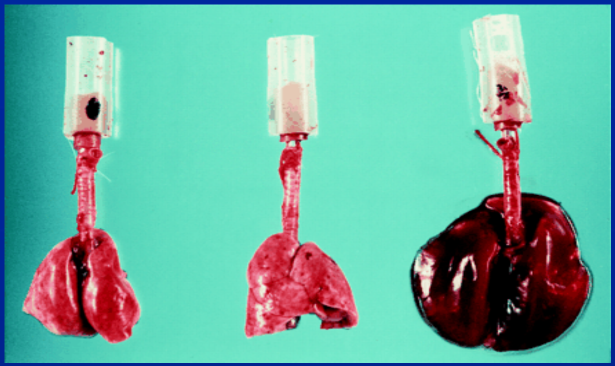
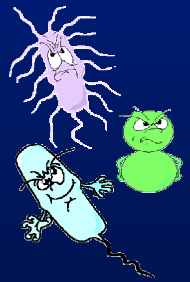


Mechanical Ventilation



Jeffrey L. Johnson, MD
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Assistant Professor of Surgery, UCHSC

Denver Health Medical Center Department of Surgery and the University Of Colorado Health Sciences Center

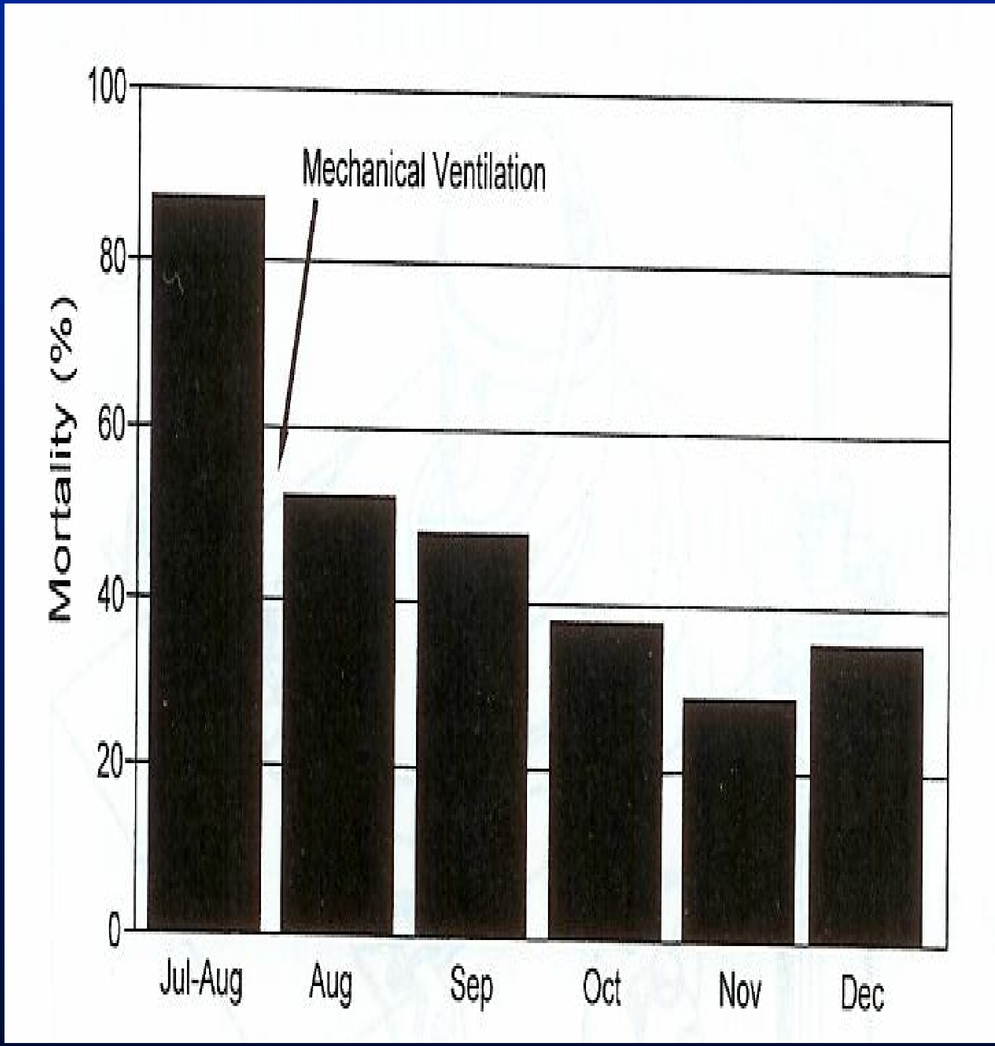
Overview

- Who needs mechanical ventilation?
- What kind should I use?
- How do I protect the lungs from the ventilator?
- Hypoxic events: Initial management
- When and how do I "wean" MV?
- For experts: Pronation, HFOV

Who needs mechanical ventilation?

1. **Inadequate ventilation (hypercapnic pulmonary failure)**
2. **Failure of oxygenation (hypoxic pulmonary failure)**
3. **Inability to maintain airway**
4. **Inadequate respiratory drive**

Mechanical Ventilation – Amazing Tool!



Ventilation

Elimination of carbon dioxide

$$PaCO_2 = k * \frac{\text{metabolic production}}{\text{alveolar minute ventilation}}$$

Alveolar MV = resp. rate * effective tidal vol.

Effective TV = TV - dead space

Take home message: Ventilatory requirement is dependent on metabolic rate, minute volume and dead space

Oxygenation

- Partial pressure of oxygen in alveolus (P_AO_2) is the driving pressure.
- P_AO_2 = ({***Ambient pressure*** - water vapor}*FiO_2) - P_aCO_2 / RQ
- Hemoglobin is fully saturated 1/3 of the way thru the capillary
- *Take home message*: Mean airway pressure and v/q mismatching are the major determinants of oxygenation

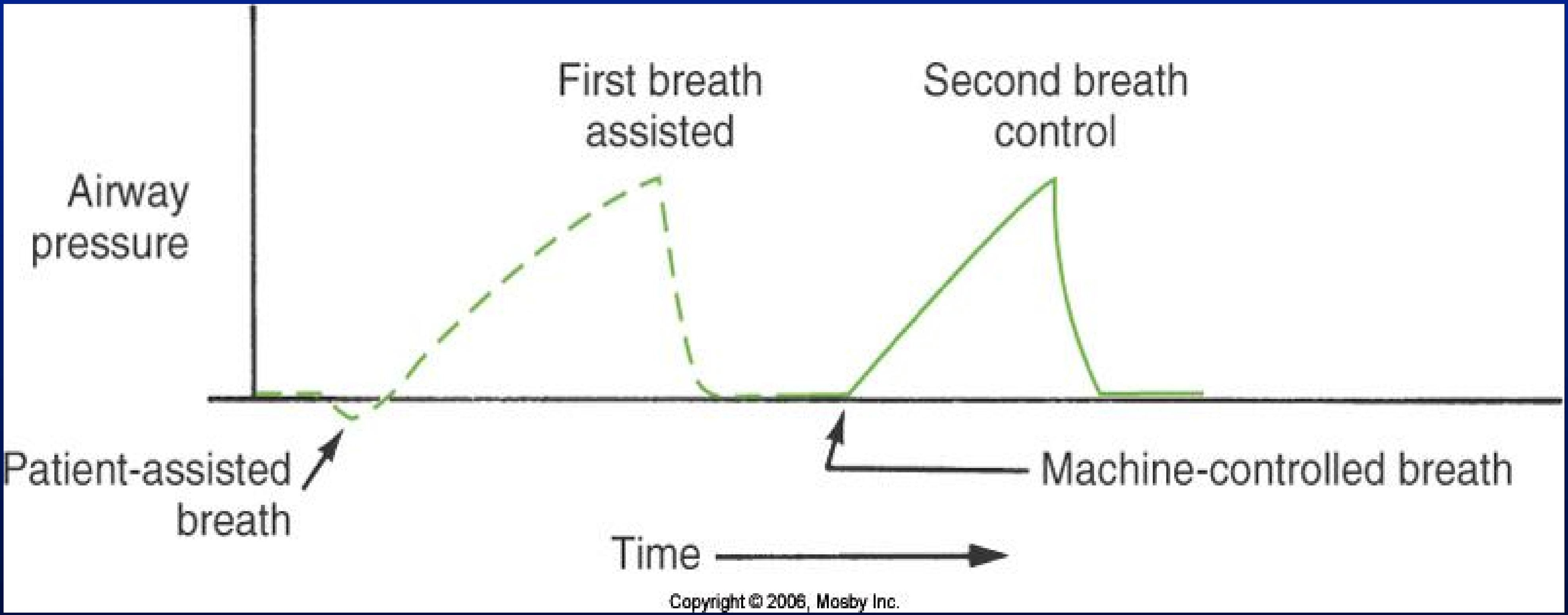
What kinds of MV are there?

- **Nomenclature seems daunting**
- **Classification is actually *simple***
  - **Triggering (by patient or machine)**
  - **Cycling (pressure, time or flow)**
  - **Limits/Controls (pressure, time or flow)**

What kinds are there: Triggering

- Triggering: how ventilator determines initiation of a breath
- Examples:
  - Machine only: CMV
  - Patient only: PSV
  - Both: SIMV, A/C

