Phase V
(1990's)

Protective ventilatory strategy for patients with lung injury.

Journals

AJRCCM

CCM

ICM

Anesth

FREQUENCY

Effects of Decreased Respiratory Frequency on Ventilator-induced Lung Injury

"…decreasing respiratory frequency can improve these indices of lung damage"

Hotchkiss,Jr., et al. Am J Respir Crit Care Med 161,463-468, 2000

Lethal Systemic Capillary Leak Syndrome Associated with Severe Ventilator-induced Lung Injury: An Experimental Study

Srinivas Mandava, et. al.

-Peak inspiratory pressure of 50 cm H_2O

-Respiratory rate of 4 breaths/min

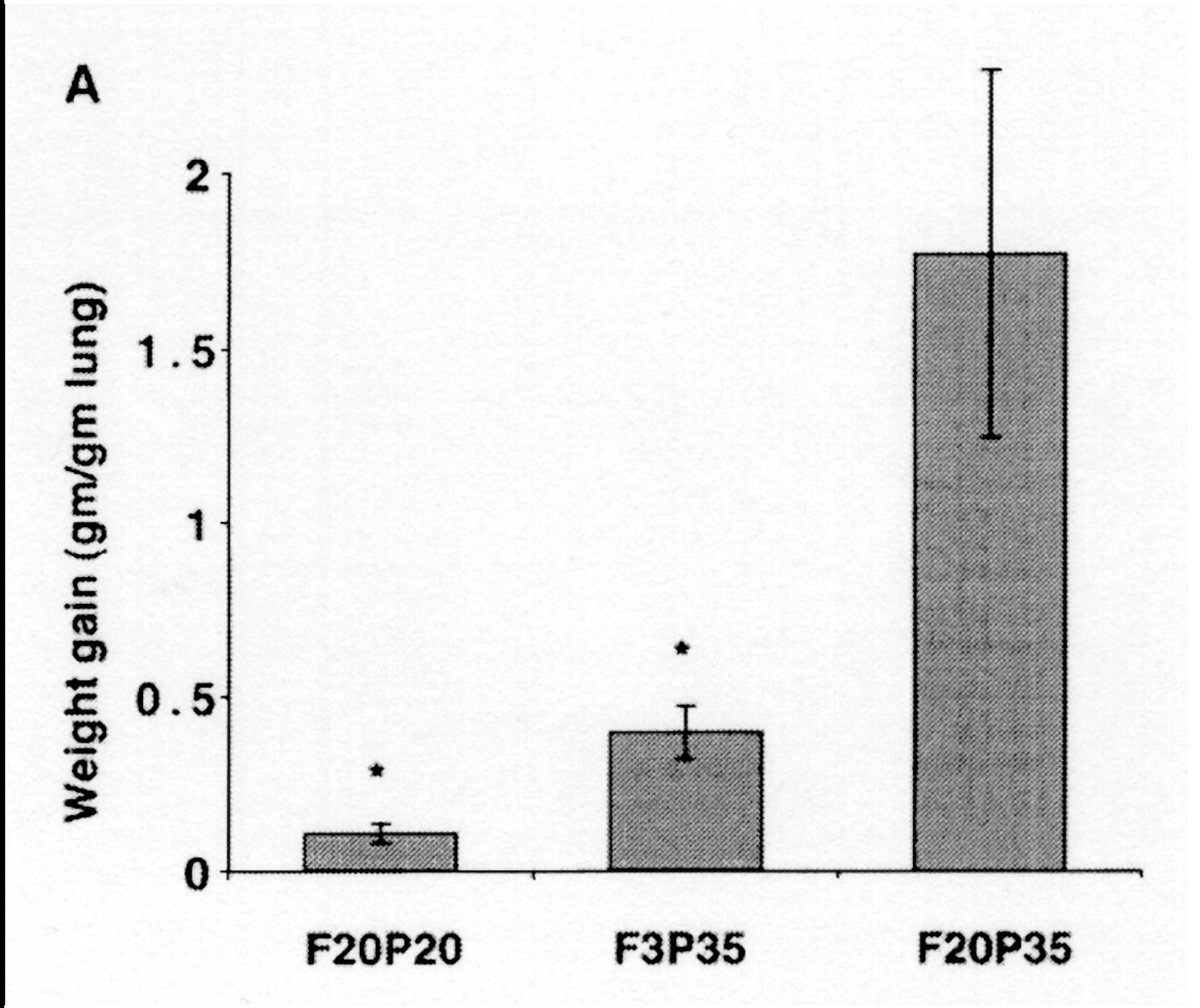
-No capillary leak syndrome

-Increased respiratory rate from 4 to 8 breaths/min

-Lethal systemic capillary leak syndrome

-Multiple system organ failure

Crit Care Med 31:2003



* $p < 0.05$ for the comparison with F20P35

FREQUENCY
HYPERCAPNIA

Shibata, et al. Hypercapnic acidosis may attenuate acute lung injury by inhibition of endogenous xanthine oxidase AJRCCM 1998; 158:1578-84

Laffey, *et al.* Therapeutic hypercapnia reduces pulmonary and systemic injury following *in vivo* lung reperfusion. AJRCCM 2000;162:2287–2294

FREQUENCY
HYPERCAPNIA
IRV

FREQUENCY

HYPERCAPNIA

IRV

IRV WITH PEEP

FREQUENCY
HYPERCAPNIA
IRV
IRV WITH PEEP
REC MANEUVER

FREQUENCY

HYPERCAPNIA

IRV

IRV WITH PEEP

REC MANEUVER

REC MANEUVER WITH PEEP

Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome

The Acute Respiratory Distress Syndrome Network

The New England Journal of Medicine, Vol. 342;1301-1308:2001

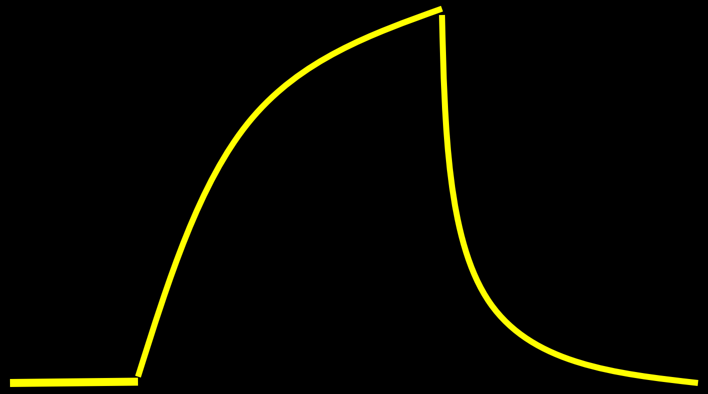
(Only 160/867 patients had P/F < 200 mmHg!)

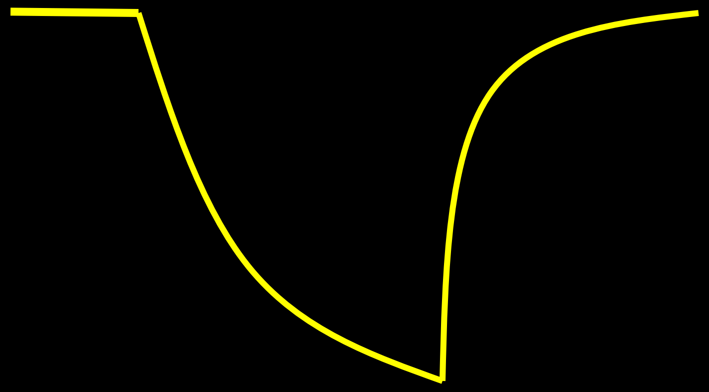
From IMV with CPAP To APRV:

A Natural Evolution From Protective to preventive Ventilation

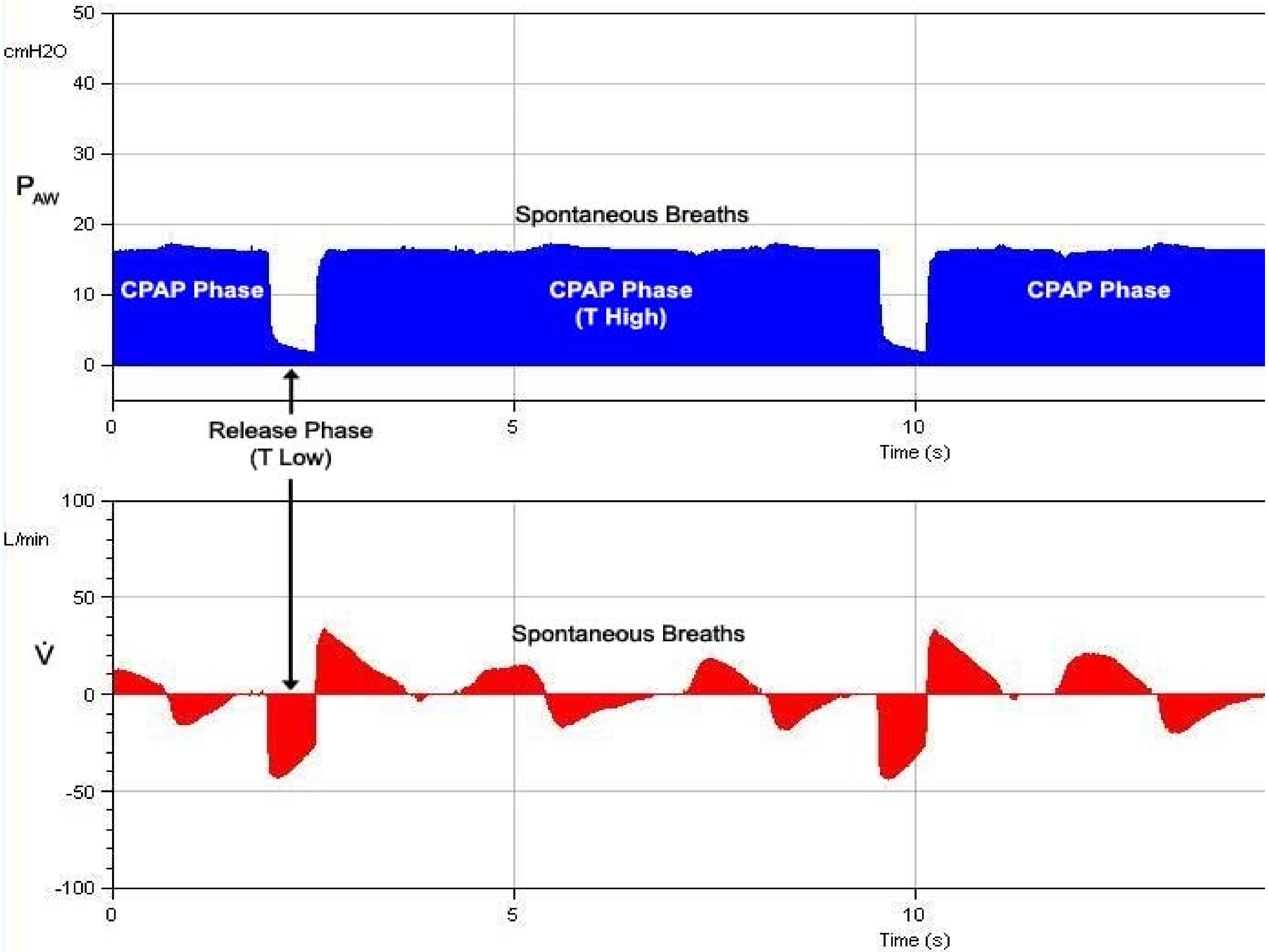
AND

A Logical Approach to Lung Protective Ventilatory Strategy

IF  , WHY NOT



?



cmH2O
P_{AW}
Spontaneous Breaths
CPAP Phase
CPAP Phase
(T High)
CPAP Phase
Release Phase
(T Low)
Time (s)
L/min
V̇
Spontaneous Breaths
Time (s)

APRV $\neq$ BIPAP

Spontaneous breathing during ventilatory support improves ventilation-perfusion distributions in patients with acute respiratory distress syndrome.

Putensen C, Mutz NJ, Putensen-Himmer G, Zinserling J.

These findings indicate that uncoupling of spontaneous and mechanical ventilation during APRV improves V A/Q matching in ARDS presumably by recruiting nonventilated lung units. Apparently, mechanical assistance of each inspiration during PSV is not sufficient to counteract the V A/Q maldistribution caused by alveolar collapse in patients with ARDS.

Am J Respir Crit Care Med. 1999 Apr;159(4 Pt 1):1241-8.

