Dynamics during Respiration
Are the Pores of Kohn a Pathway to Recruitment?

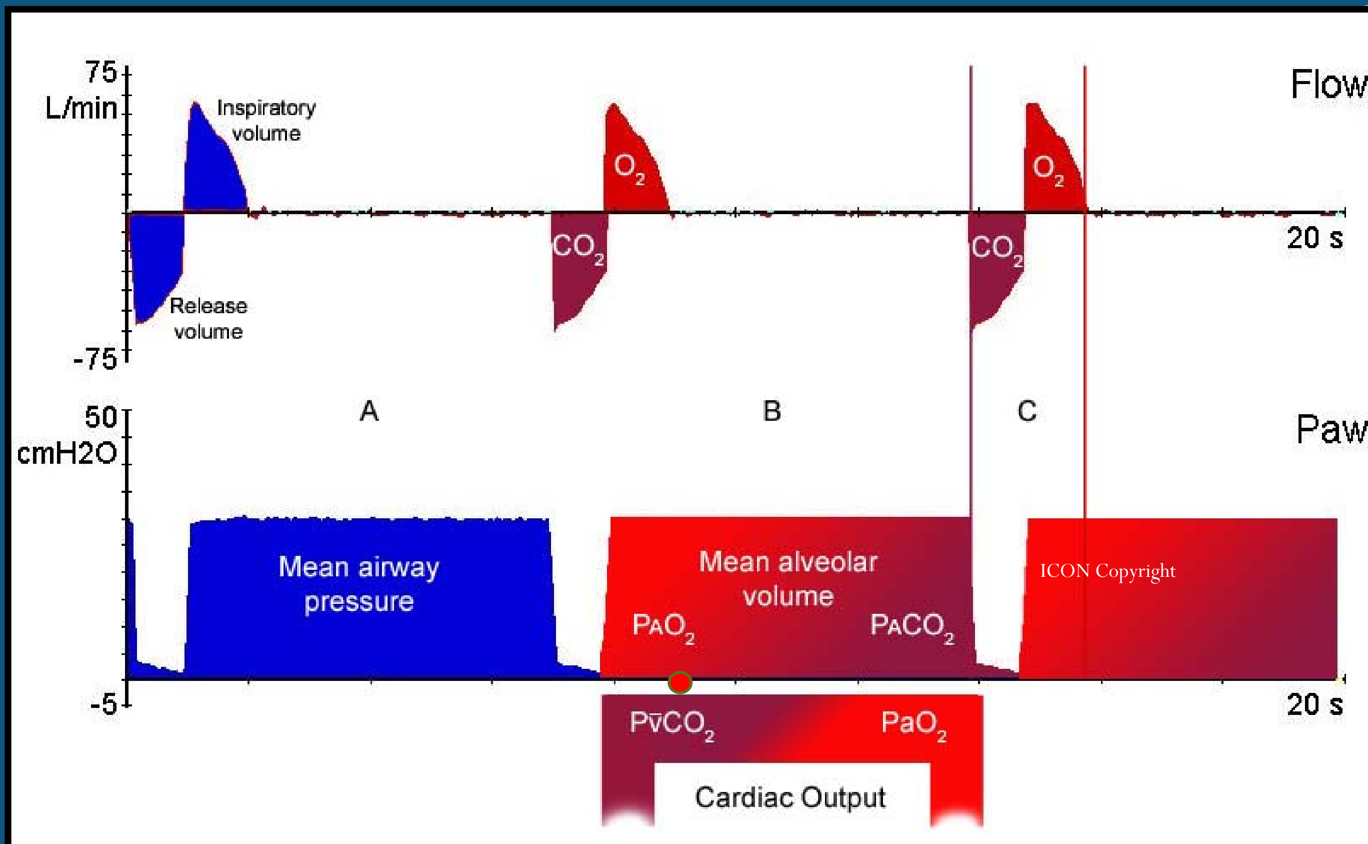
Eman Namati[1,2], Jacqueline Thiesse[1,3], Jessica de Ryk[1,3], and Geoffrey McLennan[1,3,4]

[1]Department of Internal Medicine, [3]Department of Biomedical Engineering, and [4]Department of Radiology, University of Iowa, Iowa City, Iowa; and [2]Department of Informatics and Engineering, Flinders University, Adelaide, Australia