Triggering: Assist/Control

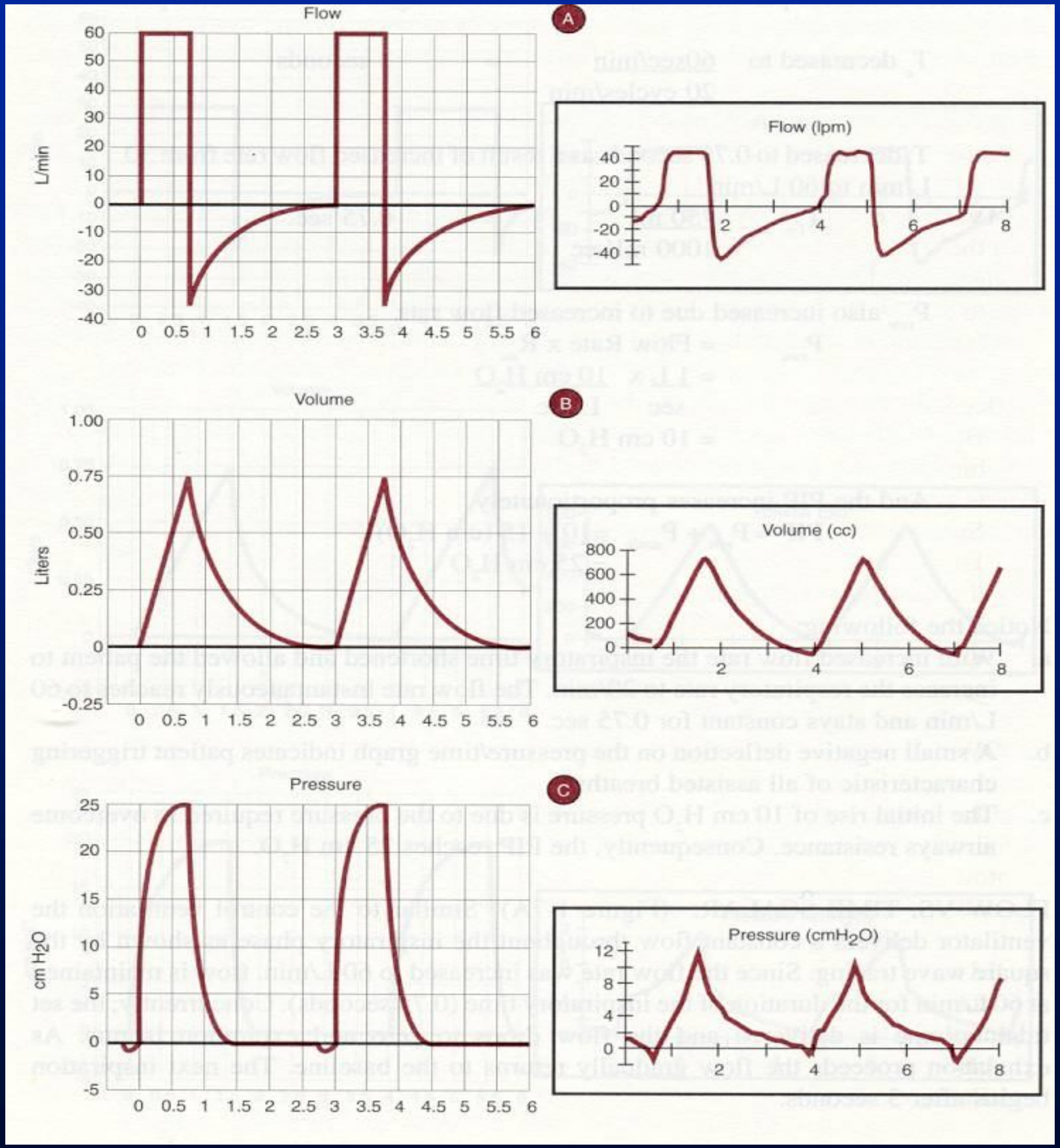


What kinds are there: cycling

- Cycling = switch between inhalation and exhalation
- How cycling can be determined:
  - Volume (assist/control)
  - Flow (PSV)
  - Time (pressure control ventilation)

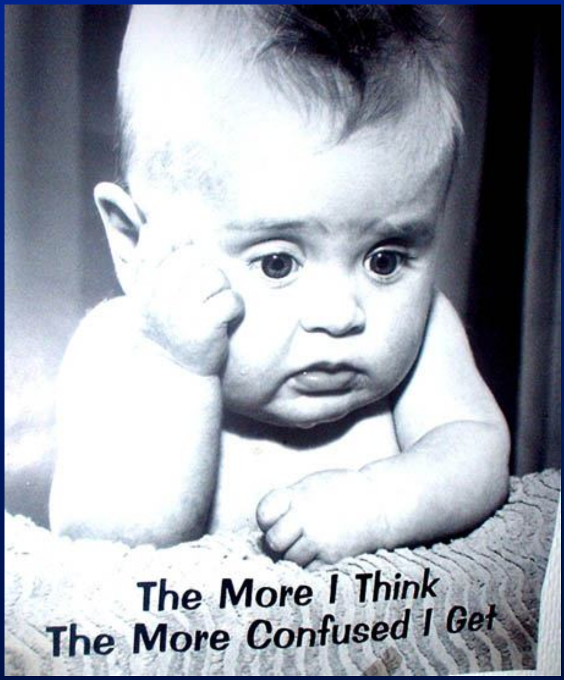
Example: Volume Cycling

A/C: Inspiration is over when a set volume is reached



So, um, *what do I use*?

- Many possible modes of ventilation
- Two potential reasons:
  - They are similarly effective
  - They are similarly *Ineffective*



Keep it simple: Only two kinds of Mechanical Ventilation

– *Full* MV support
  - Inadequate respiratory drive
  - Poor gas exchange
  - Cardiovascular instability
  - Inability to execute work of breathing

– *Partial* support

Recommended Approach

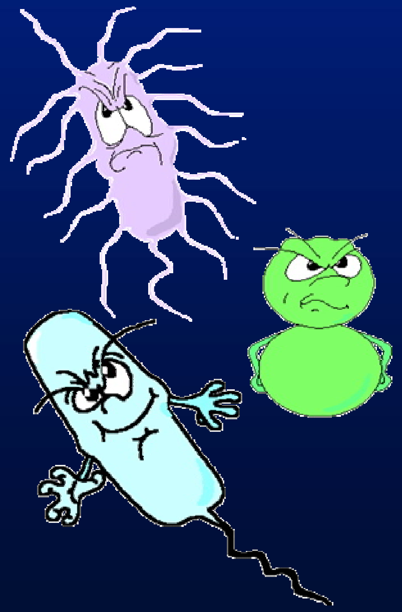
- Initial full support:
  - Goal: ensure adequate ventilation
  - Recommend: Assist-Control
    - Pt & machine triggered
    - Volume cycled – constant volume each breath
    - Flow limited – adjust flow for rate and comfort

Recommended Approach

- Subsequent partial support
  - Goal: exercise without tiring
  - Recommend: PSV
    - Pt triggered – pt determines rate and I:E
    - Flow cycled – pt determines flow rates
    - Pressure limited – adjust PS to respiratory rate
  - Spontaneous breathing trial when criteria met

How do I protect the patient?

- Mechanical ventilation
  - Largely supportive
  - Recovery is independent of the ventilator itself
  - Do no harm
- Avoid:
  - Ventilator induced lung injury (VILI)
  - Nosocomial pneumonia
- Pursue:
  - Protocol-driven care
  - Appropriate sedation



Protecting the Lung

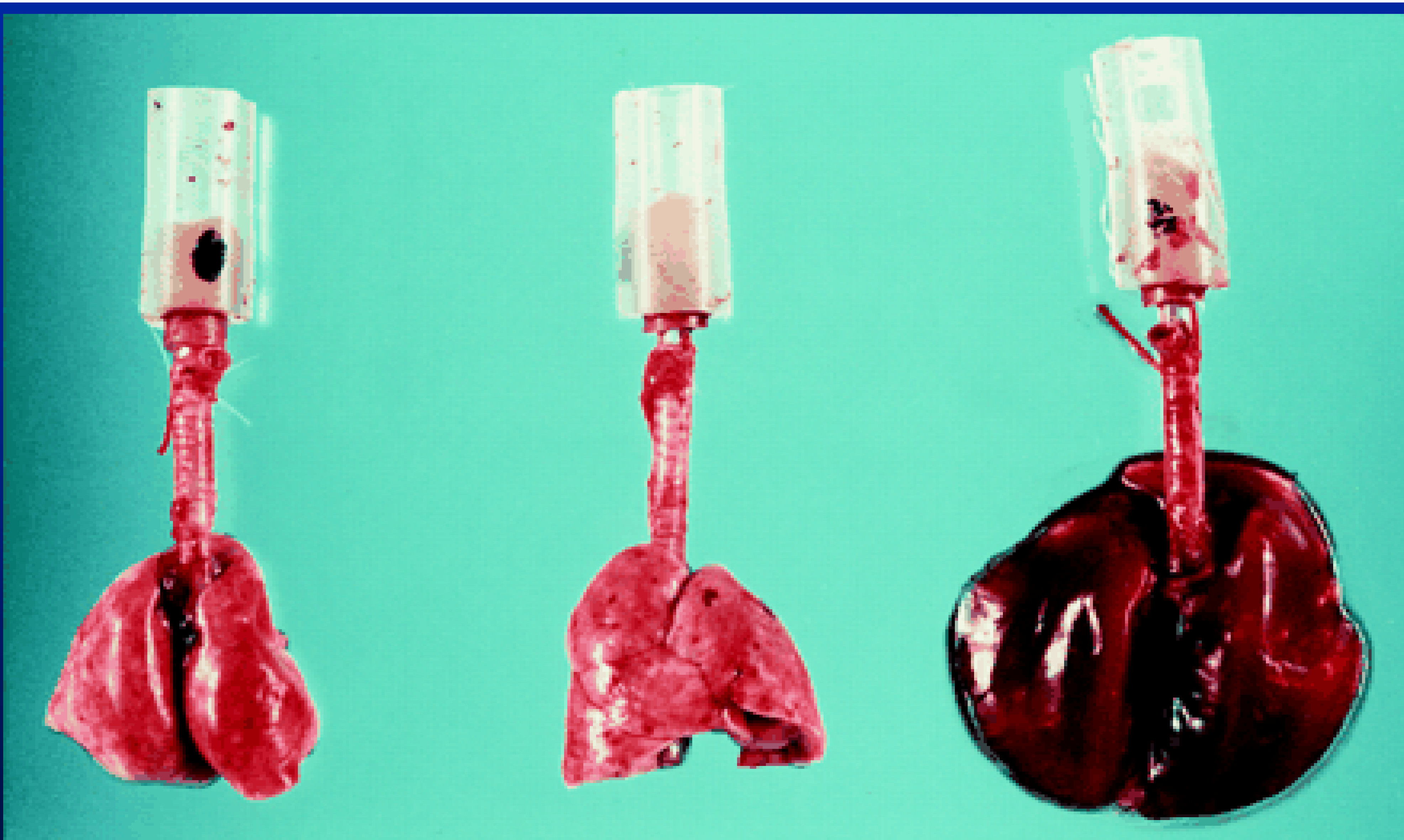
Two types of Ventilator-Induced Injury (VILI)