	PSV	PCV	APRV
P_{aw} (cm H_2O)	21 ± 1	20 ± 1	21 ± 1
P_{es} (cm H_2O)	9.2 ± 1.3	11.8 ± 0.9*	8.2 ± 0.7**
P_L (cm H_2O)	11.8	8.2	12.8

*P<0.05 to PSV
**P<0.05 to PSV & PCV

Putensen, et al
AM J Respir Crit Care Med
159: 1241-1248, 1999

	PSV	PCV	APRV
Q_{SP} / Q_T (%)	29 ± 4	33 ± 4	24 ± 3*
$P_a O_2$ (mmHg)	86 ± 4	82 ± 4	102 ± 4*
V_D/V_E (%)	41 ± 7	44 ± 9	38 ± 6*

*P<0.05

Putensen, et al
AM J Respir Crit Care Med
159: 1241-1248, 1999

	PSV	PCV	APRV
PVR (dyne/sec/cm^5)	115 ± 0.2	130 ± 19	95 ± 17**
CI (L/min/m^2)	5.3 ± 0.2	5.0 ± 0.2	5.6 ± 0.2**
O_2 DEL (L/min)	684 ± 26	683 ± 30	782 ± 28**
$\dot{V}O_2$ (ml/min/m^2)	170 ± 7	157 ± 5*	163 ± 6
O_2 ER (%)	23 ± 1	23 ± 1	21 ± 1**

*P<0.05 to PSV
**P<0.05 to PSV & PCV

Putensen, et al
AM J Respir Crit Care Med
159: 1241-1248, 1999

Pressure Support Ventilation (PSV) *IS NOT* spontaneous ventilation

Spontaneous breathing improves lung aeration in oleic acid-induced lung injury.

Wrigge M et al. Anesthesiology. 2003;99:376-84.

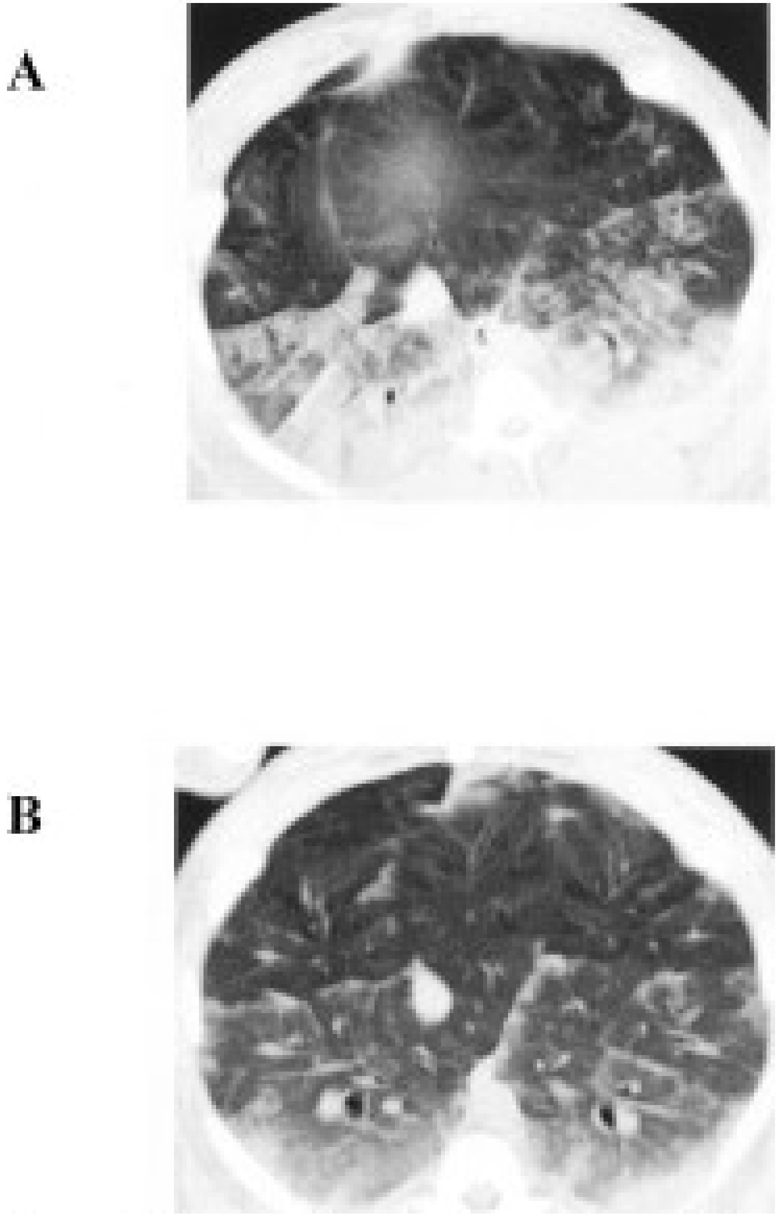


Fig. 3. Original computed tomography scans close to the diaphragm of pig 2 (*A*) during airway pressure release ventilation without spontaneous breathing and pig 3 (*B*) during airway pressure release ventilation with spontaneous breathing. Note differences in aeration and lung consolidation related to spontaneous breathing activity.

Effects of spontaneous breathing during airway pressure release ventilation on intestinal blood flow in experimental lung injury.

Hering R, et al. Anesthesiology. 2003;9):1137-44.

Effects of spontaneous breathing during airway pressure release ventilation on respiratory work and muscle blood flow in experimental lung injury.

Hering R, et al. Chest. 2005;128:2991-8.

Airway pressure release ventilation as a primary ventilatory mode in acute respiratory distress syndrome.

Initial P/F was 150 mmHg. Inspiratory pressure was lower in the APRV-group (25.9 +/- 0.6 vs. 28.6 +/- 0.7 cmH2O), but mortality was equivalent (17% and 18%, respectively).

CONCLUSION: We conclude that when used as a primary ventilatory mode in patients with ARDS, APRV did not differ from SIMV with PS in clinically relevant outcome.

Varpula T, et al. Acta Anaesthesiol Scand. 2004 Jul;48(6):722-31.

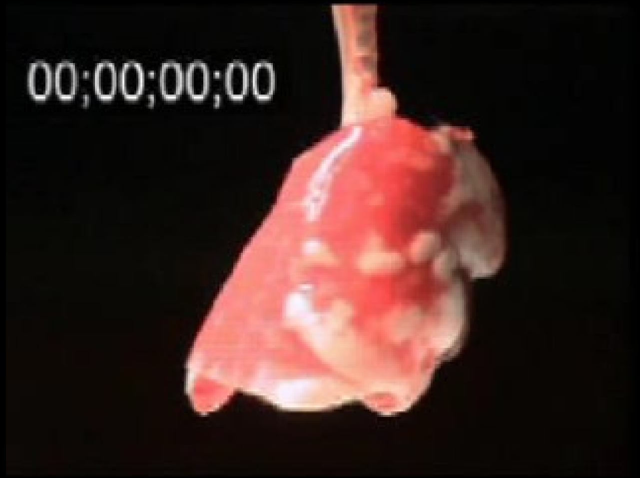
83% SURVIVAL!!!

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

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

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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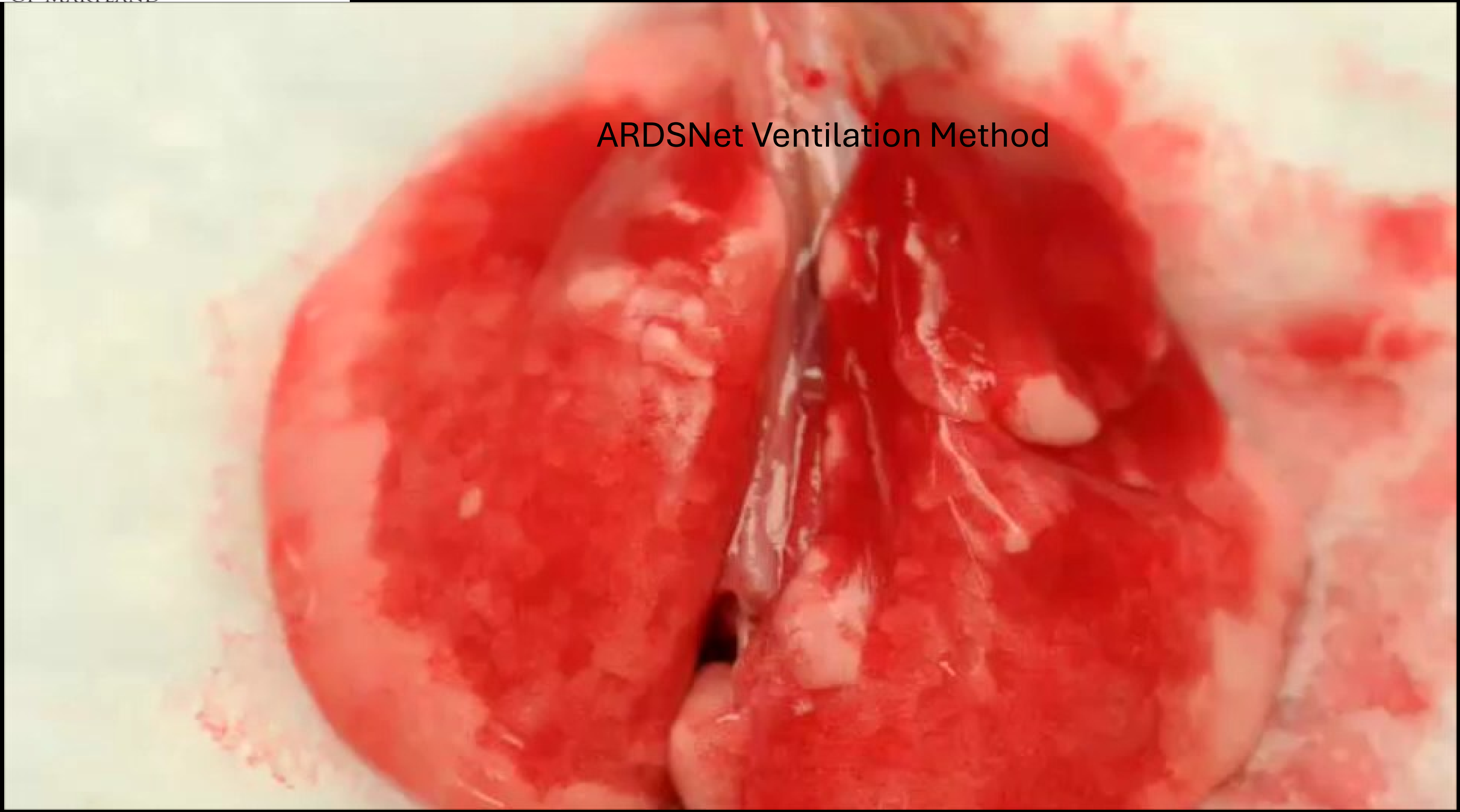
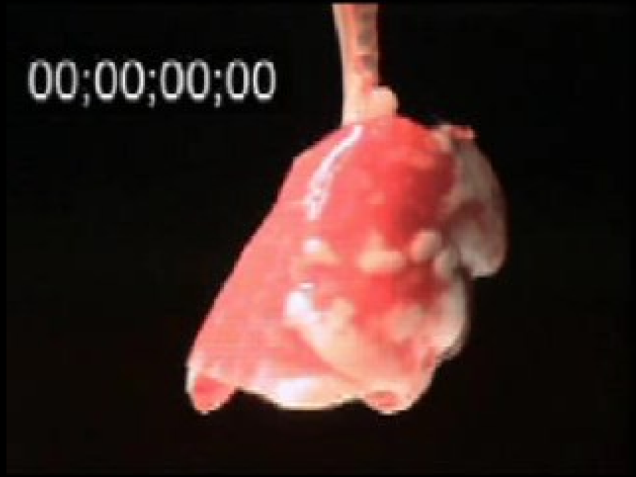