Lung Inflation

T High & CO_2 Removal

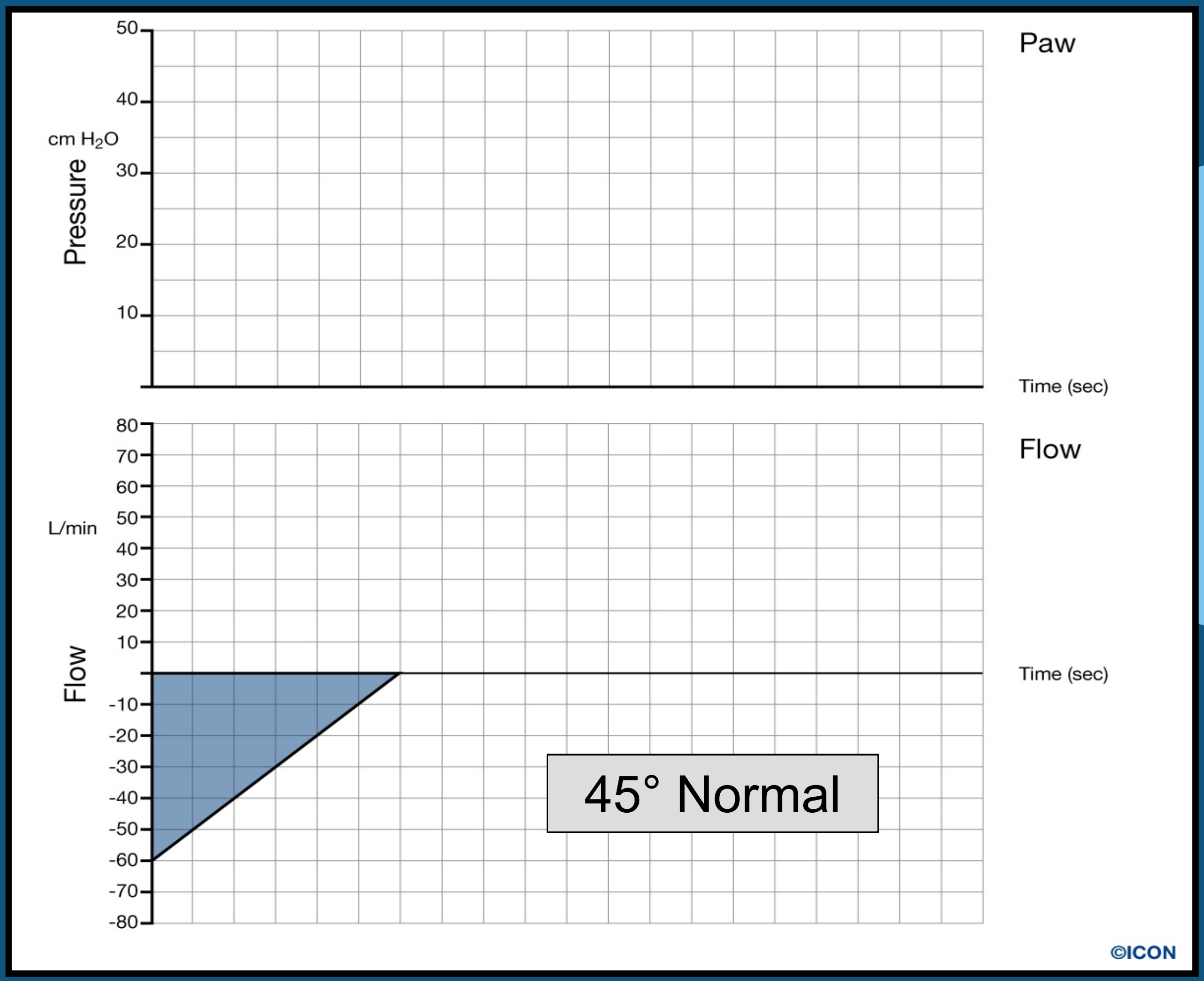


AUTO - PEEP

FLOW

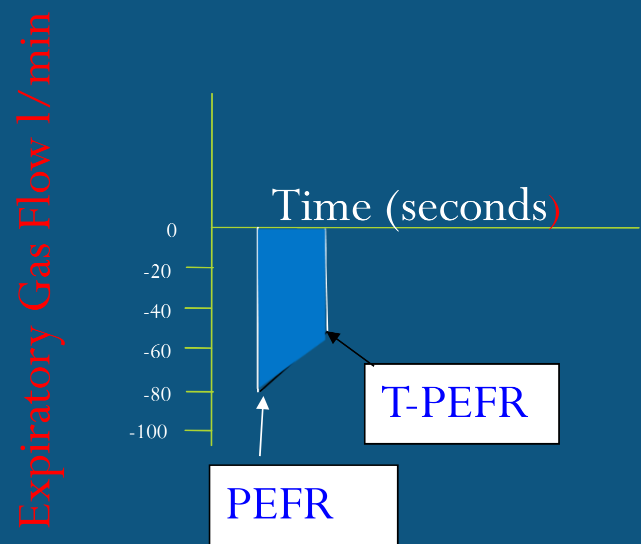
T Low

- Controlling “PEEP” with ***time*** rather than ***pressure***
- Varies from patient to patient
  - Based on lung volume and thoracic recoil
- Can also vary based on ventilator type



Paw
Pressure
cm H_2O
50
40
30
20
10
Time (sec)
Flow
L/min
80
70
60
50
40
30
20
10
-10
-20
-30
-40
-50
-60
-70
-80
Flow
Time (sec)
45° Normal
©ICON

T Low – End Expiratory Lung Volume



T LOW SETTING
T-PEFR/PEFR X 100 = 75%

60/80 X 100 = 75%

PEEP/T LOW

APRV-TCAV

Based on the assessment of the Patient

Based on a Chart PEEP/FIO2 Table

Higher PEEP/lower FiO2

FiO_2	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_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

AIRWAY PRESSURE RELEASE VENTILATION MAINTAINS ALVEOLAR STABILITY BY LIMITING LOSS OF LUNG VOLUME DURING RELEASE PHASE

N. Habashi, P. Andrews - R Adams Cowley Shock Trauma Center - University of Maryland School of Medicine, Baltimore, MD;

S. Roy, J. Satalin, K. Snyder, L. Gatto, G. Nieman - SUNY Upstate, Syracuse, NY

INTRODUCTION

Airway Pressure Release Ventilation (APRV) is a mode of mechanical ventilation that has shown promise in prevention and treatment of the acute respiratory distress syndrome (ARDS) when applied early. The P High in APRV equates to a plateau pressure. However, unlike most modes, APRV integrates within the P High tidal gas ventilation and the ability to retain a portion of the P High as positive end release pressure (PERP) similar to PEEP. As the P High is released towards the P Low, expiratory gas flow creates tidal ventilation. Because the duration of the T Low (release phase) is brief (sub-second) and confined to the initial phase of the expiratory release phase, the majority of the resistance impeding the pressure drop from P High towards P Low is created by the artificial airway (Fig. 1). This brief T Low duration prevents alveolar collapse without the need to set PEEP (i.e. P Low of 0 cmH2O) at the expiratory valve. Because of this unique integration, the T Low in APRV uses time to control the release phase and retains a portion of the P High which maintains adequate end-expiratory lung volume, promoting alveolar stability. Therefore, critical to protecting the lung, appropriate APRV application requires optimal adjustment of the T Low. We hypothesized that optimization of the T Low to limit lung volume loss during the release phase would occur at a specific point during Termination of the Expiratory Flow Rate. Specifically, termination at 75% of the Peak Expiratory Flow Rate (T-PEFR/PEFR) would retain the greatest alveolar stability and lower ratios would not achieve alveolar stability leading to greater alveolar volume change and collapse (Fig. 2).

METHODS

In-vivo microscopic fields (n=9) were prepared in anesthetized, male Sprague-Dawley rats. ARDS was induced by instilling 0.2% Tween-20 via tracheostomy. T-PEFR:PEFR was set at 10% and video in-vivo alveolar microscopy performed for multiple respiratory cycles. This procedure was repeated at progressive T-PEFR:PEFR of 25%, 50%, and 75% by decreasing the T Low respectively (Fig. 3).

Quantification of alveolar stability was measured using image analysis software to determine the percent of inflated alveoli occupying the microscopic field at inspiration and at expiration (Fig. 4).

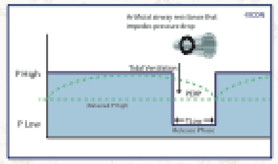


Fig 1. Integration of ventilation and positive end release pressure (PERP) within the P High. The artificial airway creates a majority of the resistance impeding the pressure drop from P High towards P Low. The T Low uses time to retain a portion of the P High, thus retaining adequate end-expiratory lung volume.

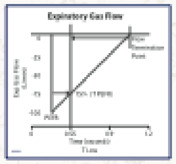


Fig 2. Expiratory gas flow pattern during APRV demonstrating adjustment of the T Low to terminate the expiratory gas flow at 75% of the Peak Expiratory Flow Rate (T-PEFR:PEFR)

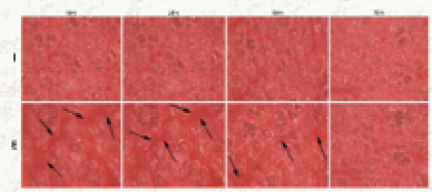


Fig 3. Alveolar Microscopy at 4 different T-PEFR:PEFR percentages. As T-PEFR:PEFR percentage increases, alveolar stability increases.
I=Inspiration E=Expiration
Black arrows illustrate interstitial expansion and alveolar collapse between aerated alveoli at expiration. A progressive decrease in interstitial expansion and greater number of recruited alveoli occupying the field is seen moving left to right from 10% to 75%.

ALVEOLAR STABILITY

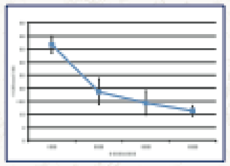


Fig 4. I-E percent alveolar areas were calculated per photomicrographic frame as the difference between the percentage of alveolar area at inspiration and its counterpart at expiration changed. Quantification of alveolar stability shows as T-PEFR:PEFR percentage increases, the alveolar I-E change decreases thus increasing alveolar stability.

RESULTS

T-PEFR:PEFR of 75% had the least alveolar volume change at expiration (10.0%) while T-PEFR:PEFR of 10%, 25% and 50% had a progressively greater alveolar volume change and collapse at expiration: 54.5%, 36.4%, and 29.4% respectively ($p<0.001$ vs T-PEFR 75%) (Fig 5).