Barotrauma: too much pressure

Volutrauma:

repetitive opening closing

regional overdistention



Normal Lung | PIP 45 cm H_20 5 Min | PIP 45 cmH_20 20 Min

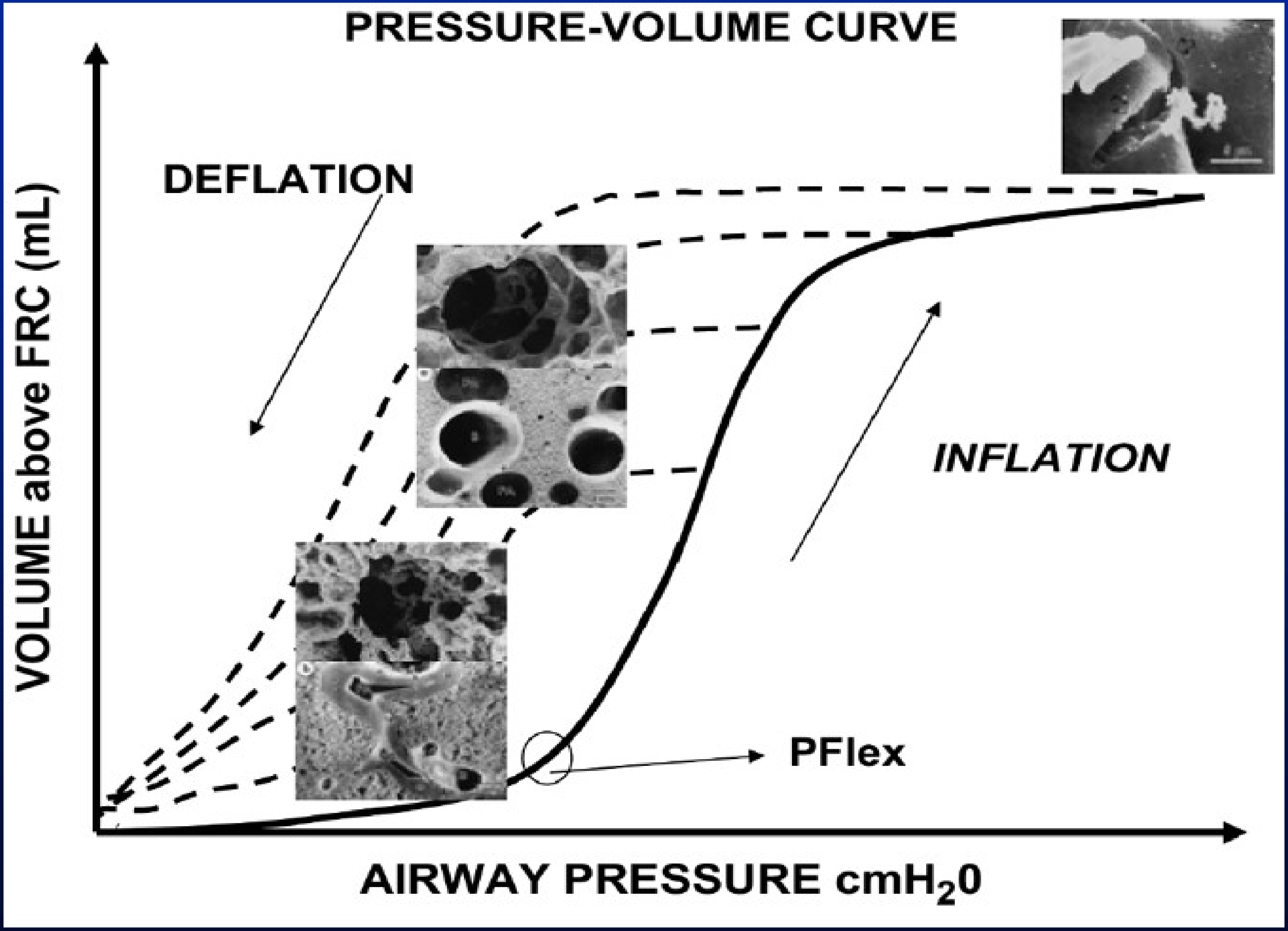
Normal
Lung

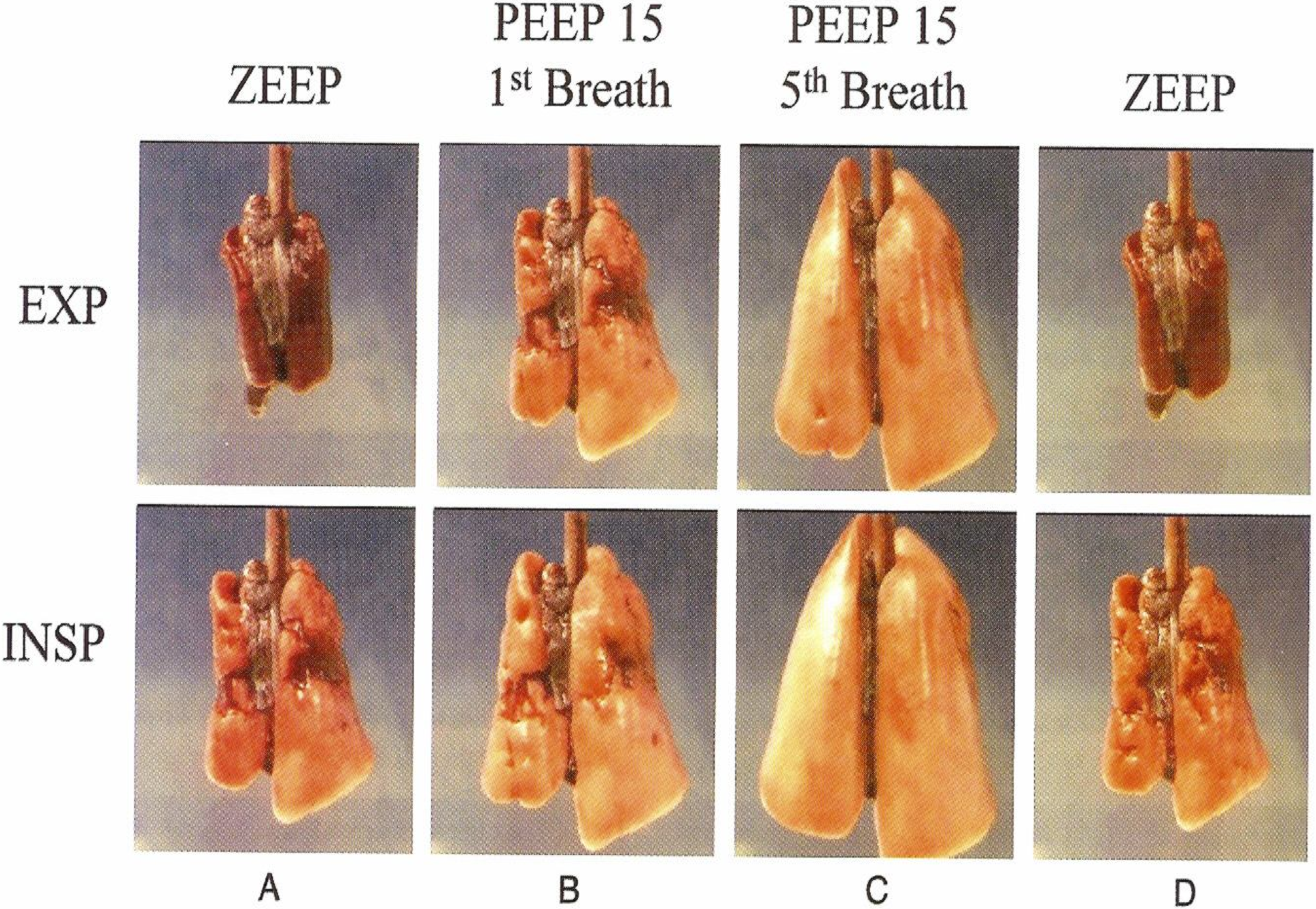
PIP 45 cm H_20
5 Min

PIP 45 cmH_20
20 Min

Dreyfuss Am Rev. Respir Dis 1985

Hysteresis: Inflation vs Deflation

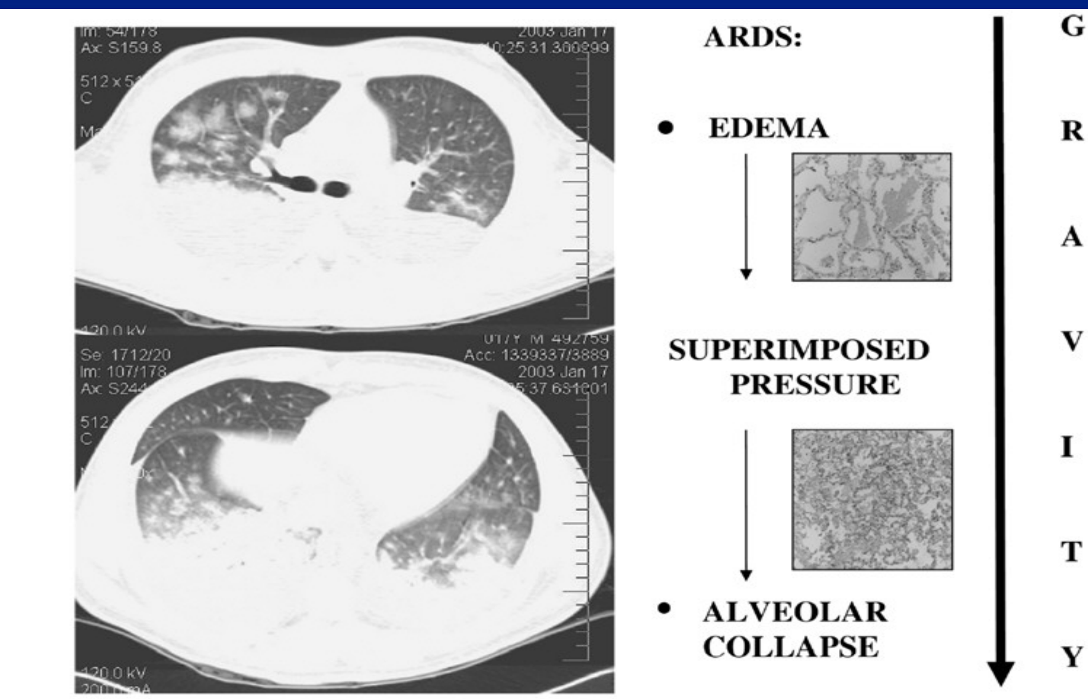


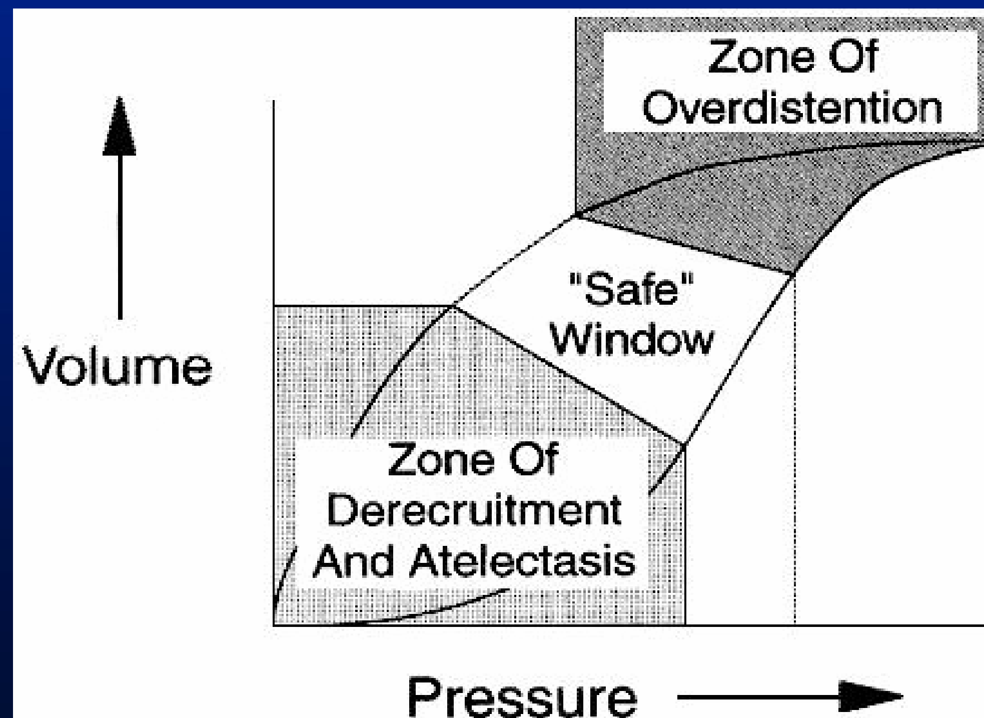

ZEEP
PEEP 15
1st Breath
PEEP 15
5th Breath
ZEEP
EXP
INSP
A
B
C
D

The Acutely Injured Lung (ALI/ARDS)

ARDS lungs
- Normal regions
- Collapsed regions
- Consolidated regions

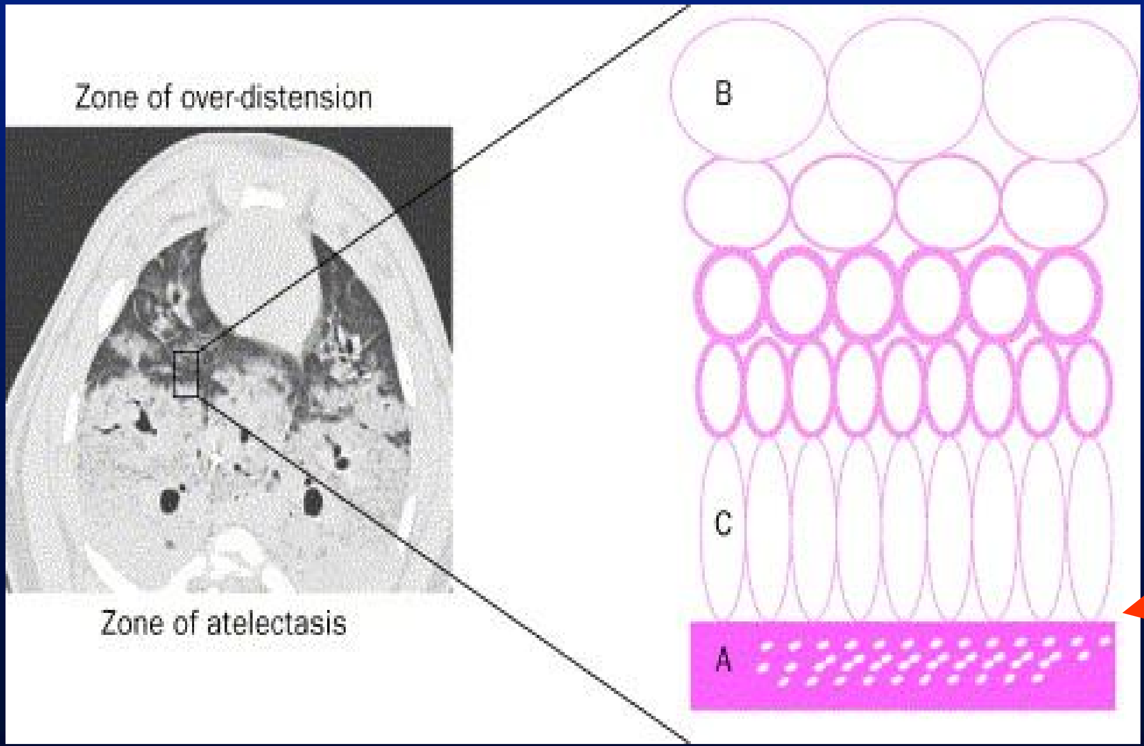
VILI
- Overdistention of alveoli from high tidal volumes
- Repetitive opening/closing of lung units from low tidal volumes