JAMA Surg, 2014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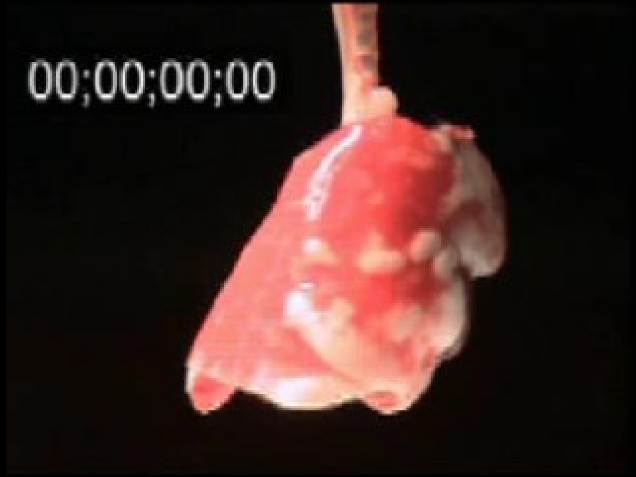
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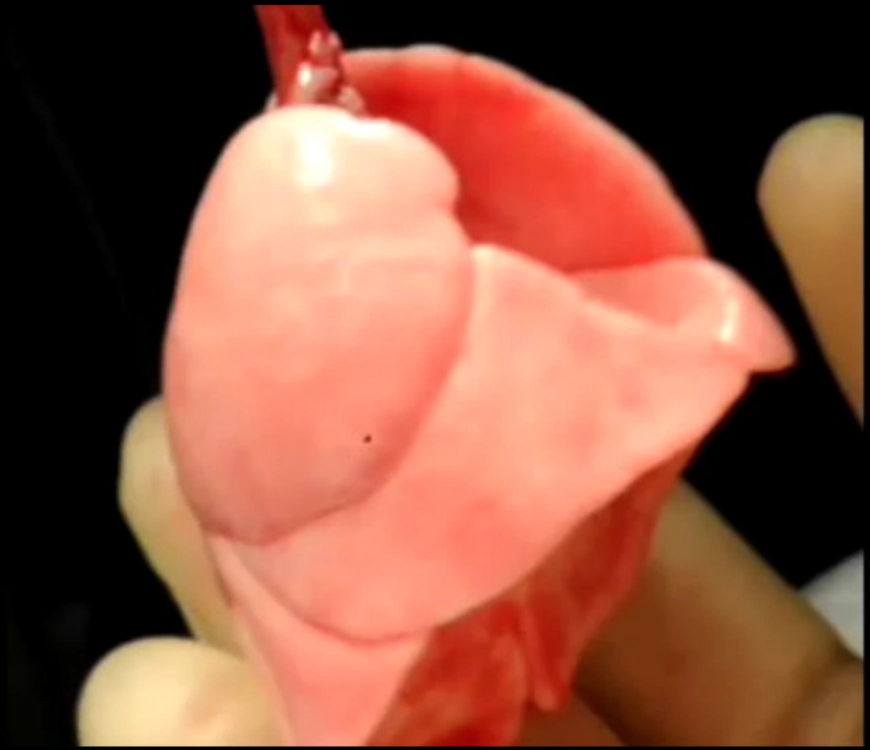


JAMA Surg, 2014

HOW TO DEBUNK JUST ABOUT ANYTHING

Daniel Drasin

Avoid examining the actual evidence.
This allows you to say with impunity,

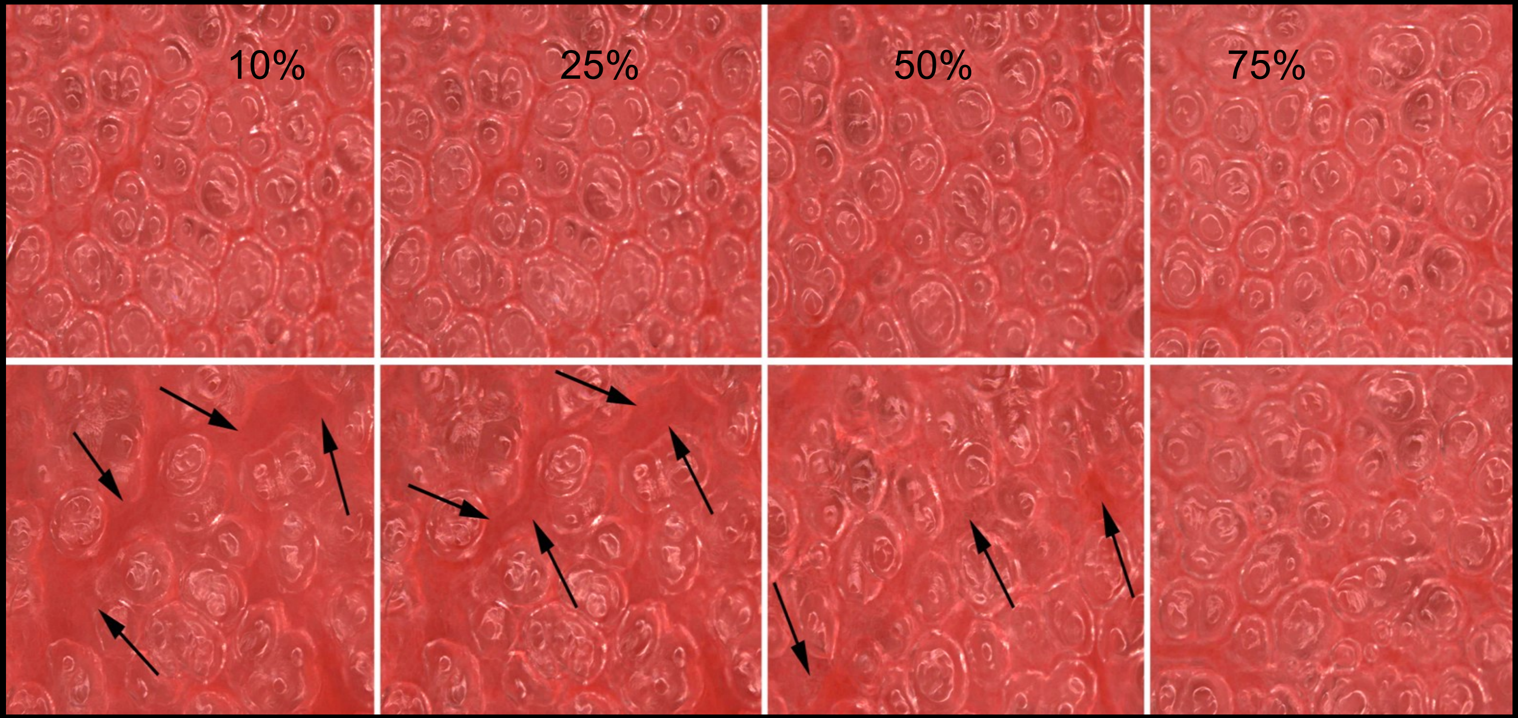
"I have seen absolutely no evidence to support such ridiculous claims!"

(Note that this technique has withstood the test of time, and dates back at least to the age of Galileo. By simply refusing to look through his telescope, the ecclesiastical authorities bought the Church over three centuries' worth of denial free and clear!)

“The only thing new is history we don’t remember.”

Harry S. Truman

N. Habashi, L. Gatto, P. Andrews, S. Roy, J. Satalin, K. Snyder, A Ghosh, B Emr, G. Nieman
1) R Adams Cowley Shock Trauma Center - University of Maryland School of Medicine, Baltimore, MD;
2) SUNY Cortland, Cortland NY; 3) SUNY Upstate Medical University, Syracuse, NY



SHOCK June 2012

N. Habashi, L. Gatto, P. Andrews, S. Roy, J. Satalin, K. Snyder, A Ghosh, B Emr, G. Nieman
1) R Adams Cowley Shock Trauma Center - University of Maryland School of Medicine, Baltimore, MD;
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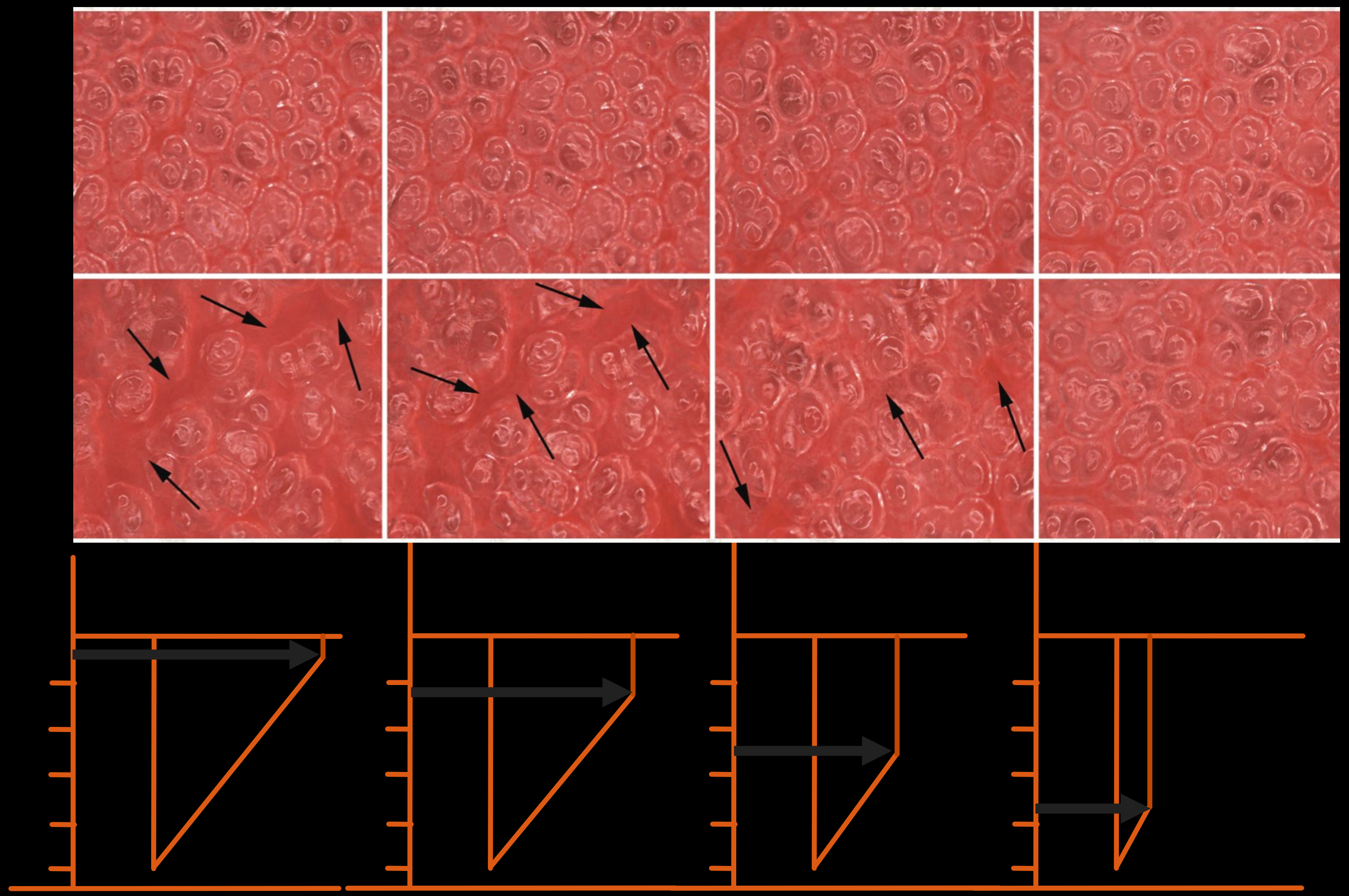
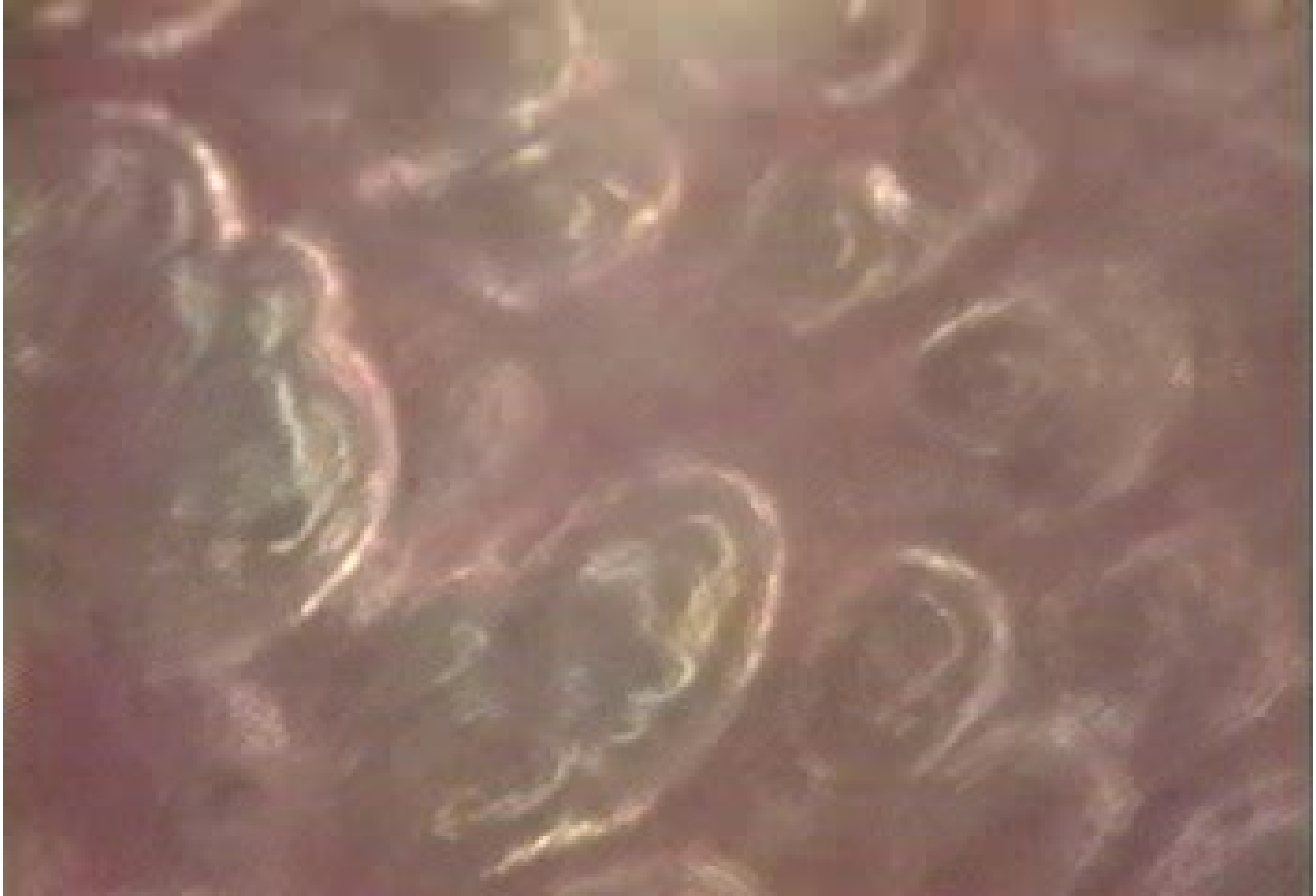
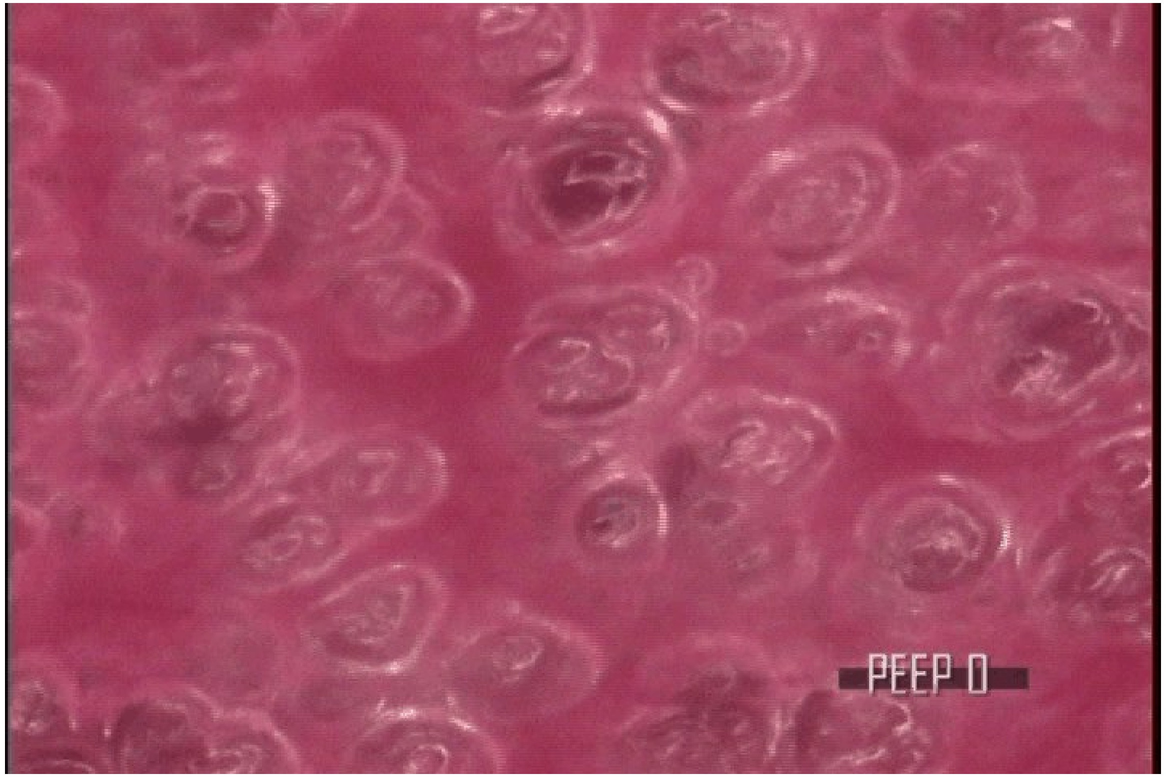