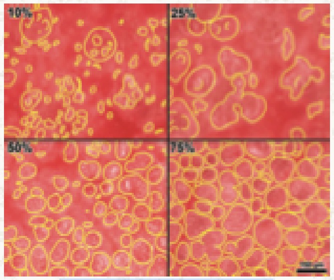


Fig 5. In vivo microscopic fields at expiration with all 4 T Low settings (T-PEFR:PEFR). Alveoli were outlined (yellow) and their collective area was calculated by digital image analysis as a percentage of the total tissue area in the frame.

CONCLUSIONS

The use of APRV as a strategy for the treatment or prevention of ALI/ARDS is contingent on the appropriate method of application. One key aspect of APRV is optimizing the T Low to control expiratory gas flow to minimize alveolar volume change/collapse and maintain alveolar stability. These data confirm that a T-PEFR:PEFR of 75% is necessary to achieve alveolar stability and that a T-PEFR:PEFR <75% may lead to alveolar collapse and lung derecruitment in acute lung injury.

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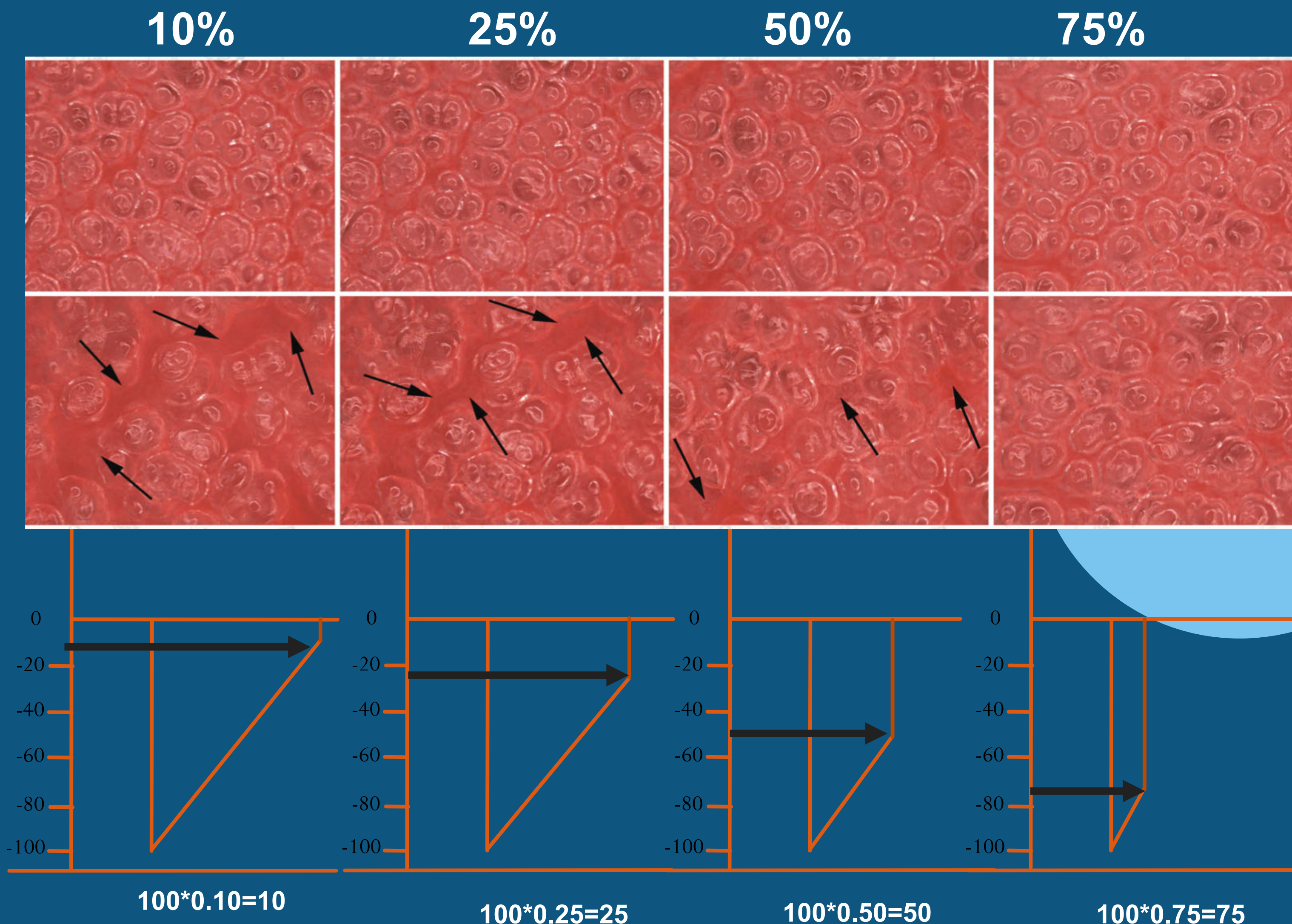


10%
25%
50%
75%
0
-20
-40
-60
-80
-100
100*0.10=10
100*0.25=25
100*0.50=50
100*0.75=75

CASE STUDIES

Session C45 - CRITICAL CARE CASE REPORTS: MECHANICAL VENTILATION FROM NIV TO ECMO

Add to Itinerary

P712 - Rapid Liberation from Extracorporeal Membrane Oxygenation (ECMO) Using Time Controlled Adaptive Ventilation (TCAV) Method

May 19, 2020, 11:15 AM - 1:00 PM

PENNSYLVANIA CONVENTION CENTER, Hall D-E (200 Level), Area E

Participant

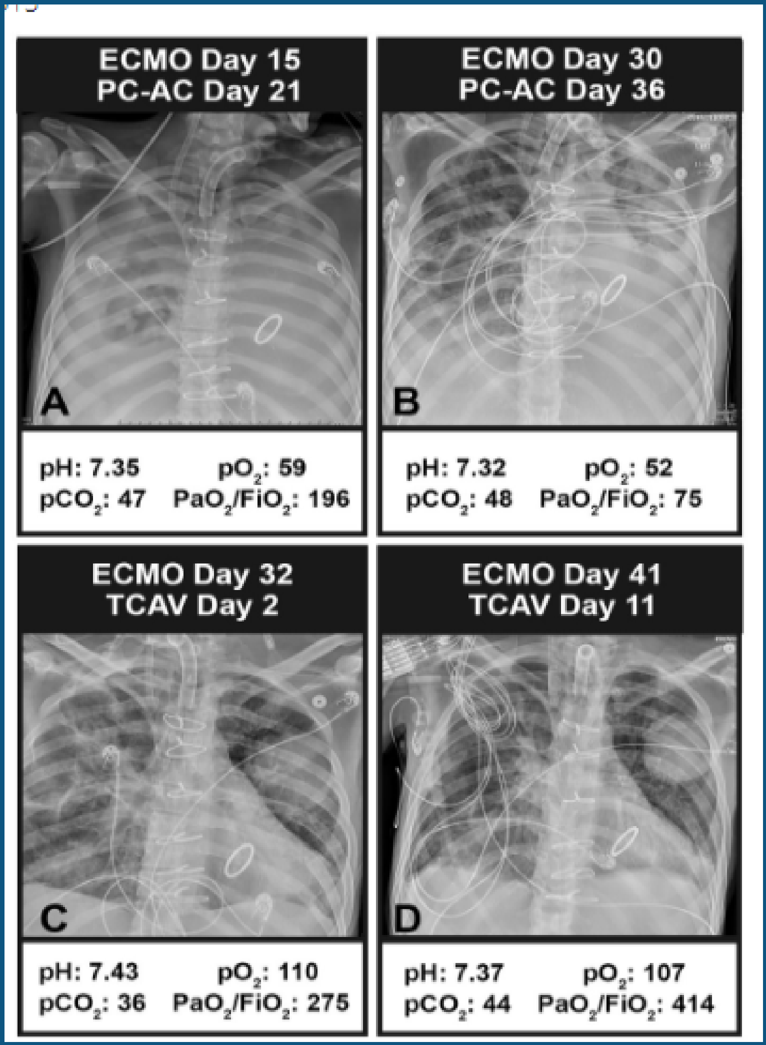
H. M. Al-khalisy[1], G. Trikha[2], I. Amzuta[3], R. Modi[1], P. Masuta[1], M. Kollisch[4], H. Ramcharran[4], J. Satalin[4], S. Blair[4], H. Alash[5], P. Andrews[6], G. Nieman[7], N. Habashi[6];