Lung Recruitment: Use as much as you can

Recruitment = "…. A sustained increase in airway Pressure (30 – 90 Sec) with the goal to open collapsed lung Tissue"



Potential pressures of > 140 cm H_20

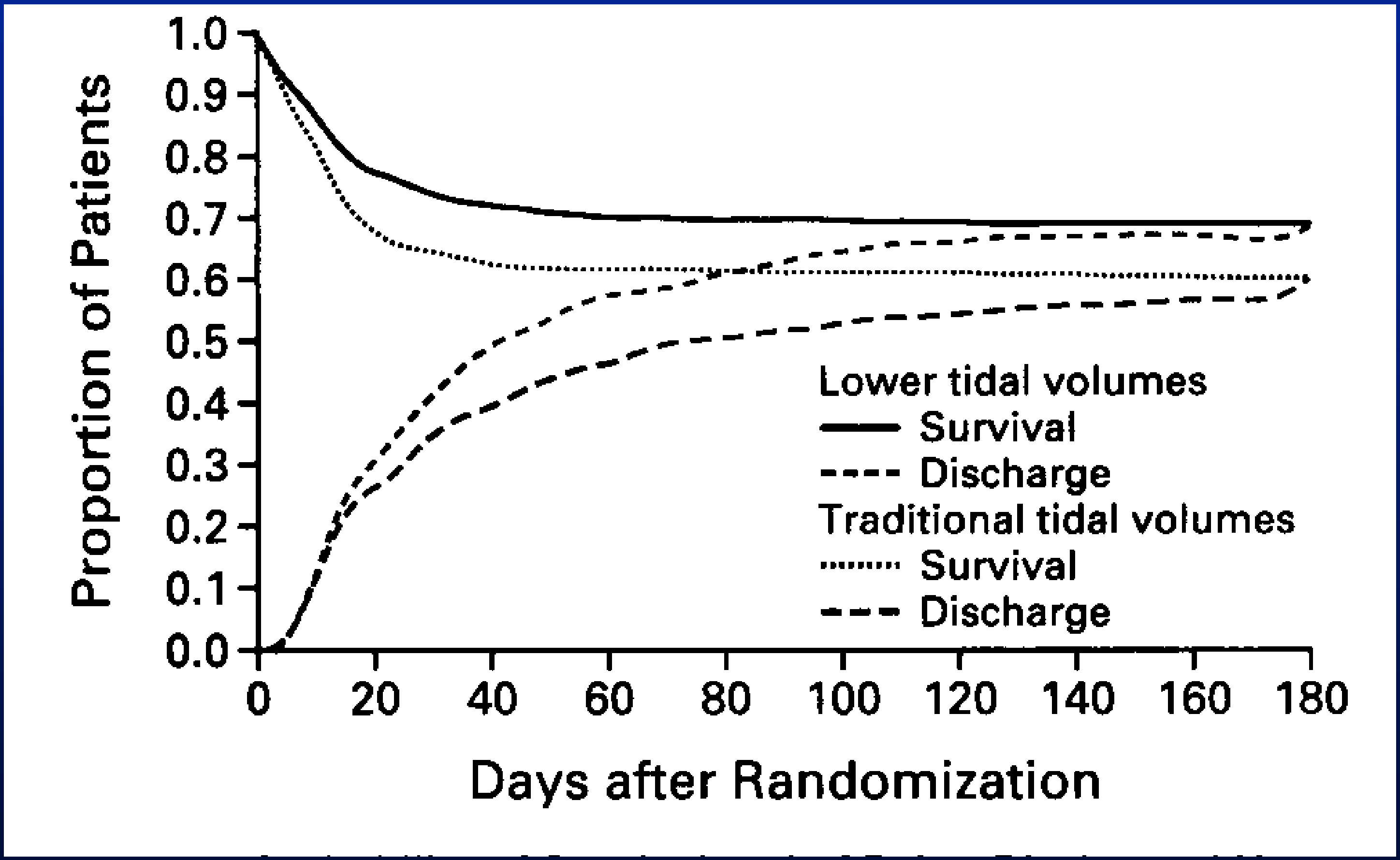
Techniques to Facilitate Lung Recruitment

- Sigh Breaths: 1.5- 2 times the Vt
- Temporary increase in PEEP
- Temporary increase in Tidal Volume
- Temporary use of CPAP
- High Frequency Ventilation
- APRV
- Pronation

Overall Strategy for MV

Ventilatory Parameter	Traditional	Lung-Protective
Inflation Volume	10-15 ml/kg	5-10 ml/kg
End-insp. pressure	Peak Pr<50cm water	Plateau Pr<35
PEEP	PRN to keep FiO_2<0.6	5-15 cm of water
ABG	Normal, pH 7.36-7.44	Hypercapnia allowed, pH 7.2-7.4