Macro vs Micro Ventilation

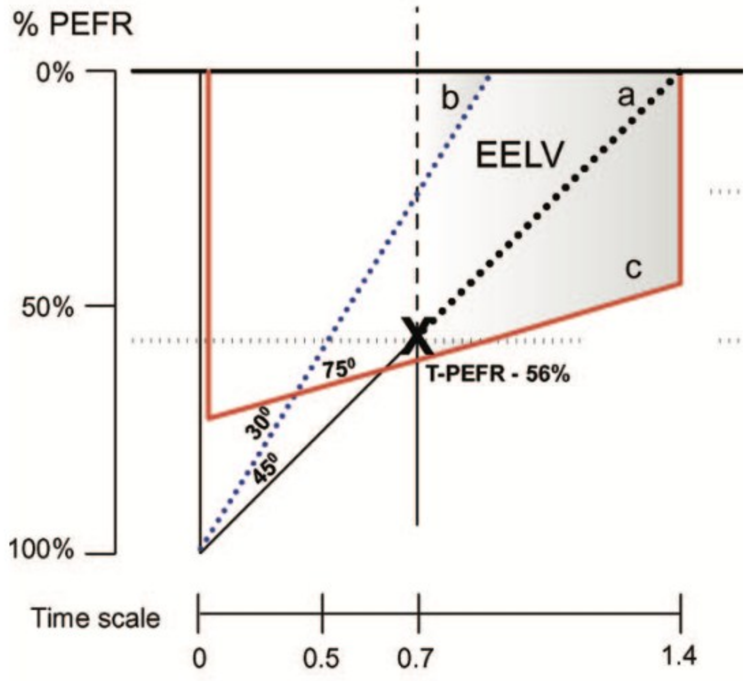
Normal Alveolar Microstrain

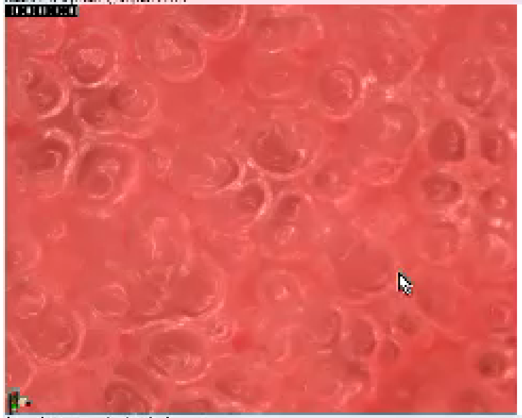
Abnormal Alveolar Microstrain

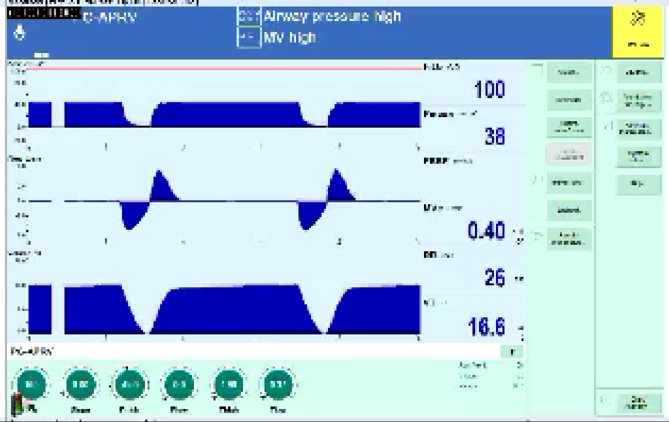


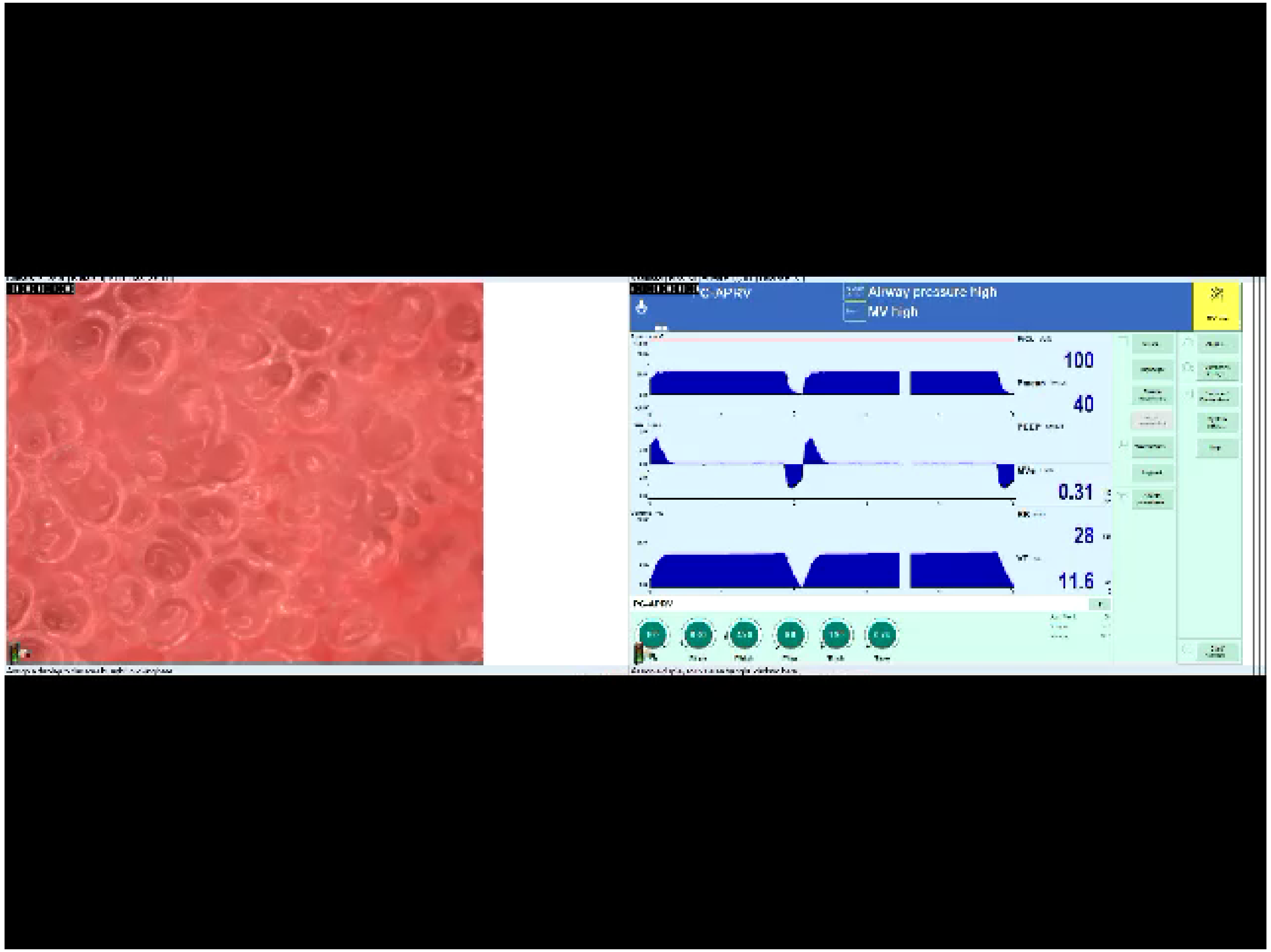

PEEP 0

Maintaining FRC with Time

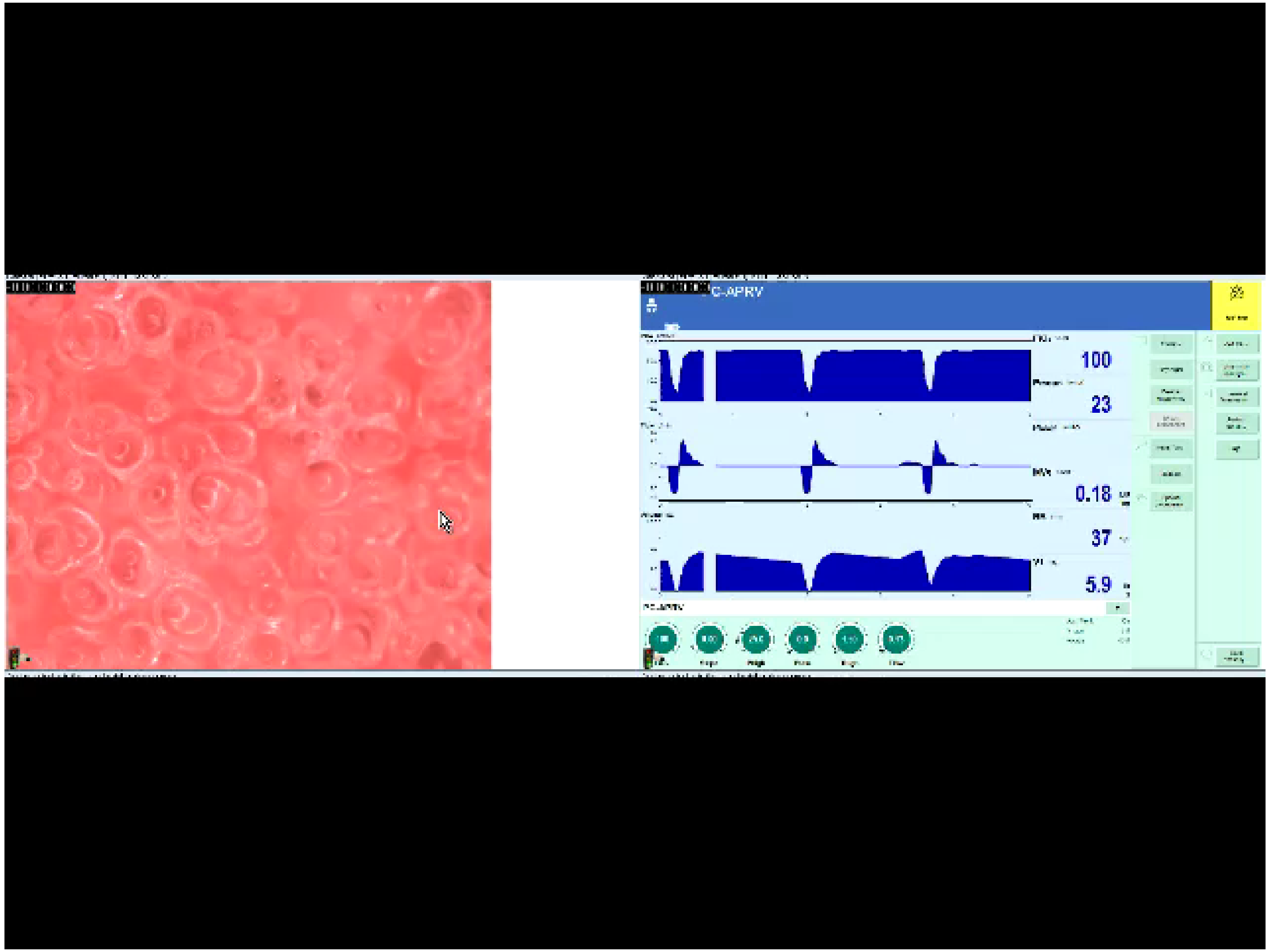




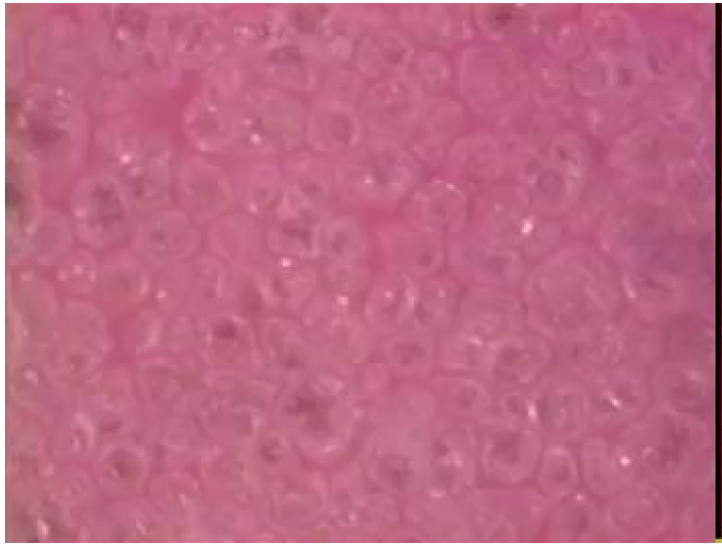

Airway pressure high
MV high
100
38
0.40
26
16.6



APRV
Airway pressure high
MV high
100
40
0.31
28
11.6

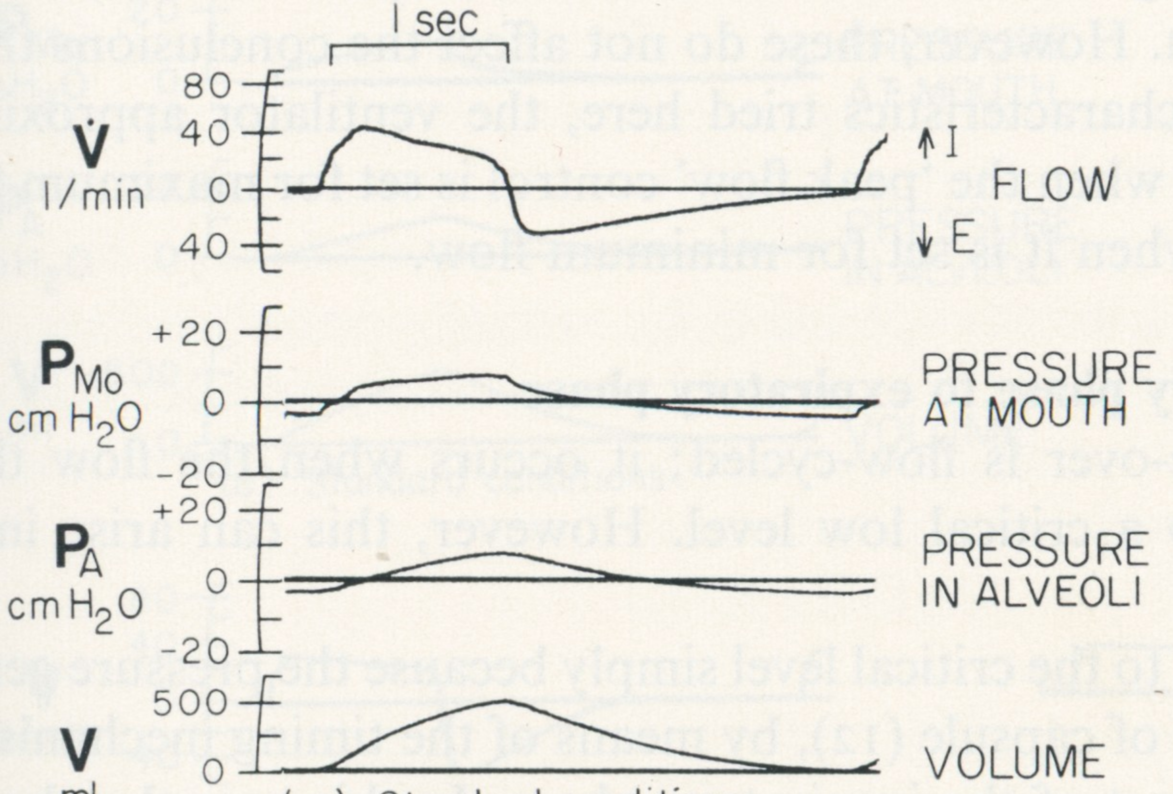

C-APRV
100
23
0.18
37
5.9

Macro vs Micro Ventilation