[1]Division of Pulmonary, Sleep and Critical Care Medicine, SUNY Upstate Medical University, Syracuse, NY, United States, [2]SUNY Upstate Medical University, Syracuse, NY, United States, [3]SUNY Upstate Medical University, Fayetteville, NY, United States, [4]Department of Surgery, SUNY Upstate Medical University, Syracuse, NY, United States, [5]Department of Cardiovascular Perfusion, SUNY Upstate Medical University, Syracuse, NY, United States, [6]University of Maryland School of Medicine - R. Adams Cowley Shock Trauma Center, Baltimore, MD, United States, [7]Surgery, Upstate Medical University, Syracuse, NY, United States.

Case Presentation:

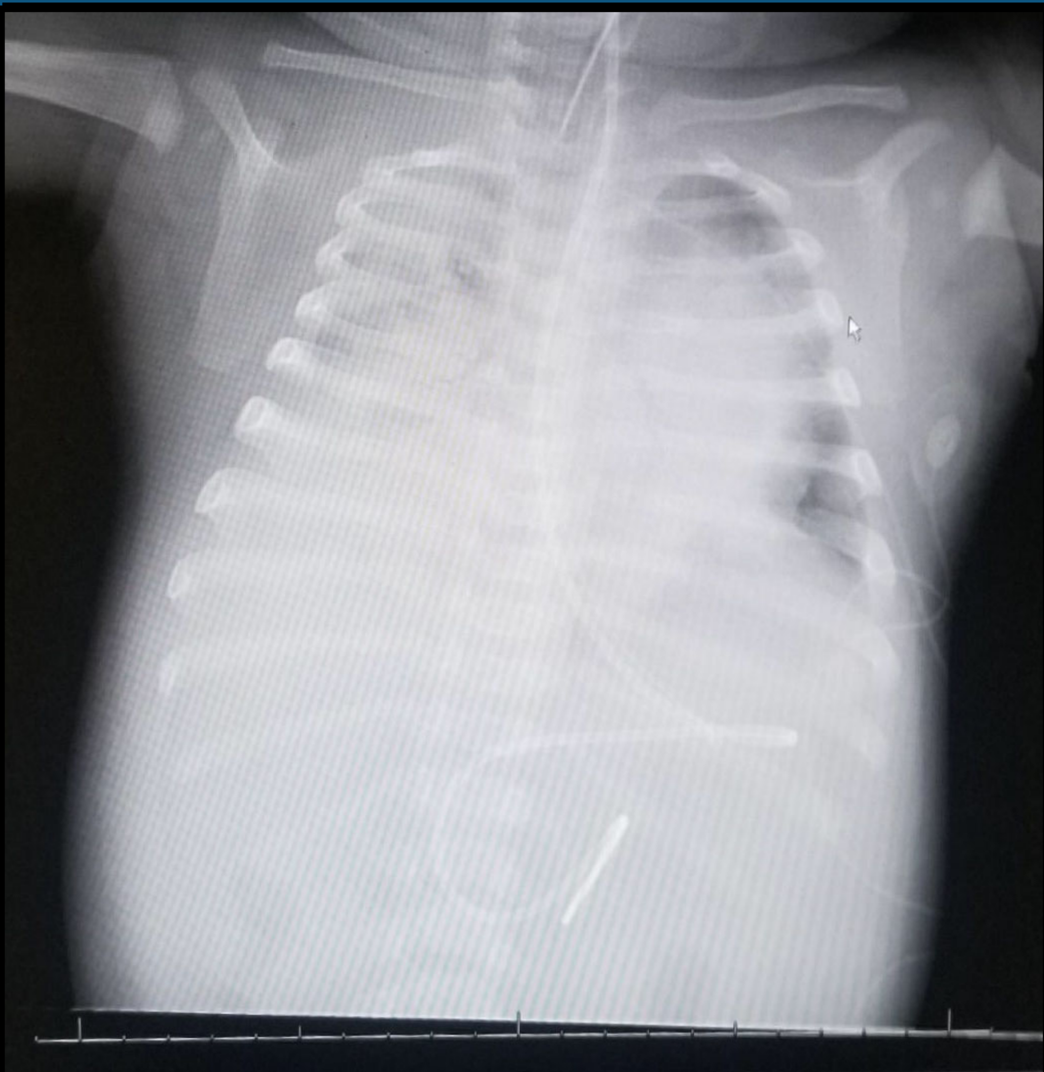
A 35-year-old man with respiratory failure required Coronary Artery Bypass Grafting and Mitral Valve repair, which led to ARDS. Initial ventilator management utilized lung protective strategies including LVt and Lung Rest using pressure-control assist-control ventilation (PC-AC)[vi].