Lung Protection Improves Survival



ARDS Network, *N Engl J Med* 2000; 342:1301

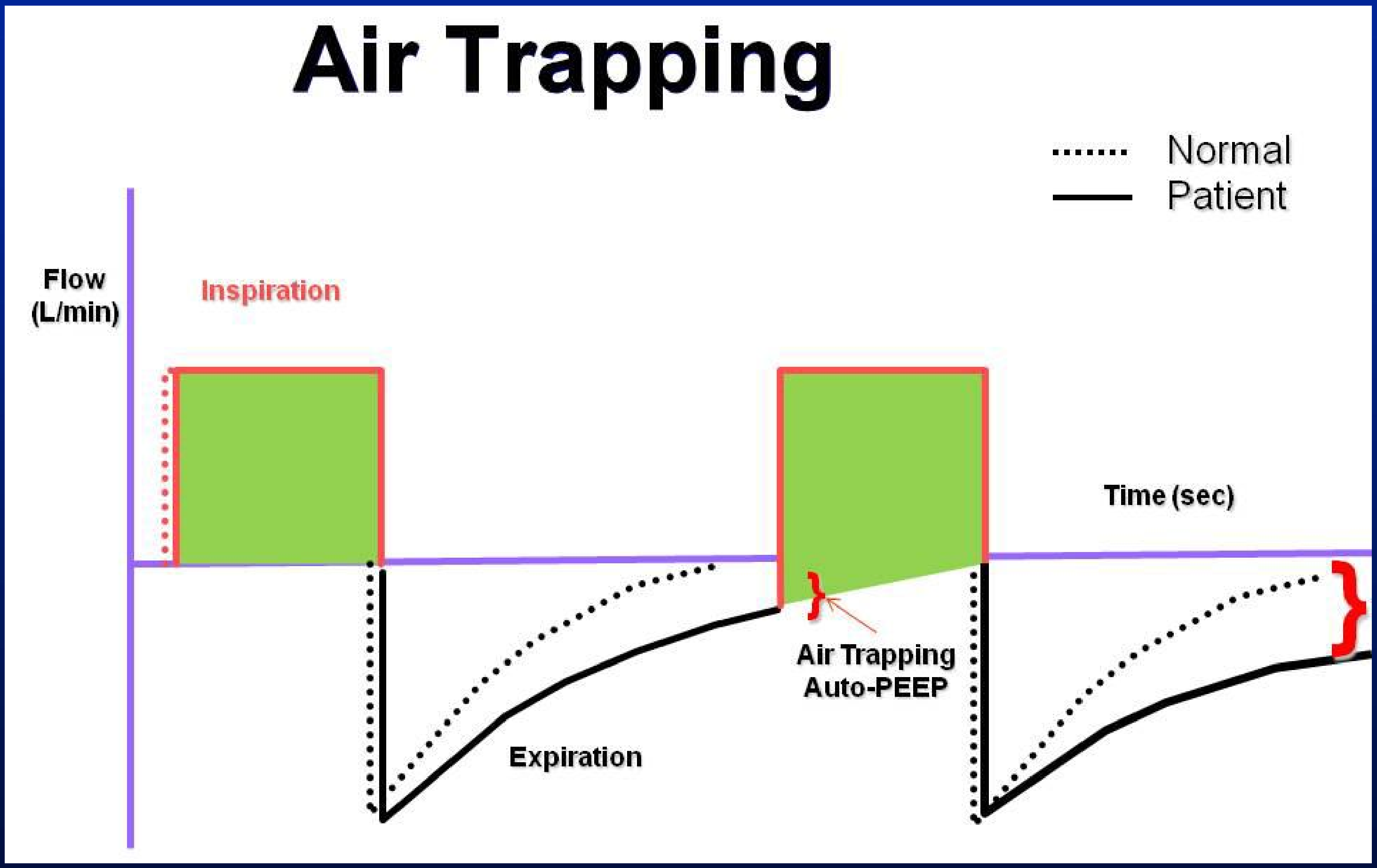
Hypoxic Events

- **Look at the patient !**
- Check Vent: (Peak pressure; volume loops; alarms)
- ABG
- Chest X ray

Hypoxic Events

- Two-thirds of hypoxic events are due to simple mechanical issues
  - ET tube
  - Mucus Plugging
  - Pt/ventilator dysynchrony
- Remaining third:
  - New pulmonary process
  - Progression of underlying ds: e.g. ARDS

Example: Look at the Patient and Vent



Tip: Examine pt sans ventilator

- Disconnect the vent, begin bag ventilation.
- Don’t forget: 100% O2
- High flow: hear the noise
- Eliminates ventilator as source of woe
- Helps gauge
  - Patency of tube
  - Pulmonary compliance
  - Adequacy of sedation

Hypoxic Events – main points

- Exam of the patient, the ventilator and CXR will identify >90% of problems
- Reach for the bag:
  - Part of the exam
  - Eliminates the ventilator as the problem

When and how do I "wean" MV?

- Withdrawal of mechanical ventilatory support
- Principles:
  - Work every day
  - Don't work too hard
  - Kind of work of little importance
    - PSV or CPAP
    - SIMV
    - T-piece

Does My Patient Need the Ventilator?

- Assess continuously
- Most patients should be on partial support during the day
- Should coincide with diminution of sedation
- Contraindications to Partial Vent Support:
  - Inadequate respiratory drive
  - Cardiovascular instability
  - Poor gas exchange
  - ICP requiring treatment
  - Minute volume > 14 lpm

Spontaneous Breathing Trials

- **Minimal Support**
  - **PEEP = 5, PS = 0 – 5, $FiO_2 \leq 50\%$**
  - **Assess for 30 – 120 min**
  - **ABG obtained at end of SBT**
- **Failed SBT Criteria**
  - **RR > 35 for >5 min**
  - **S_aO_2 <90% for >30 sec**
  - **HR > 140**
  - **Systolic BP > 180 or < 90mm Hg**
  - **Cardiac dysrhythmia**
  - **pH < 7.32**

Parameters to Predict Successful Liberation from MV

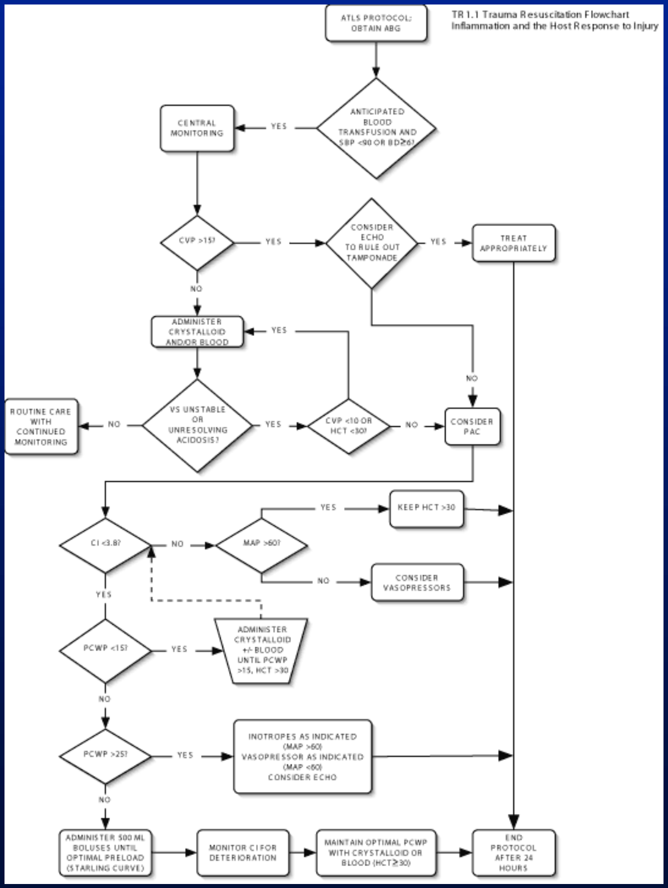
Parameter	Normal Adult range	Threshold
PaO2/FiO2	>400	200
Tidal Volume	5-7ml/kg	5ml/kg
Resp. Rate	14-18/min	<40/min
Minute Ventl.	5-7L/min	<10L/min
Vital capacity	65-75ml/kg	10ml/kg

Parameters to Predict Successful Liberation from MV

Maximal Inspiratory Pressure	>-90 cm Water (F) >-120 cm water (M)	-25cm of water
Rate/Tidal Volume (Rapid, Shallow Breathing Index)	<50/min/L	<105/min/L

Protocol-Driven Care

- Eliminates Variability
- Reduces Complexity
- Improves outcomes
  - ICU stay
  - Ventilator Days
  - Pneumonia
- Saves $$



For Experts

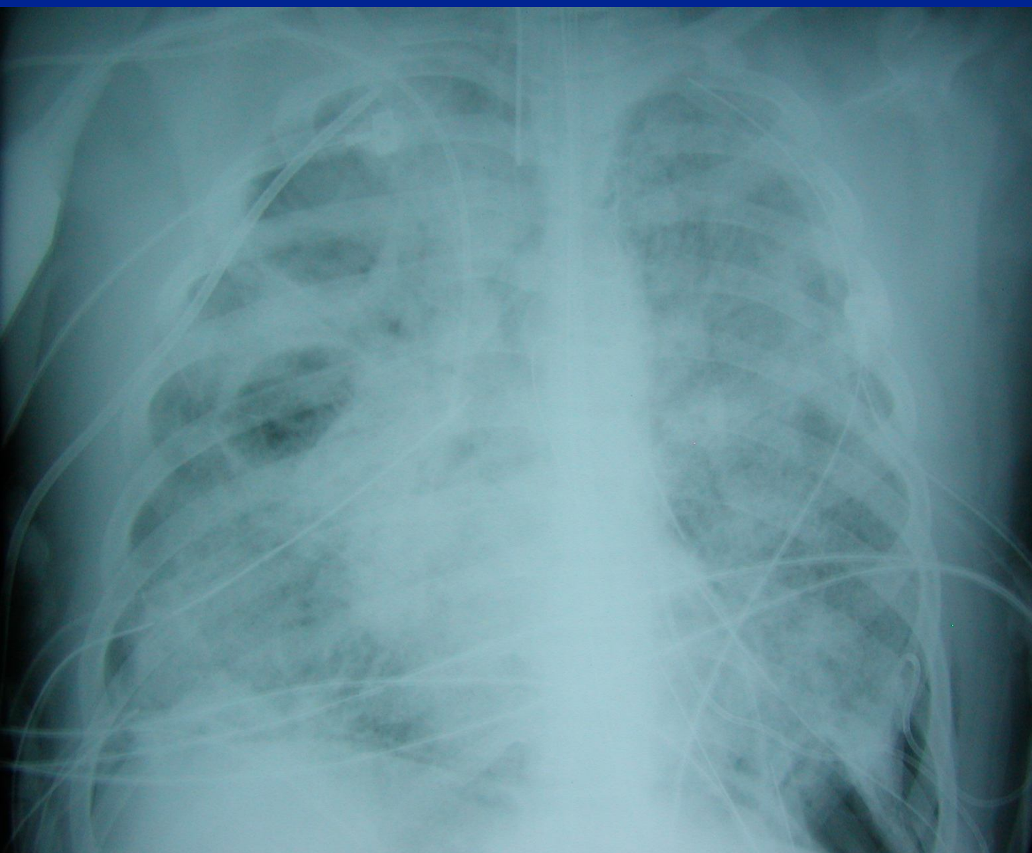
- Corticosteroids for Late ARDS
- Prone ventilation
- HFOV= high frequency oscillatory ventilation
- Noninvasive ventilation