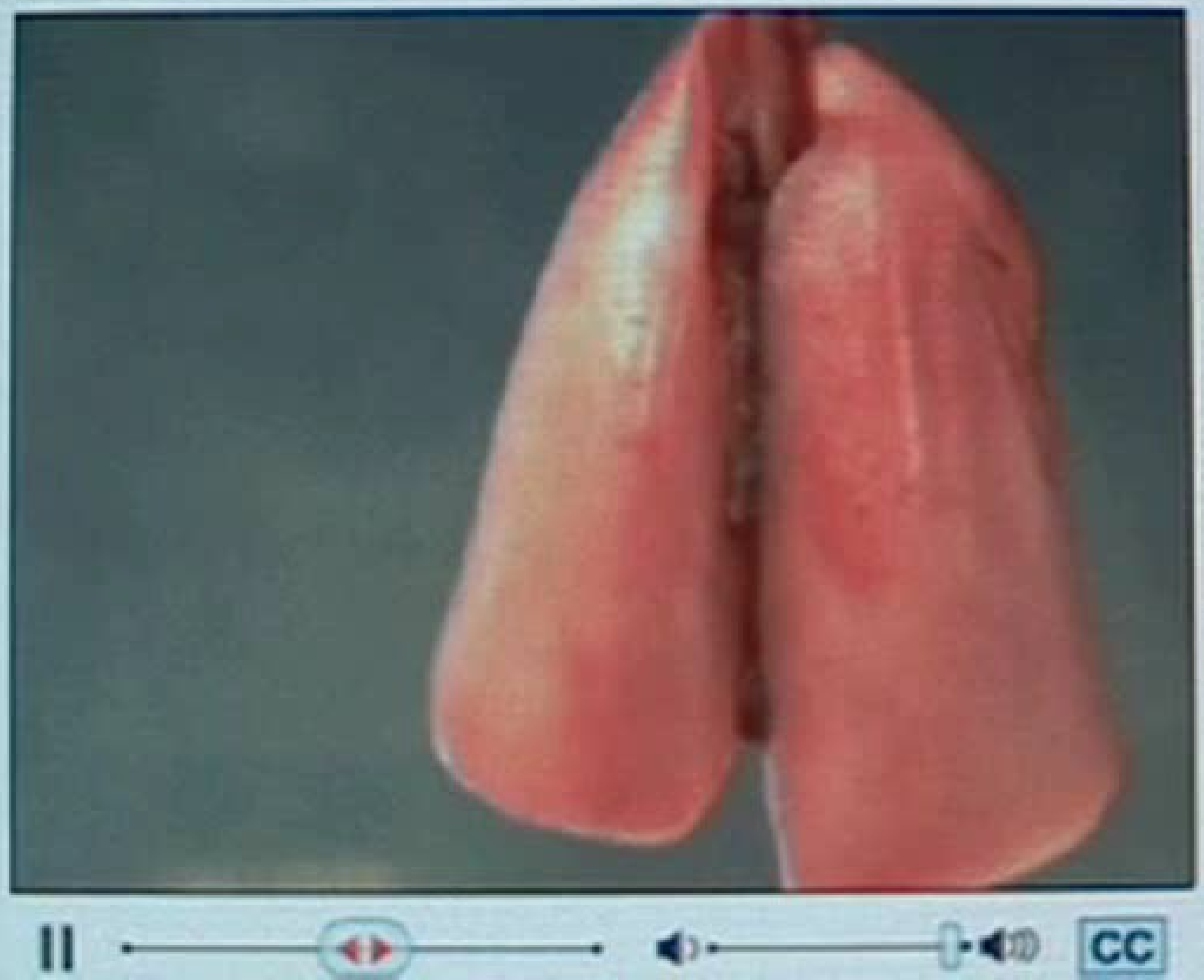
Normal Alveolar M-Strain

Abnormal Alveolar M-Strain



(a) Standard conditions

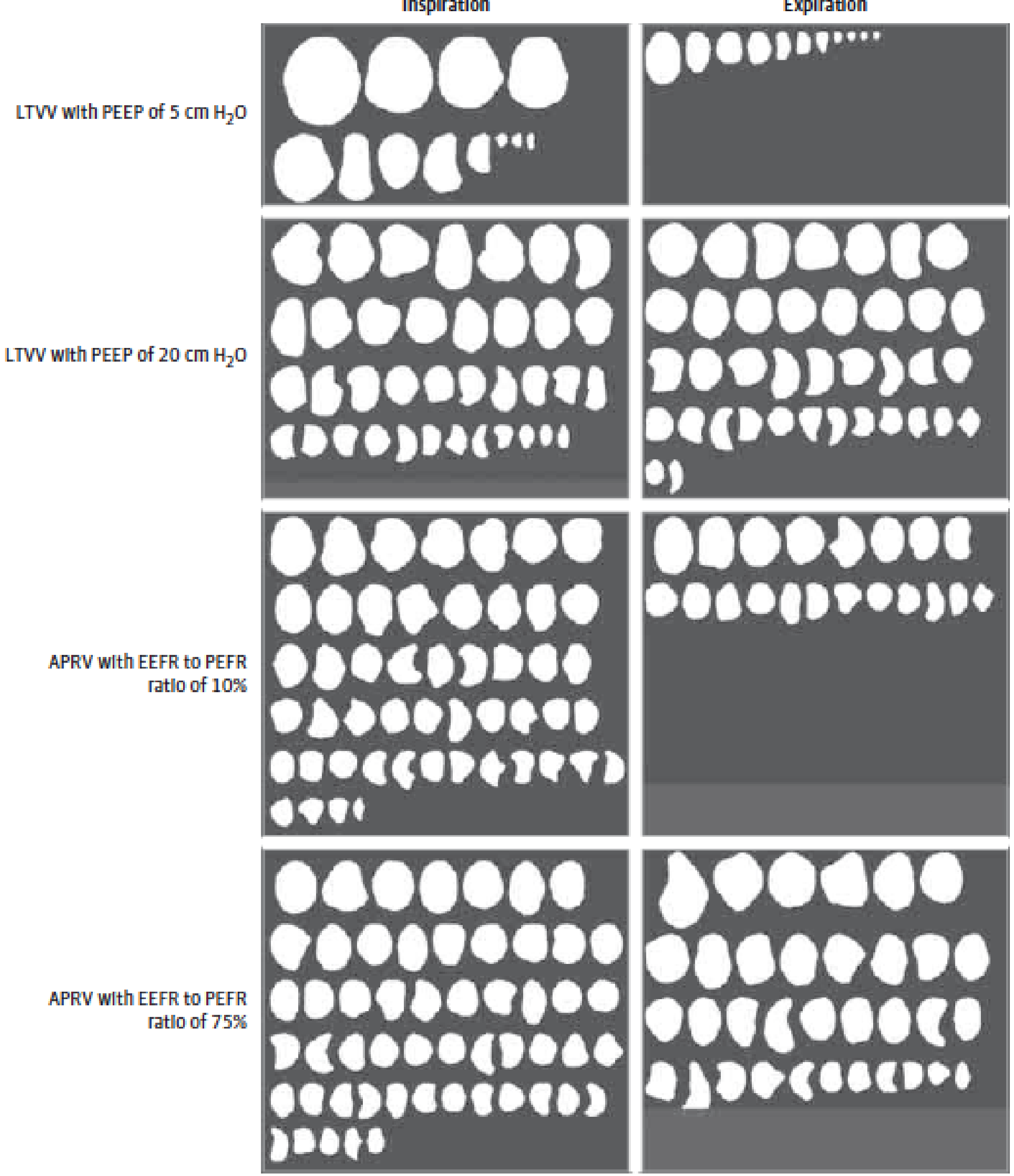
VIDEO CLIP



Effect of Airway Pressure Release Ventilation on Dynamic Alveolar Heterogeneity

Michaela Kollisch-Singule, MD; Sumeet Jain, MD, MBA; Penny Andrews, RN; Bradford J. Smith, PhD; Katharine L. Hamlington-Smith, PhD; Shreyas Roy, MD; David DiStefano, BS; Emily Nuss, BS; Josh Satalin, BS; Qinghe Meng, MD; William Marx, DO; Jason H. T. Bates, PhD; Louis A. Gatto, PhD; Gary F. Nieman, BA; Nader M. Habashi, MD