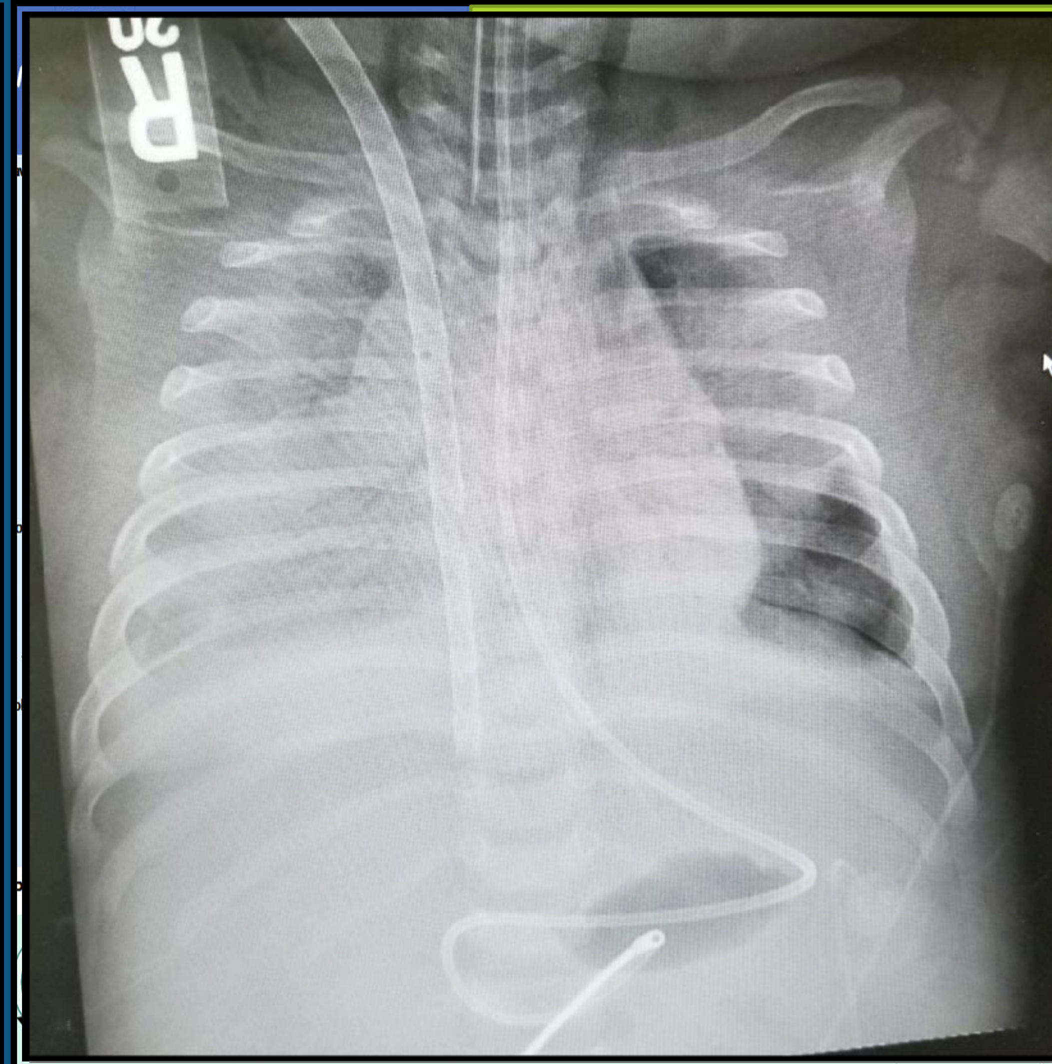
However, refractory hypoxemia and acidosis led to a cardiorespiratory arrest and Veno-Venous ECMO was initiated. Day-30 of ECMO and Day-36 of LVt and PC-AC, the patient was transitioned to TCAV and liberated from ECMO and full vent support on Day-11 of TCAV.



Conclusion:

Using TCAV to open and stabilize the lung *early* would be paradigm shift in the management of patients meeting ARDS criteria on ECMO from a strategy of 'Collapsed Lung Rest' to 'Open Lung Rest', which may significantly reduce morbidity and mortality in this patient population.



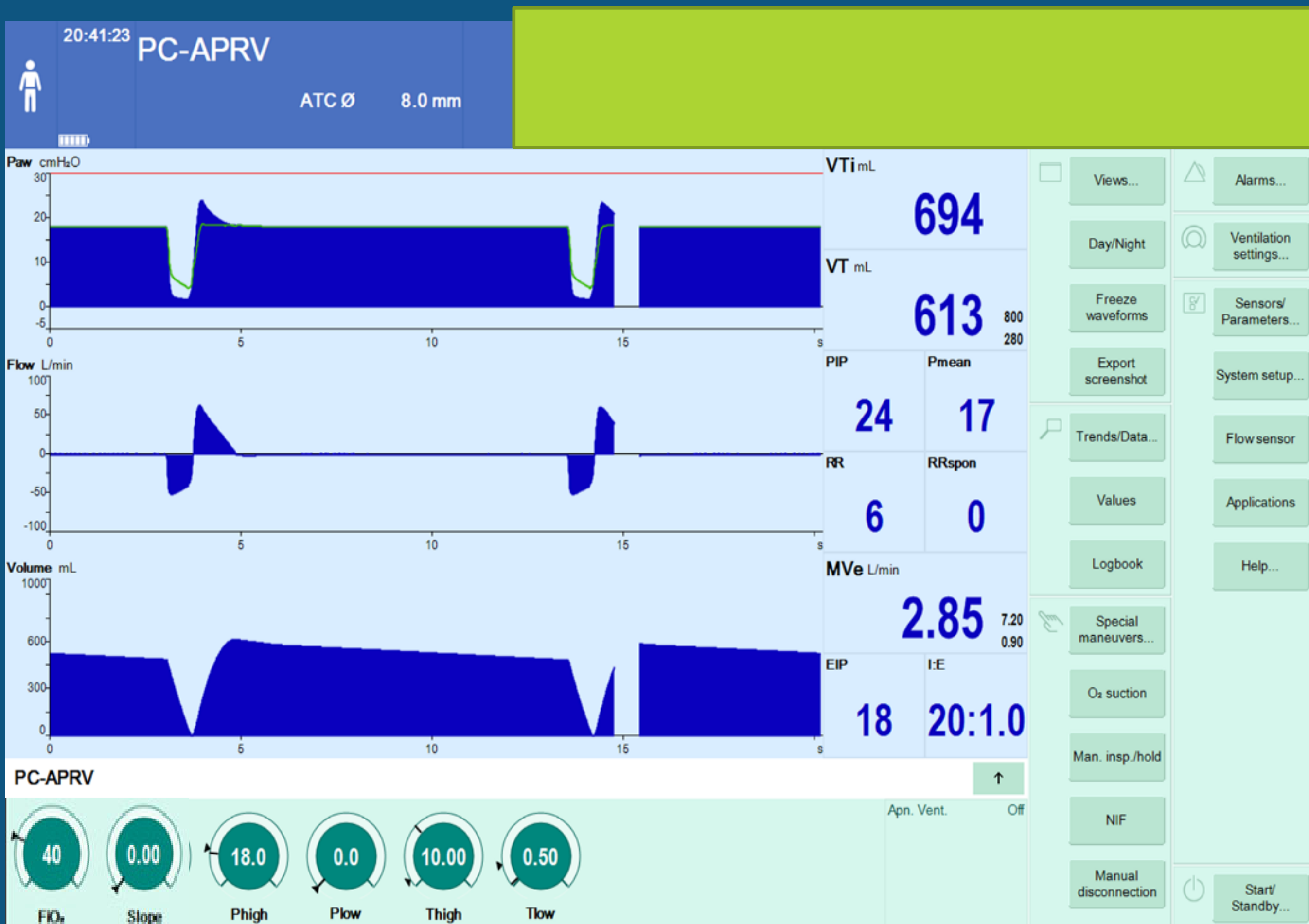


Why aren’t we using APRV-TCAV?