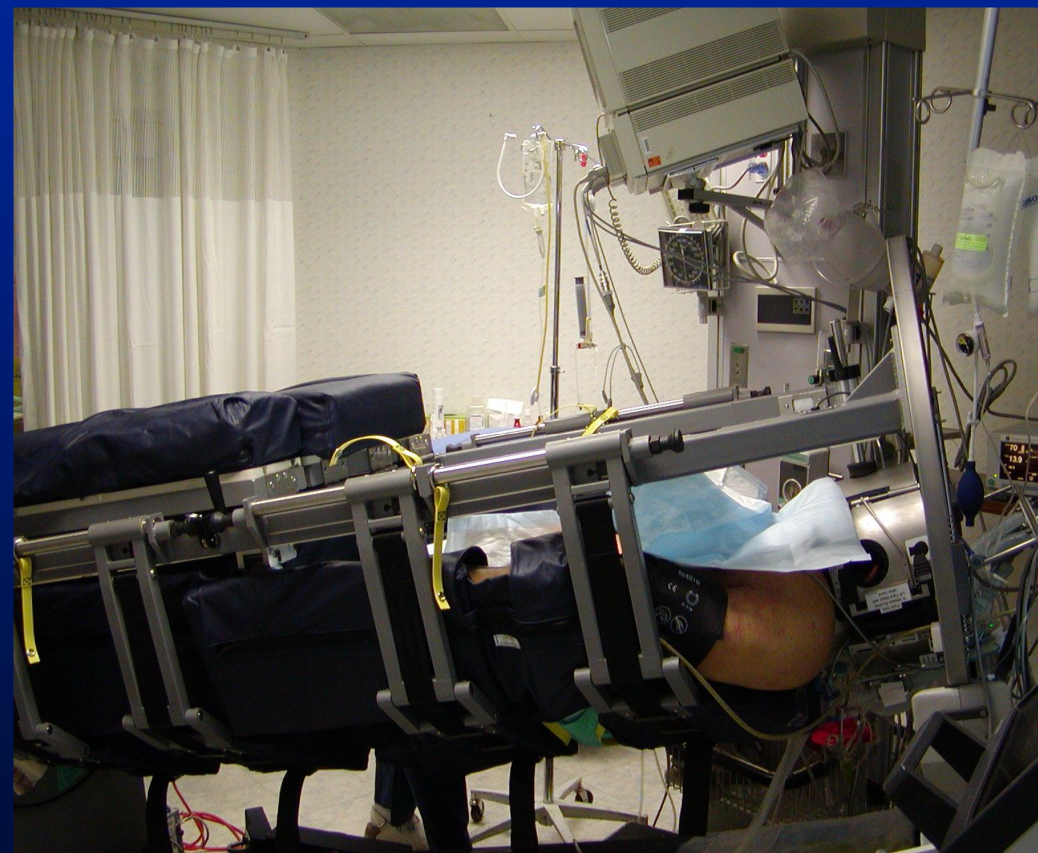
Steroids: The LaSRS Trial

- 180 Pts with ARDS of at least 7 days duration
- Randomized to Methylprednisolone vs Placebo
- Results:
  - No overall mortality benefit at 60 days
  - Pts started >2 weeks after ARDS dx may have had increased risk of death

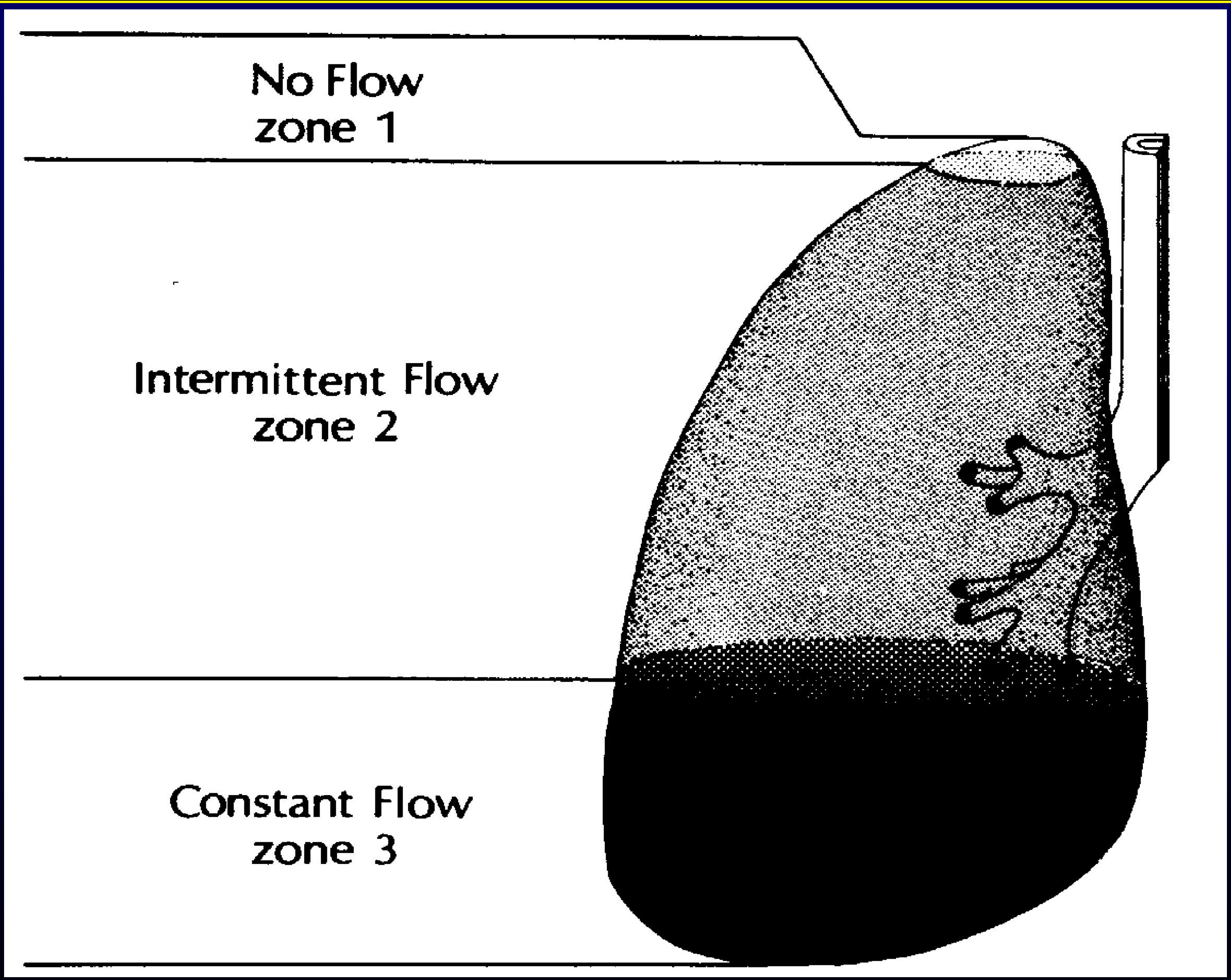
NEJM 354(16): 1671-84, 2006

Should we be Pronating Patients?