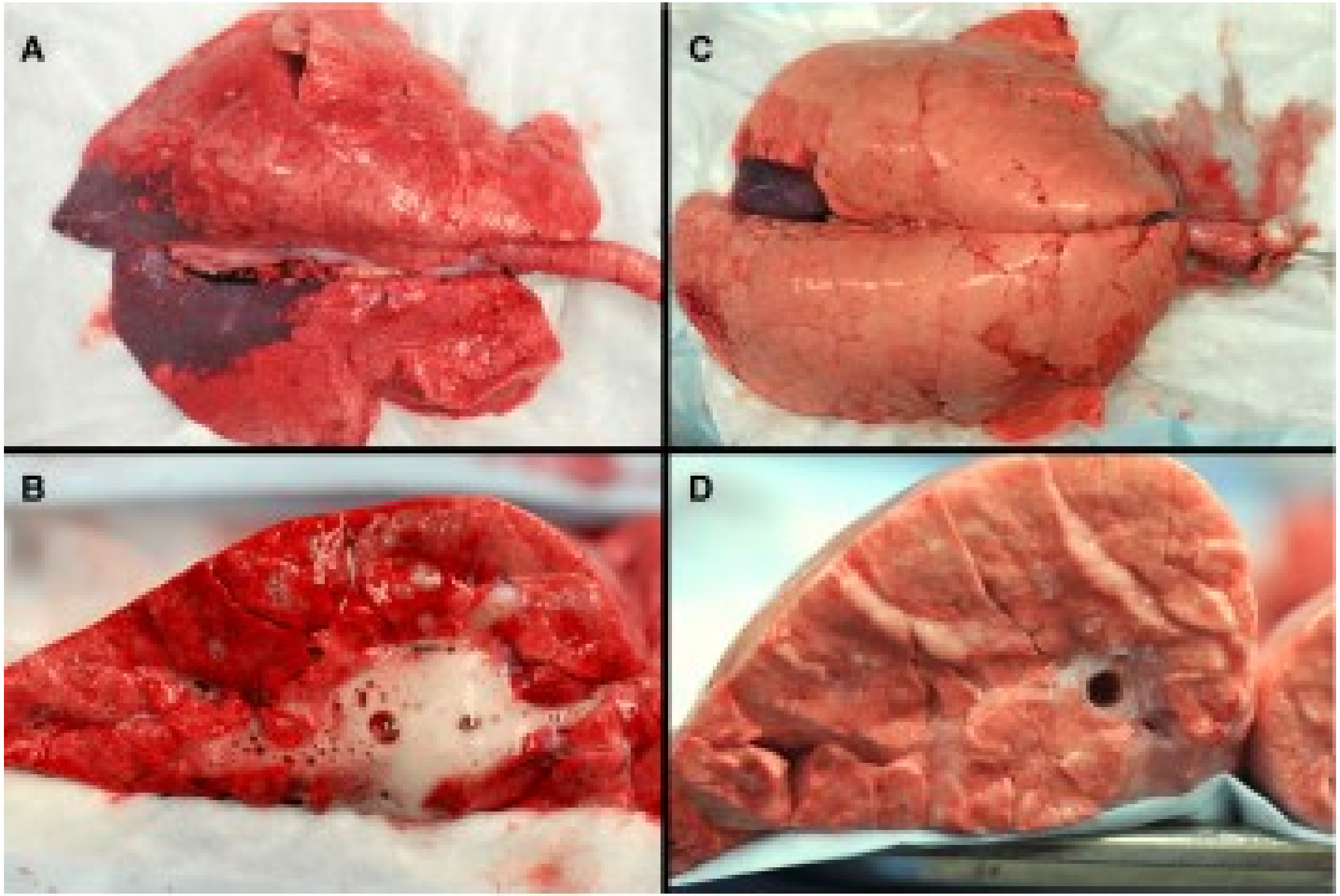
JAMA Surg. doi:10.1001/jamasurg.2015.2683
Published online October 7, 2015.



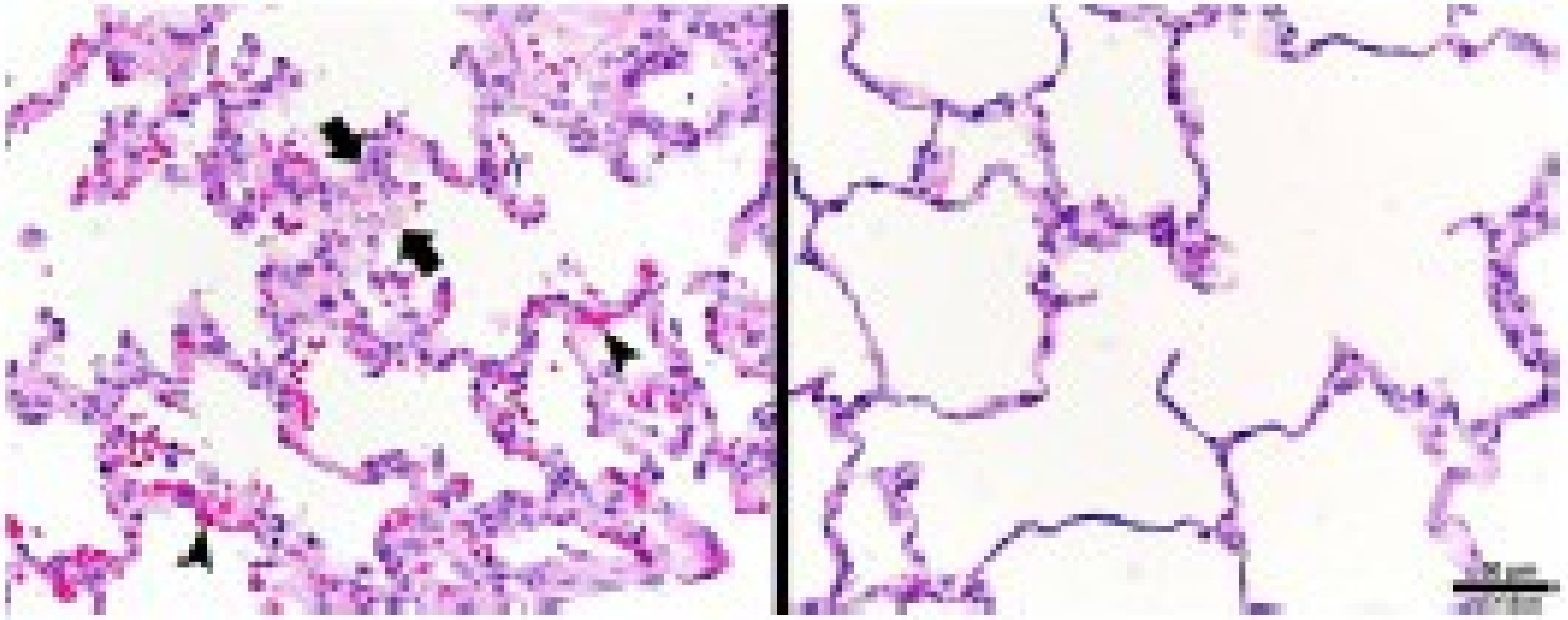
Inspiration
Expiration
LTVV with PEEP of 5 cm H_2O
LTVV with PEEP of 20 cm H_2O
APRV with EEFR to PEFR ratio of 10%
APRV with EEFR to PEFR ratio of 75%

The effects of airway pressure release ventilation on respiratory mechanics in extrapulmonary lung injury

Michaela Kollisch-Singule[1], Bryanna Emr[1], Sumeet V. Jain[1], Penny Andrews[2], Joshua Satalin[1*], Jiao Liu[1], Elizabeth Porcellio[1], Van Kenyon[1], Guirong Wang[1], William Marx[1], Louis A. Gatto[1,3], Gary F. Nieman[1] and Nader M. Habashi[2]



LTV APRV

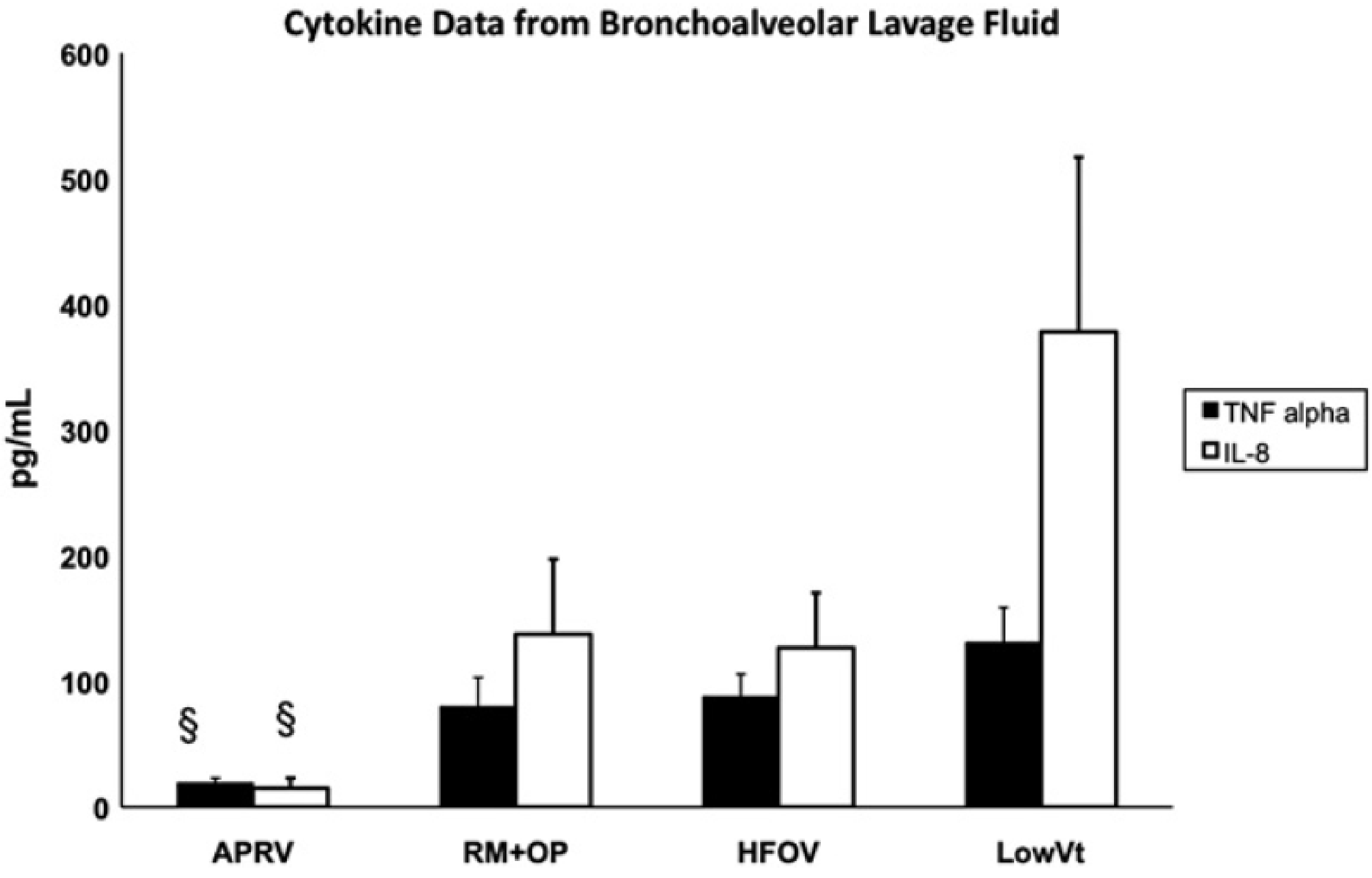


LTV

APRV

Comparison of "Open Lung" Modes with Low Tidal Volumes in a Porcine Lung Injury Model

Scott Albert, M.D.,* Brian D. Kubiak, M.D.,* Christopher J. Vieau, B.A.,* Shreyas K. Roy, M.D.,*,[1]
Joseph DiRocco, M.D.,* Louis A. Gatto, Ph.D.,† Jennifer L. Young, Ph.D.,‡ Sudipta Tripathi, Ph.D.,*
Girish Trikha, M.D.,§ Carlos Lopez, M.D.,|| and Gary F. Nieman, B.A.*


Cytokine Data from Bronchoalveolar Lavage Fluid
600
500
400
300
200
100
0
pg/mL
§
§
APRV
RM+OP
HFOV
LowVt
TNF alpha
IL-8

Preventive

Prior to developing ARDS, most patients receive mechanical ventilation for some period of time.