ECMO Patient

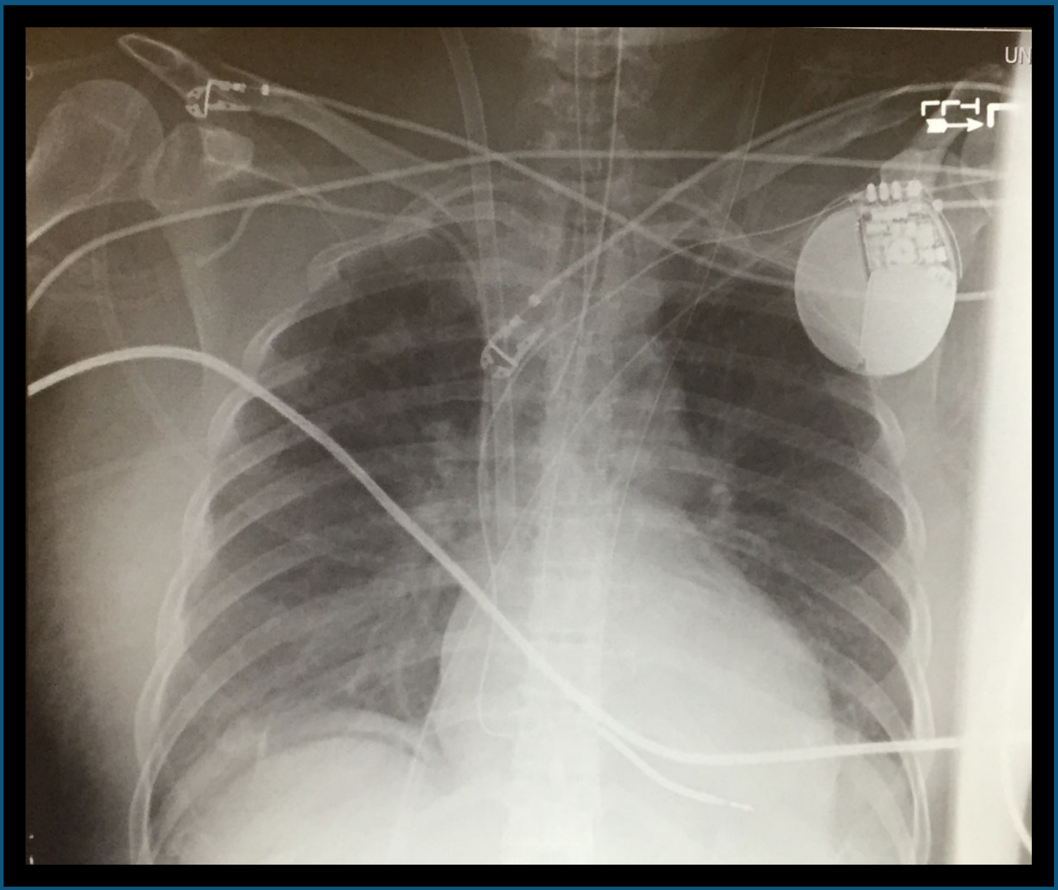
- 53 year old female involved in a motor vehicle collision
- < 24 hours patient received 14+ liters of fluid and blood products.

Ventilator Assessment

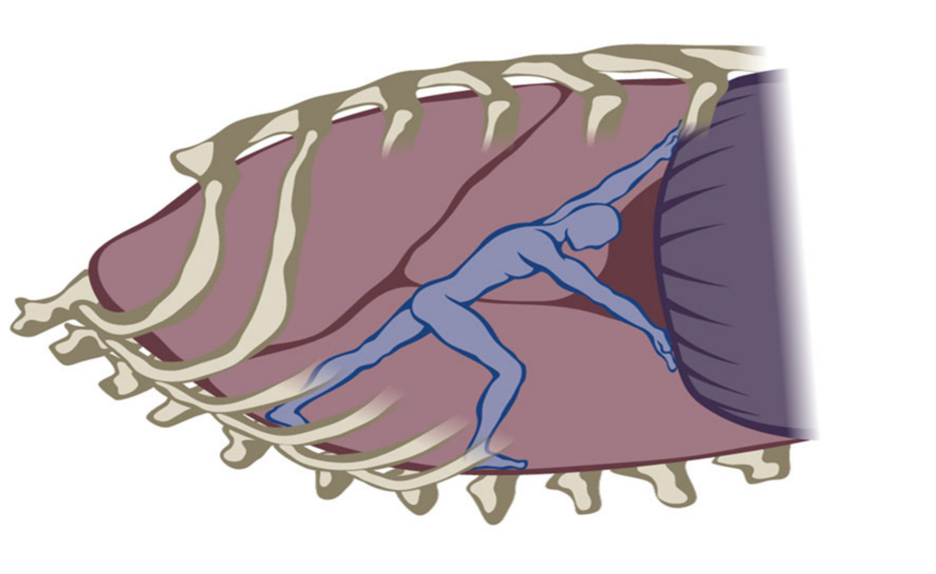


TIME & SETTINGS APRV	2000 18/0 10/0.5	2300 20/0 10/0.5
RR	6	9
VT	613	524
VE	3.7	3.1
T/P%	75%	60%

What is the right dose of APRV?



P HIGH P LOW	T HIGH T LOW
18/0	10/0.5
22/0	10/0.5
25/0	10/0.35



APRV Used to Keep the Lungs Open in ECMO

UVA is using APRV-TCAV in all their Pediatric VA-ECMO patients to keep the lungs open

Ryan Sharkey MS, RRT-ACCS

Pediatric Respiratory Supervisor

THE USE OF AIRWAY PRESSURE RELEASE VENTILATION (APRV) PREVENTS THE NEED FOR EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO) IN A TRAUMA PATIENT

Dolly, Kate[1]; Madden, Maria[1]; Andrews, Penny [1]; Habashi, Nader[1]

University of Maryland Medical Center
R Adams Cowley Shock Trauma Center, University of Maryland

Data Table

TIME	MODE	SETTINGS	pH	$PaCO_2$	PaO_2	SPO_2	HCO_3	BE	P/F RATIO
0430	PRVC	FiO_2 100% RR 22 VT470 mL PEEP 14 PIP 50 cmH_20	7.09	61	72	88%	17	-13.3	72
0730	APRV	FiO_2 97% P High 36 cmH_2O P Low 0 cmH_2O T High 2.0 sec T Low 0.65 sec	7.36	29	216	100%	16	-7.8	223
1600	APRV	FiO_2 47% P High 35 cmH_2O P Low 0 cmH_2O T High 5.0 sec T Low 0.75 sec	7.42	25	141	98%	16	-6.0	300

Use of Airway Pressure Release Ventilation (APRV) as a Rescue Mode from High Frequency Oscillatory Ventilation (HFOV)

Penny Andrews[1], David Madden[2], Jeffrey Brauer[2], Maria Madden[1], Nader Habashi[2]
1) University of Maryland Medical Center/R Adams Cowley Shock Trauma Center, Baltimore, MD; 2) Sinai Medical Center, Baltimore, MD

INTRODUCTION

High-frequency oscillatory ventilation (HFOV) and Airway Pressure Release Ventilation (APRV) are strategies of mechanical ventilation used to improve oxygenation by keeping the lung inflated for an extended period of time with mean airway pressure. An increased mean airway pressure maintains lung volume and promotes alveolar homogeneity. Unfortunately, these modes of ventilation are typically applied as a last resort or as a 'rescue mode' when treating acute respiratory distress syndrome (ARDS). In our facility, Sinai Medical Center in Baltimore, MD, the ARDSnet protocol is used as an initial lung protective strategy and patients are transitioned to HFOV if the ARDSnet protocol fails to resolve ARDS. We hypothesized that APRV could still be used as a rescue mode even after ARDSnet, nitric oxide therapy, prone positioning and HFOV failed to improve oxygenation, preventing a patient from requiring a hospital transfer for Extracorporeal Membrane Oxygenation (ECMO).