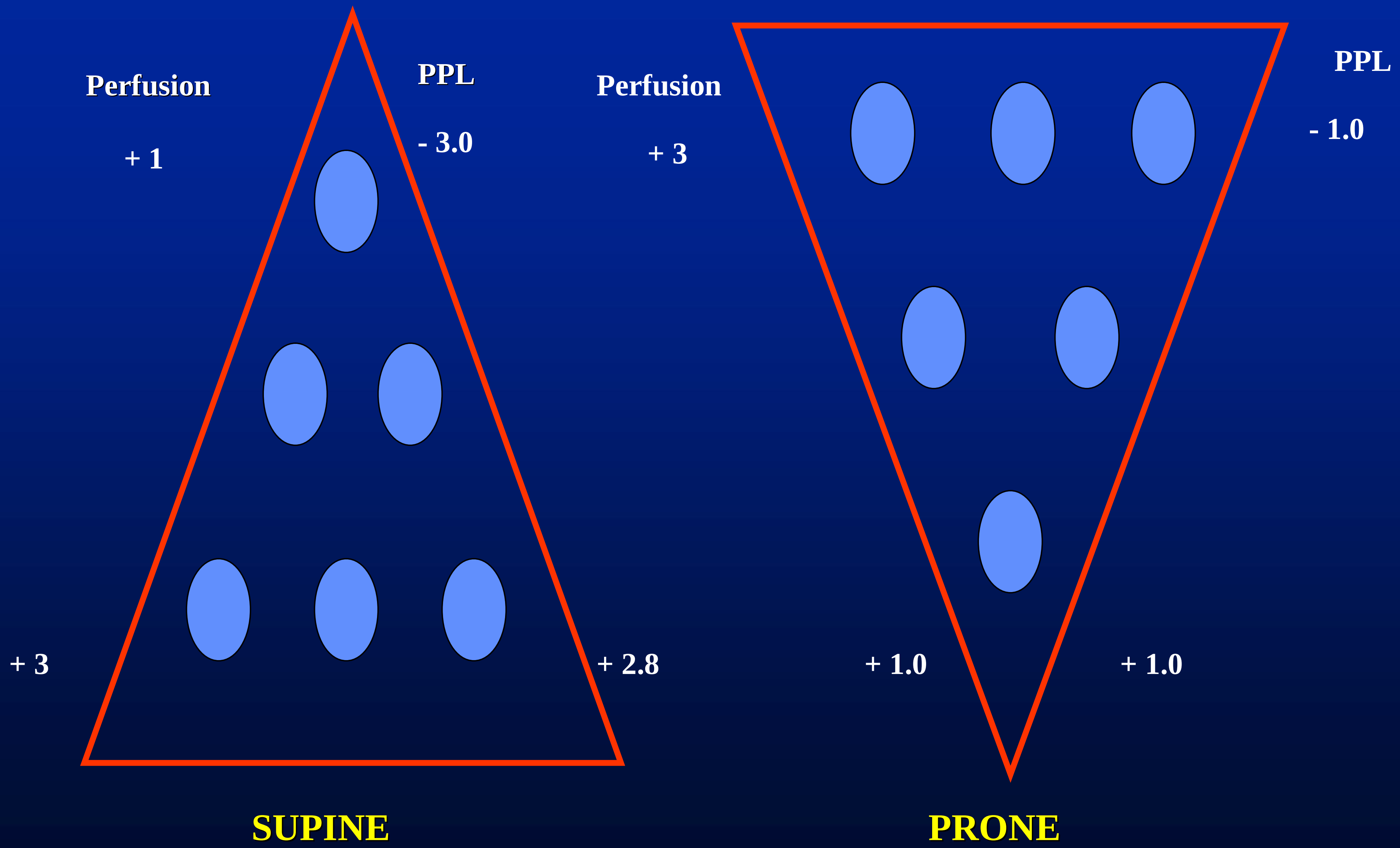




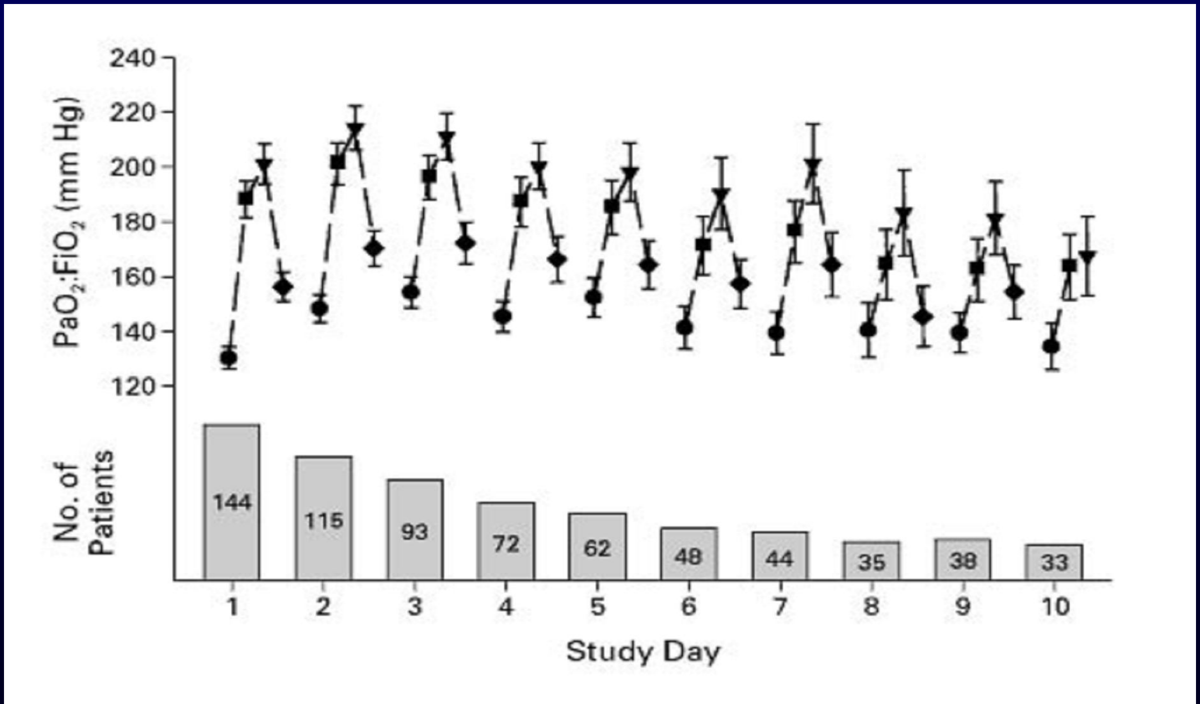
Normal Distribution of Pulmonary Perfusion in the Standing Human
Note the Profound Effect of Gravity on Blood Flow Through the Lung



Mechanism of Improved Gas Exchange with Prone Positioning



Prone Position for ARDS

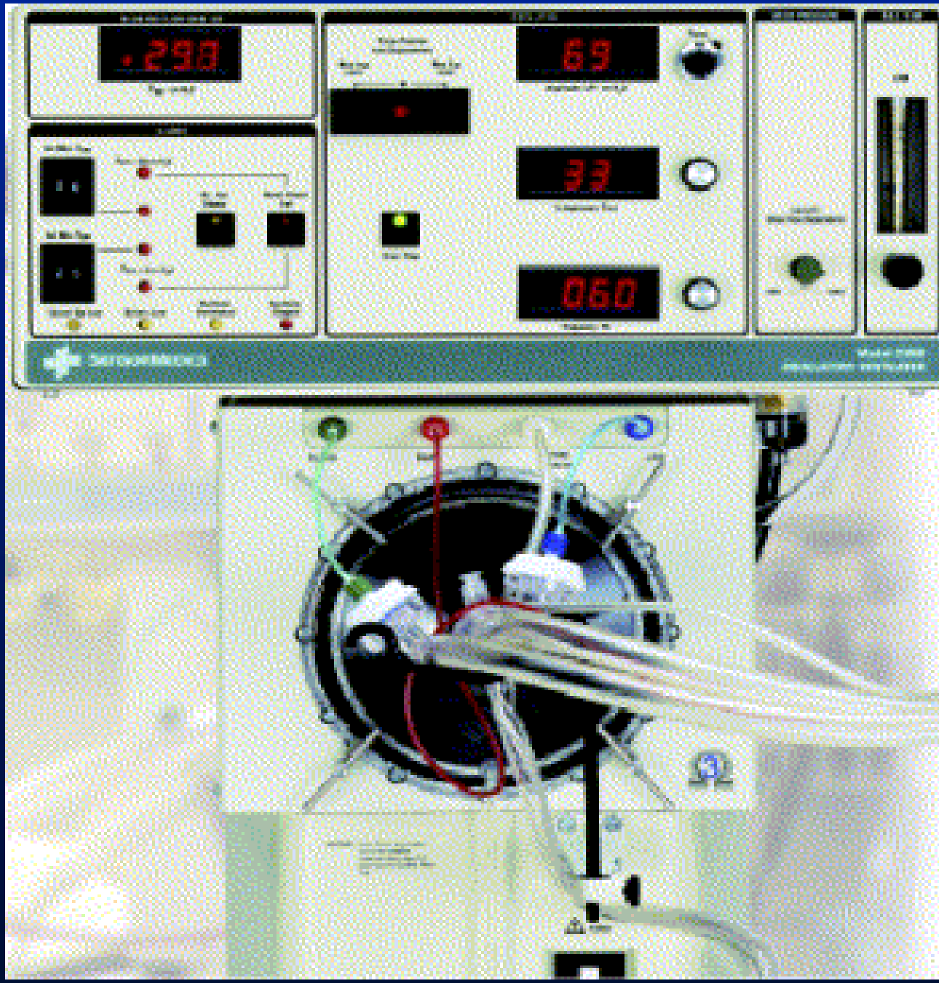


- 152 supine; 152 prone ARDS
- No difference in ICU mortality : 50.7 % vs. 48.0%
- Improved am PaO_2 in prone Pt.
- More pressure sores in prone

L. Gattinoni; N Engl J Med 2001; 345:568-573

Rationale for High Frequency Oscillation Based L.P.V.S

- Minimizes peak alveolar pressures
- Maintains higher end-expiratory pressures
- Improves oxygenation

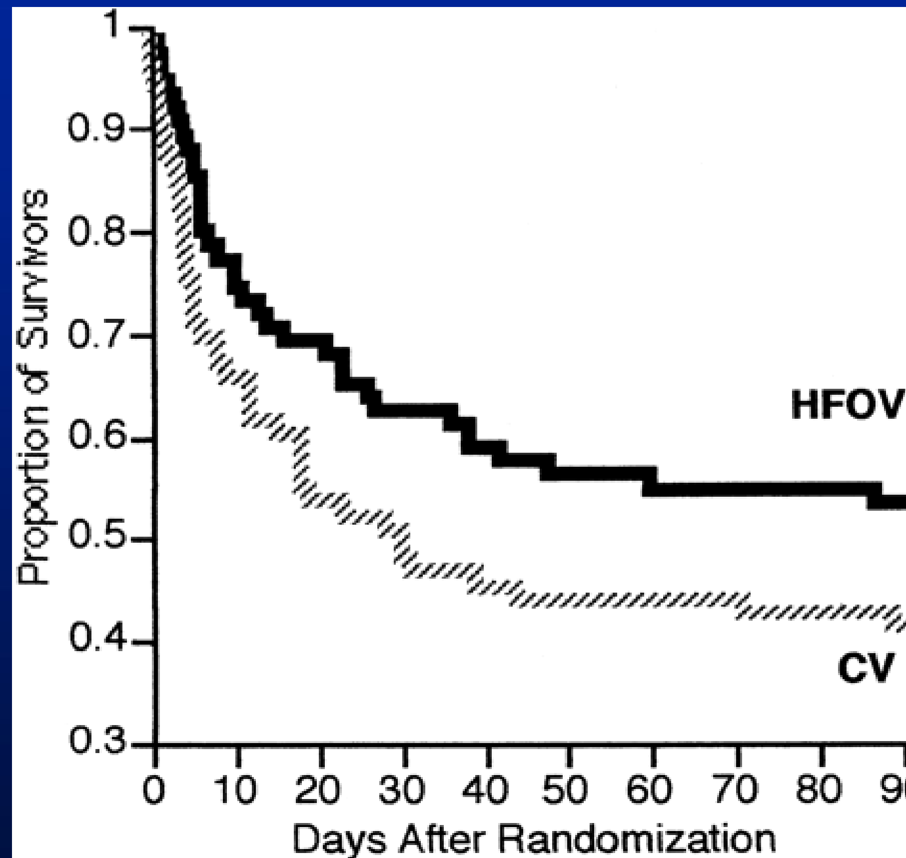


Trials of HFOV in adults with acute respiratory distress syndrome

Reference	HFOV Device	Patient Population	Study Design	Mortality
Fort et al, 97	3100B	17 ARDS	Prospective, Observational	**53%**
Mehta et al, 01	3100B	24 ARDS	Prospective, Observational	**66%**
Anderson et al, 02	3100B	16 ARDS	Retrospective	**31.2%**
Derdak et al, 02	**3100B**	**148 ARDS**	**PRCT**	**37%**
David et al, 03	3100 B	42 ARDS	Prospective Observational	**43%**
Metha et al, 04	3100B	156 ARDS	Retrospective	**61.7%**
ARDSNet, 02		**846 ALI/ARDS**	**RCT**	**31%**

High-Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adults
A Randomized, Controlled Trial

- RCT comparing CV vs HFOV
- 148 adults with P/F < 200 mm Hg
- HFO = 75 Pts, CV = 73Pts
- P/F ratio no diff after 24 Hours
- O.I. decreased in both groups by 72 Hrs
- **Mortality in HFO: 37%, CV: 52% (P= 0.102)**



Am J Resp Crit Care Med vol 166. pp 801-808,2002

High-Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adults

A randomized, Controlled Trial

Ventilator Settings

24 Hours

	HFOV	CV
n	60	57
FIO_2	0.51± 0.15	0.60 ± 0.17
Plat Press	----	37 ± 8
PEEP	----	13 ± 3
Vt, ml/Kg IBW	----	10.1± 2.8
mPAW,cm H_2O	29.6 ± 6	23 ± 7
RR, Hz/BPM	4.7 ± 0.7	20.7 ± 7
ΔP, cm H_2O	66 ± 14	-----

Noninvasive Ventilation

- Pay attention to the debate !!!