UPSTATE MEDICAL UNIVERSITY

Established-ARDS: Difficult to Treat

TABLE 1. SELECTED RANDOMIZED CONTROLLED CLINICAL TRIALS IN ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME*

	Year	No. Patients	Intervention	Clinical Outcome Result*
Surfactant trials				
Weg (27)	1994	51	Exosurf—aerosolized	NSD
Anzueto (11)	1996	725	Exosurf—aerosolized	NSD
Gregory (14)	1997	59	Bovine surfactant—endotracheal instillation	NSD
Spragg (13)	2004	448	Protein C surfactant—endotracheal instillation	NSD
Kesecioglu (12)	2009	418	HL 10 surfactant—endotracheal instillation	NSD
Spragg (1)	2011	843	Protein C surfactant—endotracheal instillation	NSD
Other trials				
Zapol (18)	1979	90	ECMO	NSD
Amato (2)	1998	53	Lower tidal volume + higher PEEP	Lung-protective approach better
Stewart (28)[†]	1998	120	Lower tidal volume/inspiratory pressure	NSD
Brochard (29)	1998	116	Lower tidal volume/plateau pressure	NSD
Brower (30)	1999	52	Lower tidal volume/plateau pressure	NSD
Abraham (17)	1999	350	Prostaglandin E1	NSD
ARDS Network/Steinberg (31)	2000	234	Ketoconazole	NSD
ARDS Network/Brower (3)	2000	861	Lower tidal volume/plateau pressure	Lower tidal volume better
Gattinoni (32)	2001	304	Prone position	NSD
ARDS Network/Abraham (19)	2002	235	Lisofylline	NSD
Derdak (33)	2002	148	High frequency oscillatory ventilation	NSD
Taylor (16)	2004	385	Inhaled nitric oxide	NSD
ARDS Network/Brower (34)	2004	549	Higher PEEP	NSD
Kacmarek (35)	2006	311	Partial Liquid Ventilation	NSD
Mancebo (36)	2006	136	Prone positioning	NSD
ARDS Network/Steinberg (37)	2006	180	Methylprednisolone for persistent ARDS	NSD
ARDS Network/Wiedemann (38)	2006	1000	Fluid-conservative hemodynamic strategy	NSD[‡]
ARDS Network/Wheeler (39)	2006	1000	Pulmonary artery vs central venous catheter	NSD
Villar (4)	2006	95	Lower tidal volume + higher PEEP	Lung-protective approach better
Meduri (8)	2007	91	Methylprednisolone for early ARDS	Methylprednisolone better
Mercat (40)	2008	767	Higher PEEP	NSD
Meade (41)	2008	983	Higher PEEP	NSD
Taccone (42)	2009	342	Prone positioning	NSD
Peek (9)	2010	180	Transfer to ECMO-capable center	Transfer better
Papazian (10)	2010	340	Neuromuscular blockade	Neuromuscular blockade better

Definition of abbreviations: ALI = acute lung injury; ARDS = acute respiratory distress syndrome; ECMO = extracorporeal membrane oxygenation; NSD = not significantly different PEEP = positive end-expiratory pressure.

Included trials enrolled at least 50 patients. Some trials with more than 50 patients were not included because they were pilot studies for subsequent trials.

* Results of primary outcome variable analysis.

† Patients at risk for ALI.

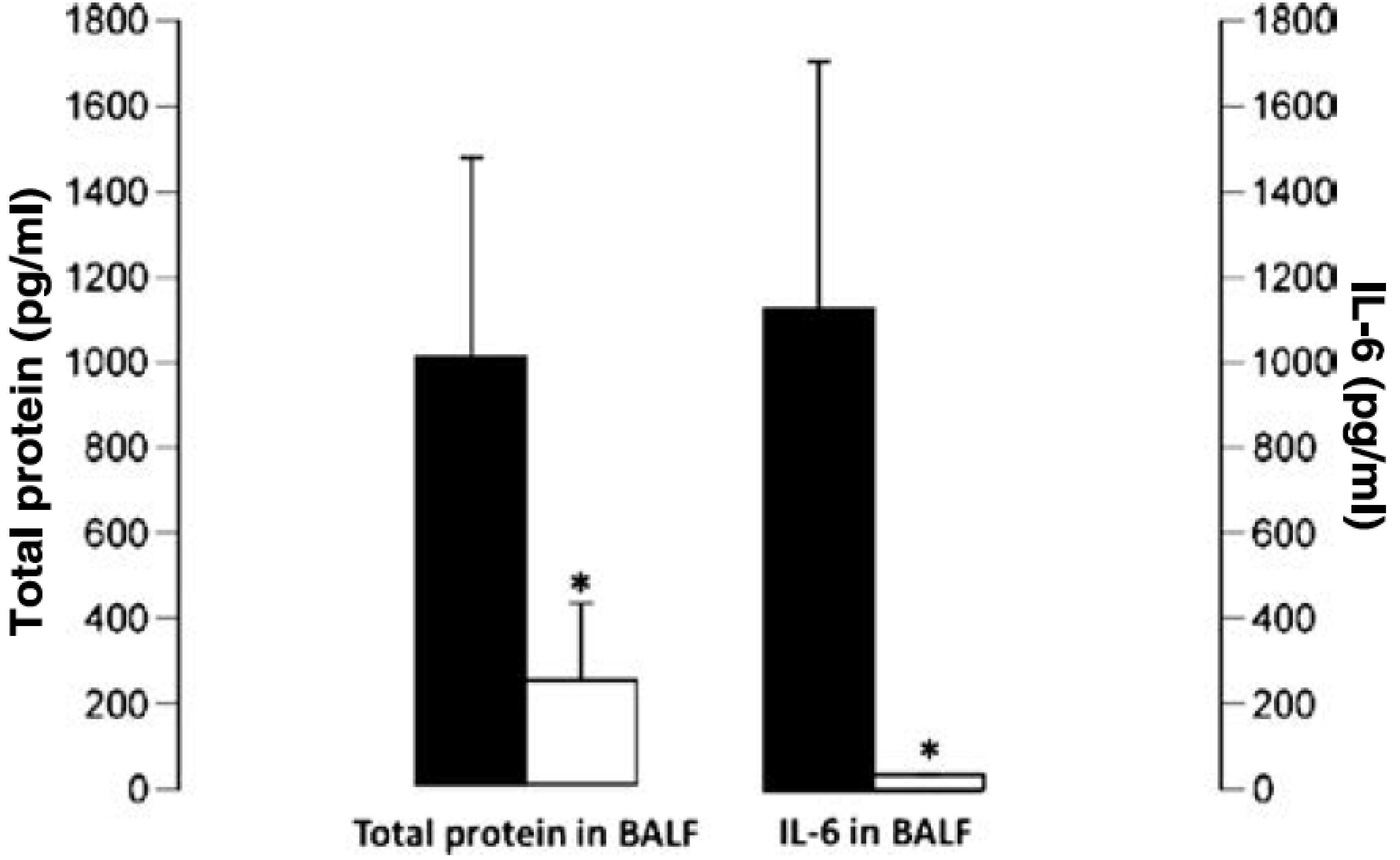
‡ Ventilator-free days (secondary outcome variable) was significantly greater in the fluid-conservative group.