CASE SUMMARY

A 40 year old male was admitted to the ICU after being found down and unresponsive with aspiration syndrome. The patient was intubated rapidly upon admission with an initial P/F ratio of 45 and chest x-ray (CXR) demonstrating bilateral alveolar densities consistent with the American-European Consensus Conference diagnosis of ARDS (Fig 1). Requiring increased ventilatory support due to refractory hypoxemia, ARDSnet protocol was implemented within one day of intubation. However, continued hypoxemia and hypercarbia led to the addition of nitric oxide and prone positioning as adjunctive therapies. With worsening oxygenation, the patient was transitioned to HFOV (SensorMedics 3100b) by Day 2 with heavy sedation and neuromuscular blocking agents (NMBAs). After 4 days of HFOV and FiO_2 requirements of 90-100%, there was essentially no improvement. Therefore, consideration was given to transfer the patient to the University of Maryland in Baltimore for ECMO. However, prior to transfer, APRV was applied as a rescue therapy. Within 15 minutes of transitioning to APRV (Dräger Evita XL), the SpO_2 increased from 83% to 100%. Subsequently, within 12 hours, FiO_2 requirements were rapidly decreased, significant improvements were seen by CXR (Fig 1) and P/F ratio increased from 59 to 334. The patient remained on APRV where the FiO_2 was weaned, sedation was decreased, NMBAs were weaned and discontinued and spontaneous breathing was introduced. The pressure requirements of APRV were reduced using the Drop & Stretch weaning method where the patient was ultimately transitioned to CPAP and subsequently extubated 11 days after admission with no reintubation required (Fig 2).

DISCLOSURE

The authors have no conflicts of interest nor research funding, sponsorship, or financial support.

Data Table

	Day 1	DAY 4	DAY 5
Ventilator Mode	*CMV	*HFOV	*APRV
FiO_2	100%	100%	60%
Ventilator Settings	Rate 30 Vt 350 ml PEEP 24 cmH_2O	Hz – 7 Amplitude 90	P High 35 cmH_2O P Low 0 cmH_2O T High 6.0 seconds T Low 0.7 seconds
Peak Pressure (cmH_2O)	39	N/A	35
Mean Airway Pressure (cmH_2O)	30	37	32
P/F RATIO	53	59	334
ABG Results (pH/$PaCO_2$/PaO_2/HCO_3/BE)	7.13/76/53/25/-6 SpO_2 74%	7.29/63/59/40/1 2 SpO_2 84%	7.53/40/167/36/13 SpO_2 100%
Adjunctive Therapies	Nitric Oxide	Nitric Oxide Prone Therapy	None
Chest X-Ray Interpretations	Near complete opacification of right hemithorax; worsening diffuse bilateral infiltrates	Complete atelectasis of right upper lobe; patchy infiltrates	Lung bases clear; significant improvement with no pleural effusion
Heart Rate (b/min)	99	98	95
Blood Pressure (mmHg)	115/75	109/78	131/86

Table 1 – Ventilator and hemodynamic data after transitioning from CMV to HFOV and ultimately to APRV. This data demonstrates improved oxygenation and ventilation with improving chest radiographs and hemodynamic stability.

*CMV – Controlled Mechanical Ventilation; HFOV – High Frequency Oscillatory Ventilation; APRV – Airway Pressure Release Ventilation

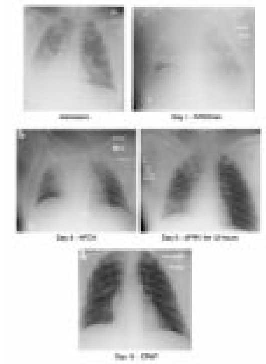


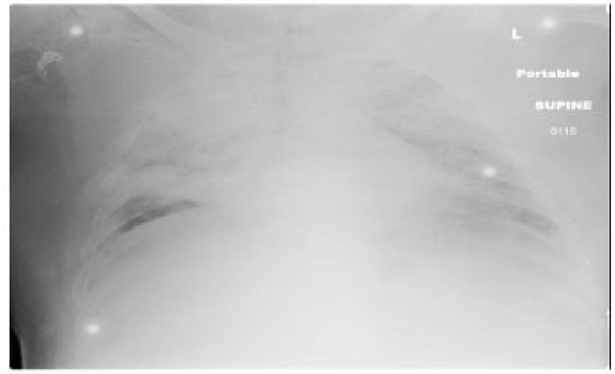
Figure 1 - Serial chest radiographs. From left to right: Admission; Day 1 (ARDSnet); Day 4 (4 days of HFOV); Day 5 (12 hours after transition to APRV); Day 11 (CPAP).

Figure 2 – Ventilatory strategies from left to right: Admission, 1 day of ARDSnet, 4 days of HFOV, 8 days of APRV, 2 days of CPAP and extubation.

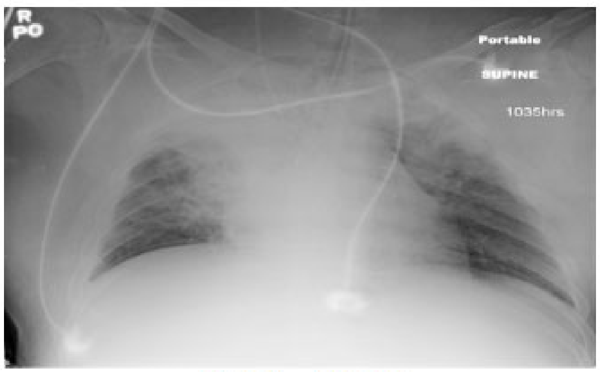
DISCUSSION

APRV was applied as a rescue mode in this case of aspiration syndrome when ARDSnet protocol, HFOV and adjunctive therapies (nitric oxide and prone positioning) failed. Although recent animal data demonstrates early application of APRV prevents ARDS, the mechanism of oxygenation and ventilation leading to a rapid improvement after transitioning to APRV in this case is unclear. However, the mechanism may be related to the recent data that has shown APRV is associated with less lung inflammation, edema prevention, redistribution of lung water and surfactant retention and regeneration. During ARDSnet ventilation and after transitioning to HFOV in this case study, sedation requirements were increased with the addition of NMBAs. After transitioning from HFOV to APRV and alveolar stability was maintained as evidence by improved oxygenation and ventilation, NMBAs were weaned and discontinued in addition to a reduction in sedation. The reduction in sedation facilitated the introduction of spontaneous breathing, weaning of APRV pressure requirements and transition to CPAP. This case study demonstrates that APRV can be used as a rescue therapy for HFOV and may reduce the need for ECMO.