Brower RG, *Am J Resp Crit Care Med*, 2011

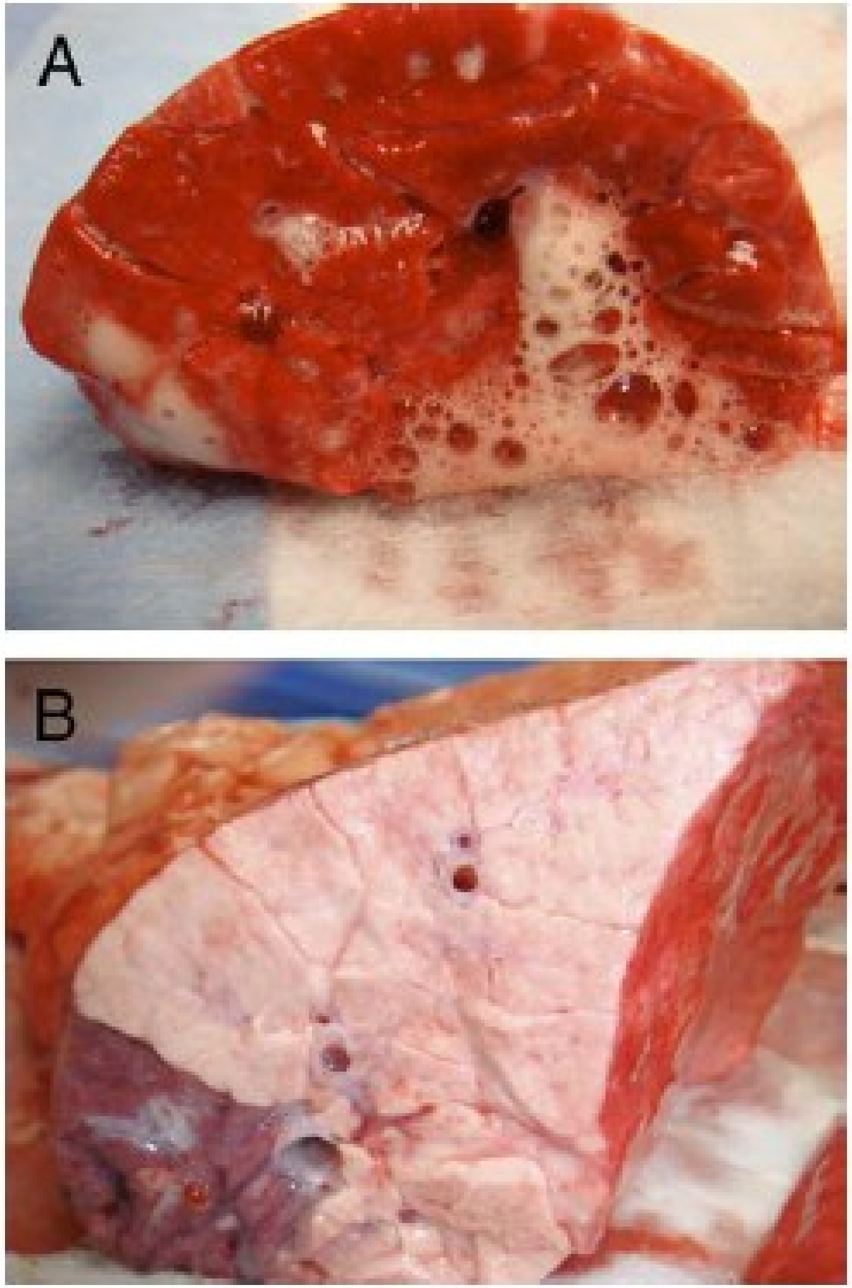
EAST 2012 PLENARY PAPER

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*

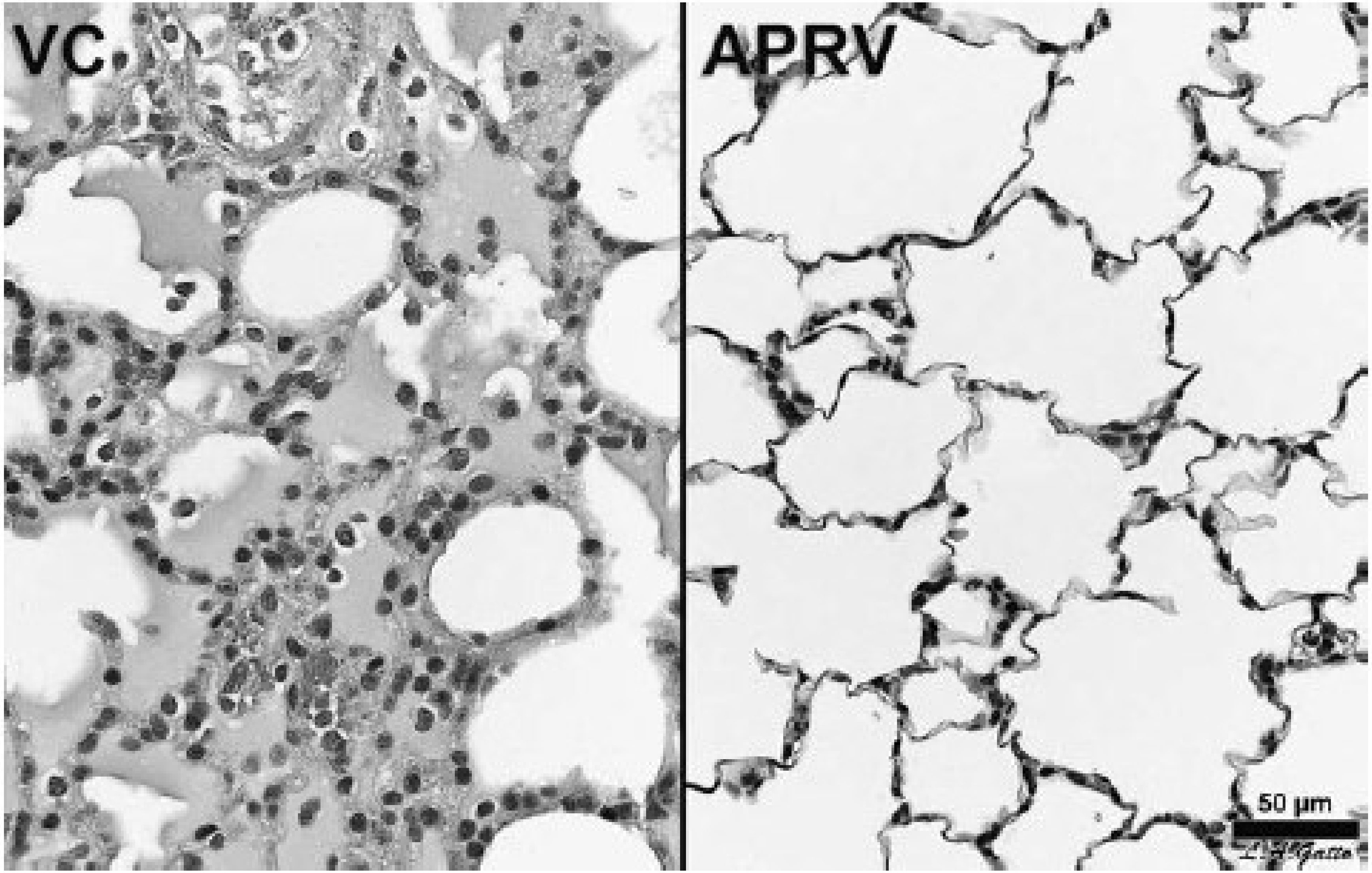


Total protein (pg/ml)
1800
1600
1400
1200
1000
800
600
400
200
0
*
*
Total protein in BALF
IL-6 in BALF
IL-6 (pg/ml)


A
B

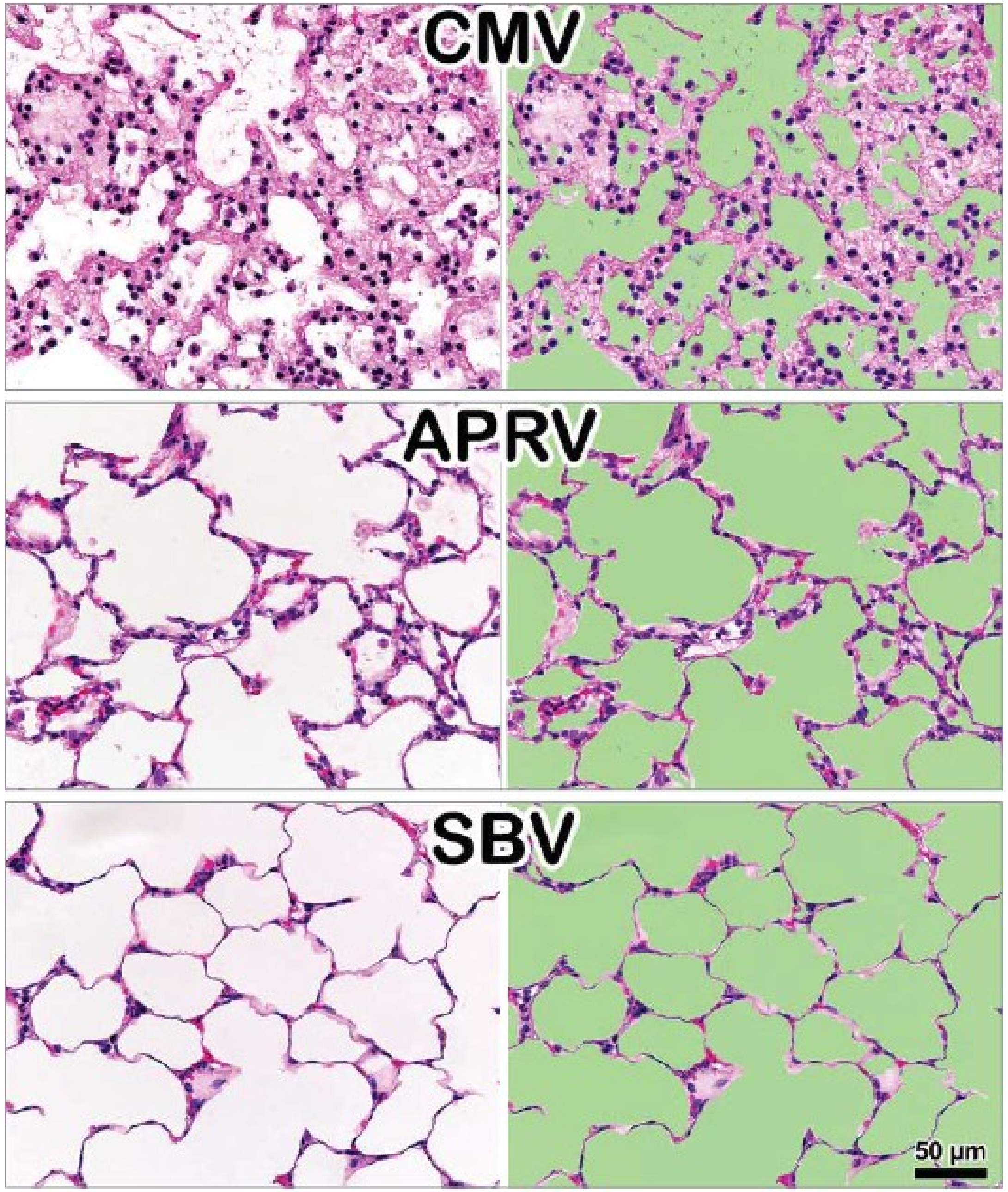
PREEMPTIVE APPLICATION OF AIRWAY PRESSURE RELEASE VENTILATION PREVENTS DEVELOPMENT OF ACUTE RESPIRATORY DISTRESS SYNDROME IN A RAT TRAUMATIC HEMORRHAGIC SHOCK MODEL

Shreyas K. Roy,* Bryanna Emr,* Benjamin Sadowitz,* Louis A. Gatto,*† Auyon Ghosh,* Joshua M. Satalin,* Kathy P. Snyder,* Lin Ge,* Guirong Wang,* William Marx,‡ David Dean,§ Penny Andrews,‖ Anil Singh,* Thomas Scalea,‖ Nader Habashi,‖ and Gary F. Nieman*


VC
APRV
50 µm

Airway Pressure Release Ventilation Prevents Ventilator-Induced Lung Injury in Normal Lungs

Bryanna Emr, MD; Louis A. Gatto, PhD; Shreyas Roy, MD; Joshua Satalin, BS; Auyon Ghosh, BS; Kathy Snyder, BS; Penny Andrews, RN; Nader Habashi, MD; William Marx, DO; Lin Ge, PhD; Guirong Wang, PhD; David A. Dean, PhD; Yoram Vodovotz, PhD; Gary Nieman, BA


CMV
APRV
SBV
50 μm

ORIGINAL ARTICLE

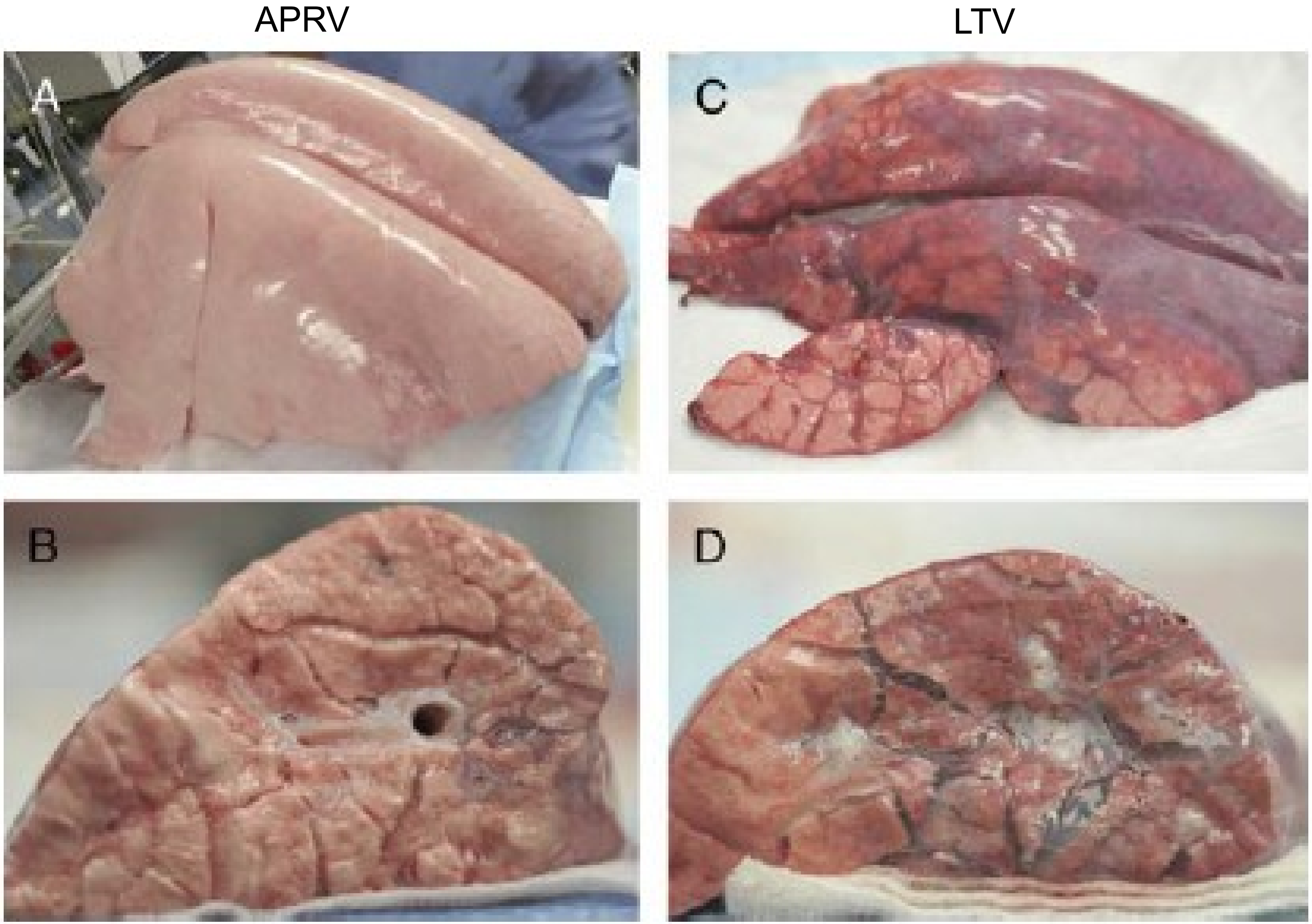
Early application of airway pressure release ventilation may reduce mortality in high-risk trauma patients: A systematic review of observational trauma ARDS literature

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*

SHOCK, Vol. 39, No. 1, pp. 28–38, 2013

EARLY AIRWAY PRESSURE RELEASE VENTILATION PREVENTS ARDS—A NOVEL PREVENTIVE APPROACH TO LUNG INJURY

Shreyas Roy,* Nader Habashi,† Benjamin Sadowitz,* Penny Andrews,† Lin Ge,* Guirong Wang,* Preyas Roy,‡ Auyon Ghosh,* Michael Kuhn,§ Joshua Satalin,* Louis A. Gatto,‖ Xin Lin,¶ David A. Dean,¶ Yoram Vodovotz,** and Gary Nieman*


APRV
LTV
A
B
C
D