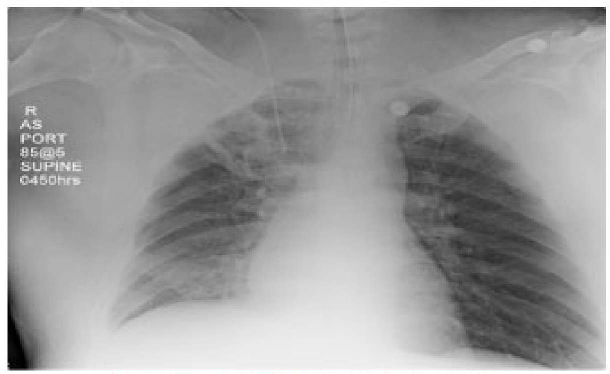
Admission



Day 1 - ARDSnet



Day 4 - HFOV



Day 5 - APRV for 12 hours

Day 11 - CPAP

ADMISSION 3/16/2012

1 DAY — 4 DAYS — 8 DAYS — 2 DAYS →

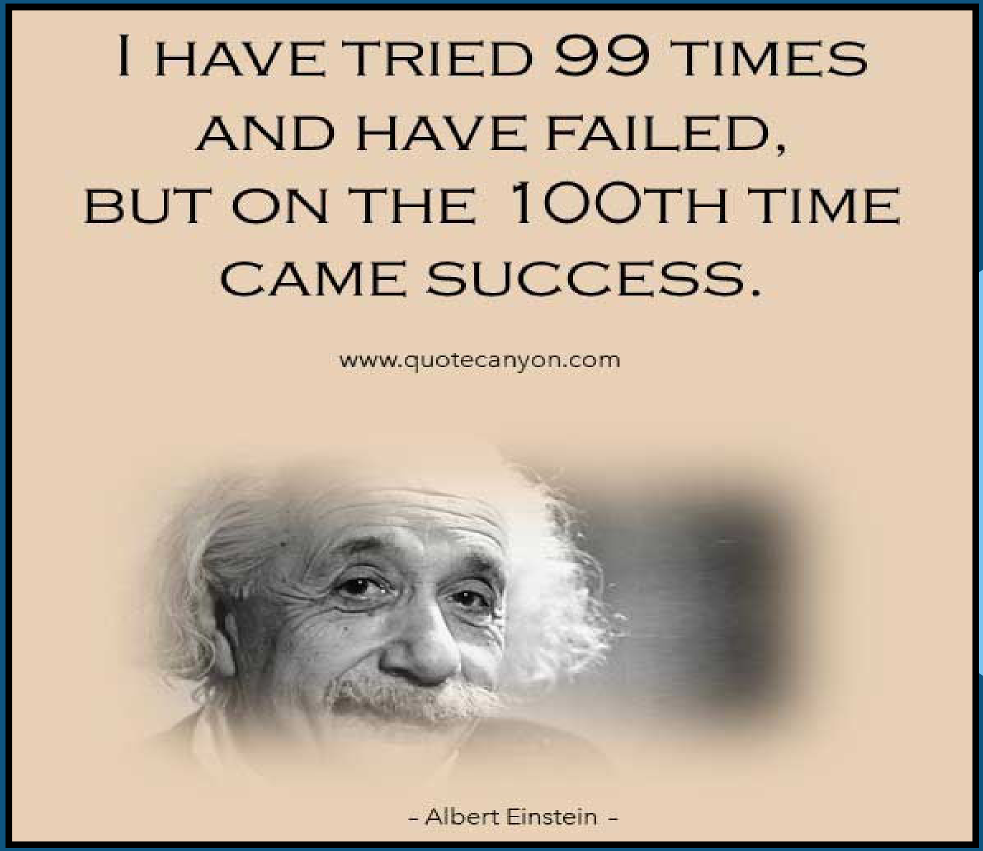
ARDSnet ← HFOV → ← APRV → CPAP

EXTUBATED 3/28/2012

	DAY 1	DAY 4	DAY 5
Ventilator Mode	CMV	HFOV	APRV
FiO2	100%	100%	50%
Ventilator Settings	Rate 30 Vt 380 ml PEEP 24 cmH2O	Hz – 7 Amplitude 90	P High 35 cmH2O P Low 0 cmH2O T High 6.0 seconds T Low 0.7 seconds
Plateau Airway Pressure	39	N/A	35
Mean Airway Pressure	30	37	32
P/F Ratio	53	59	334
ABG	7.13/75/53/25/-6 SpO2 74%	7.29/83/59/40/12 SpO2 84%	7.53/42/167/35/12/SpO2 100%
Adjunctive Therapies	Nitric Oxide	Nitric Oxide Prone Positioning	None
Chest X-Ray	Near complete opacification of right hemithorax; worsening diffuse bilateral infiltrates	Complete atelectasis of right upper lobe; patchy infiltrates	Lung bases clear; significant improvement with no pleural effusion
Heart Rate	99	99	95
Blood Pressure	115/75	105/78	131/80

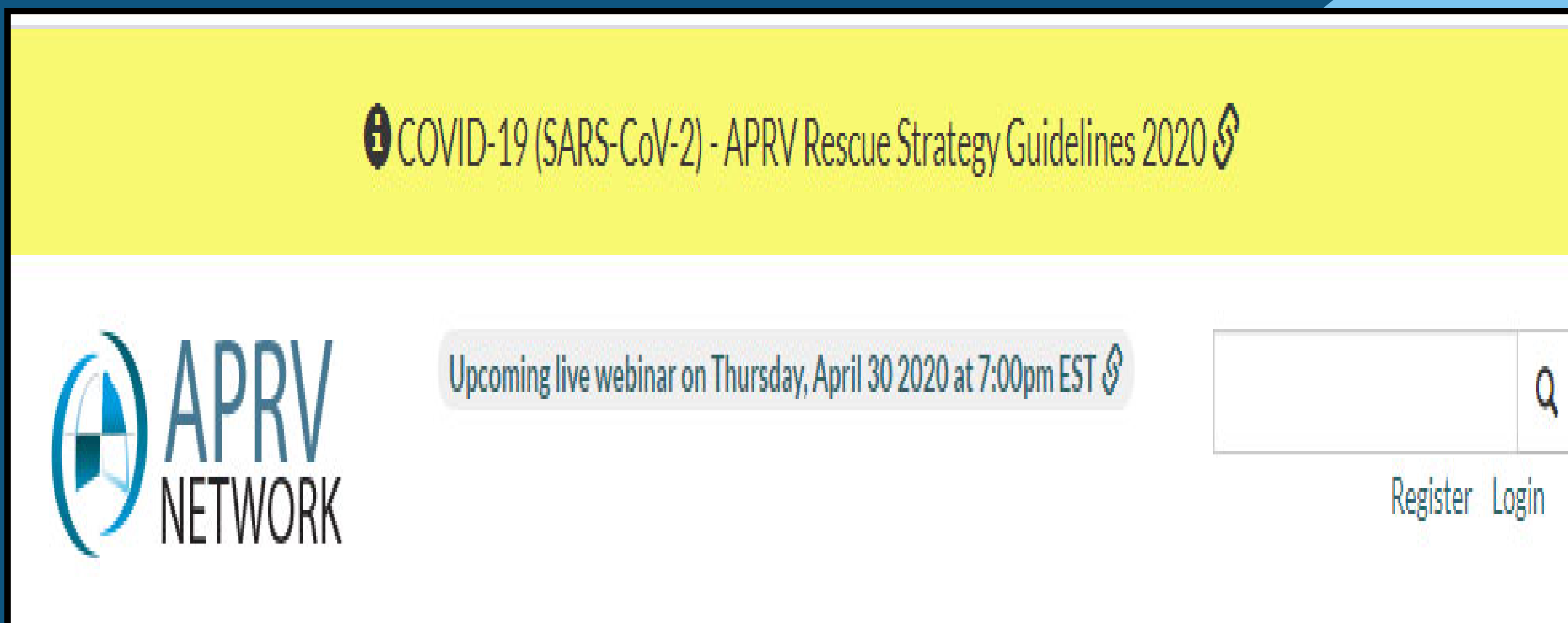
SUMMARY

- Benefits of APRV
  - Same amount of Plateau Pressure from previous mode creates higher mean airway pressure
  - Using Long Inspiratory Time to help recruitment
  - Personalizing the T Low setting to the patient



More Research

www.aprvnetwork.org



THANK YOU!

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