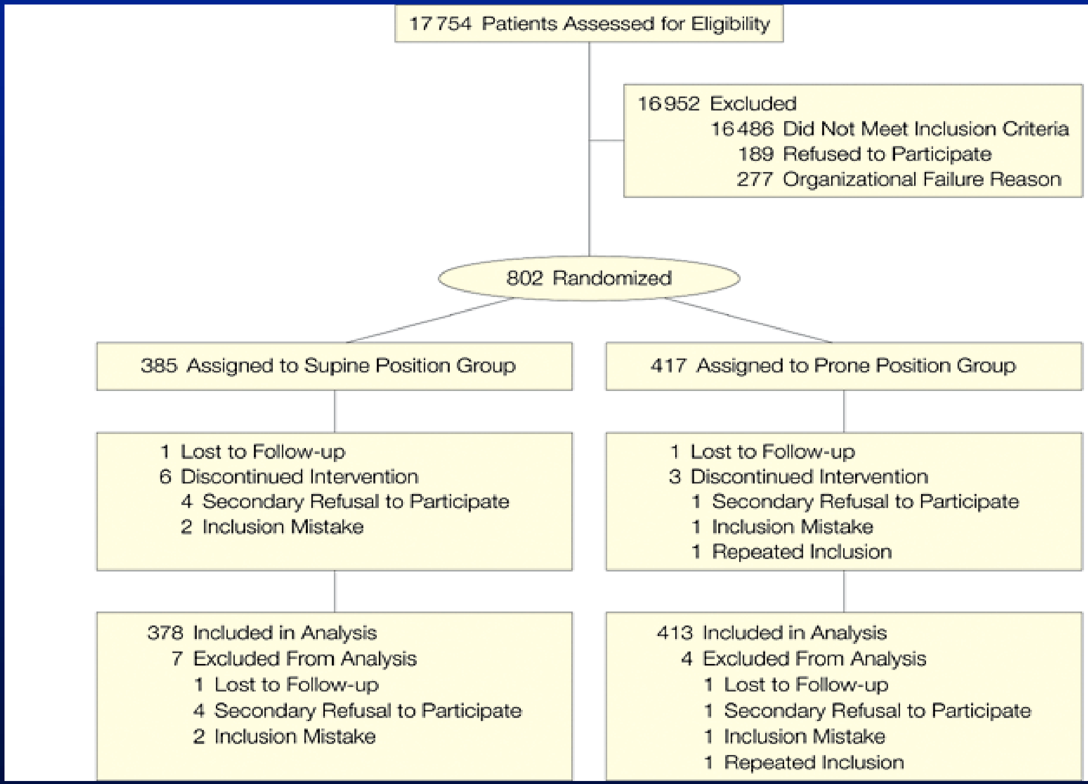
Thank You

JJ

Effects of Systematic Prone Positioning In Hypoxemic Acute Respiratory Failure

A Randomized Controlled Trial

- Prospective, multi-center controlled trial
- Dec 14, 1998-Dec 31, 2002
- 8 Hours/Day of Prone
- Main Outcome Measures: 28 Day Mortality
- Secondary Outcome: 90 day mortality
  Duration of MV
  VAP, Oxygenation



JAMA, November 17, 2

Effects of Systematic Prone Positioning In Hypoxemic Acute Respiratory Failure

A Randomized Controlled Trial

Baseline Characteristics

	Supine	Prone
N	378	413
Age	62.5	62.0
Simplified Apache	46.1	45.1
# of failed organs	2.3	2.2
Pao_2/FIo_2	155	150
PEEP	7.5	7.9
Vt ml/Kg mBW	11	10

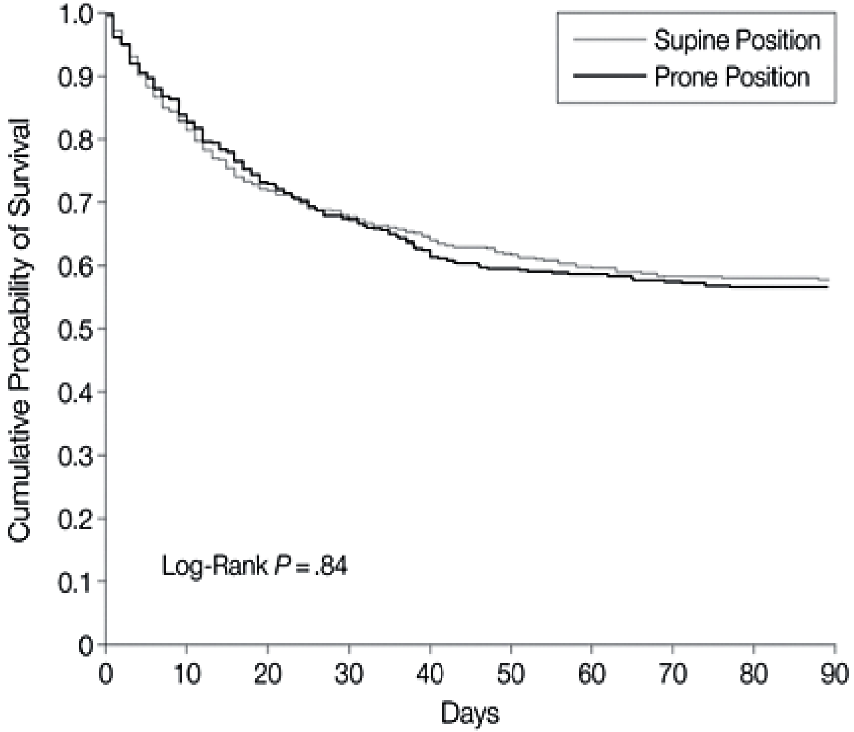
Guerin Jama Nov

PaO_2/FIO_2 Response

PaO_2/FIO_2, (mean)	Supine	Prone
Day		
1	182 (78)	188 (78)
2	193 (76)	210 (82)
3	199 (78)	213 (85)
4	206 (84)	227 (87)
5	205 (79)	224 (88)
6	204 (78)	223 (91)
7	206 (78)	228 (91)

Guerin Jama Nov 17, 2004

Outcome Measures



No. at Risk										
Supine Position	378	314	273	257	244	234	226	220	219	218
Prone Position	413	346	302	279	258	246	242	237	234	234

- **No Diff in ICU Mortality 31.3% vs 32.4%**
- **No Diff in 90 Day Mortality**
- **Duration of MV: 14.1 (8.6) vs 13.7 (7.8)**
- **Signifigantly less VAP/Prone**
- **PaO_2/FIO_2 Higher in Prone**
- **More complications in Prone**

Guerin Jama, Nov 17, 2004

Prone Studies Shortcomings???

Gattinoni Study	Guerin Study
Prone for only 6 Hrs/Day	Prone for only 8 Hrs/Day
No lung protective approach	No lung protective approach
No Vent protocols	No Vent protocols
Poor compliance with protocol	Aprox 20% crossover
No sedation NMB protocols	No sedation NMB protocols
Potential delays in proning	Delays of 24 Hrs till proning

Prone Conclusions

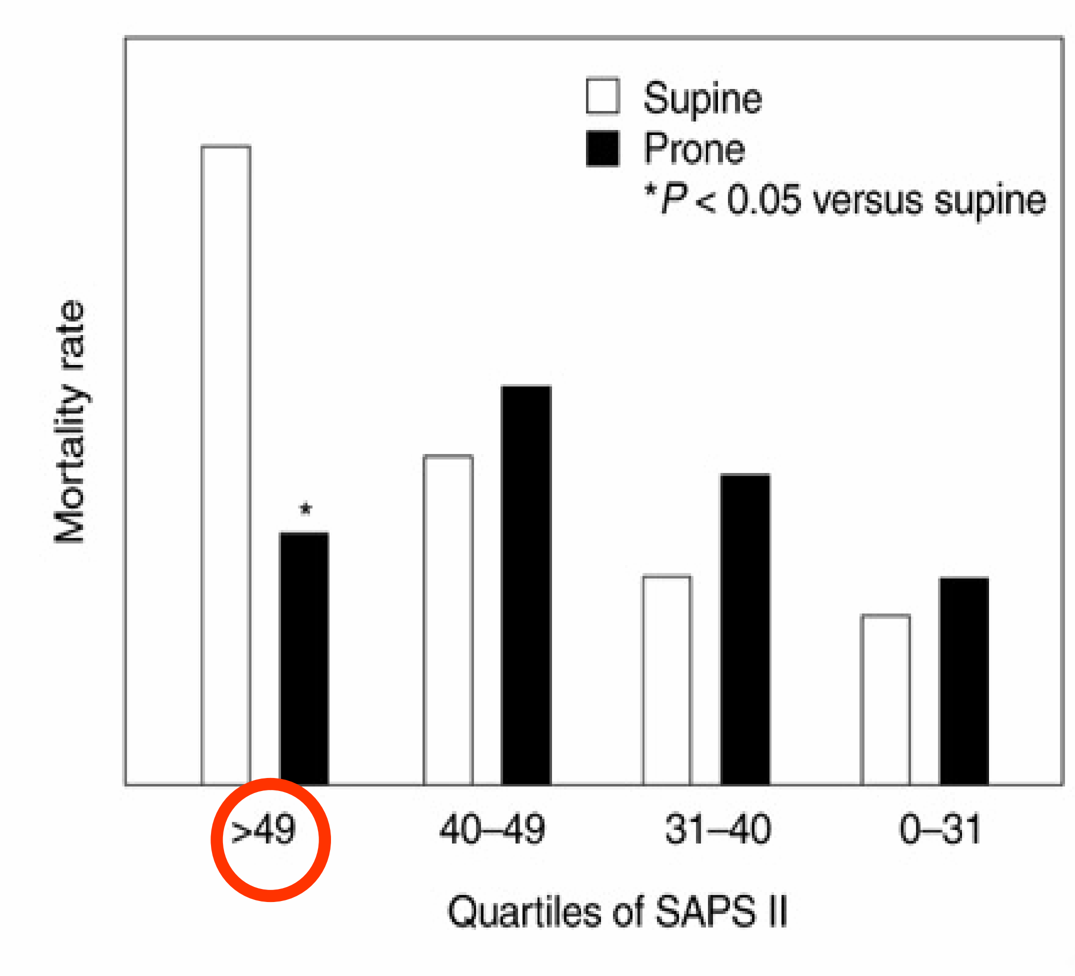
Overall prone positioning improves oxygenation in two thirds of pts

Post hoc analysis revels improved mortality in the more critically ill

Prone positioning is safe

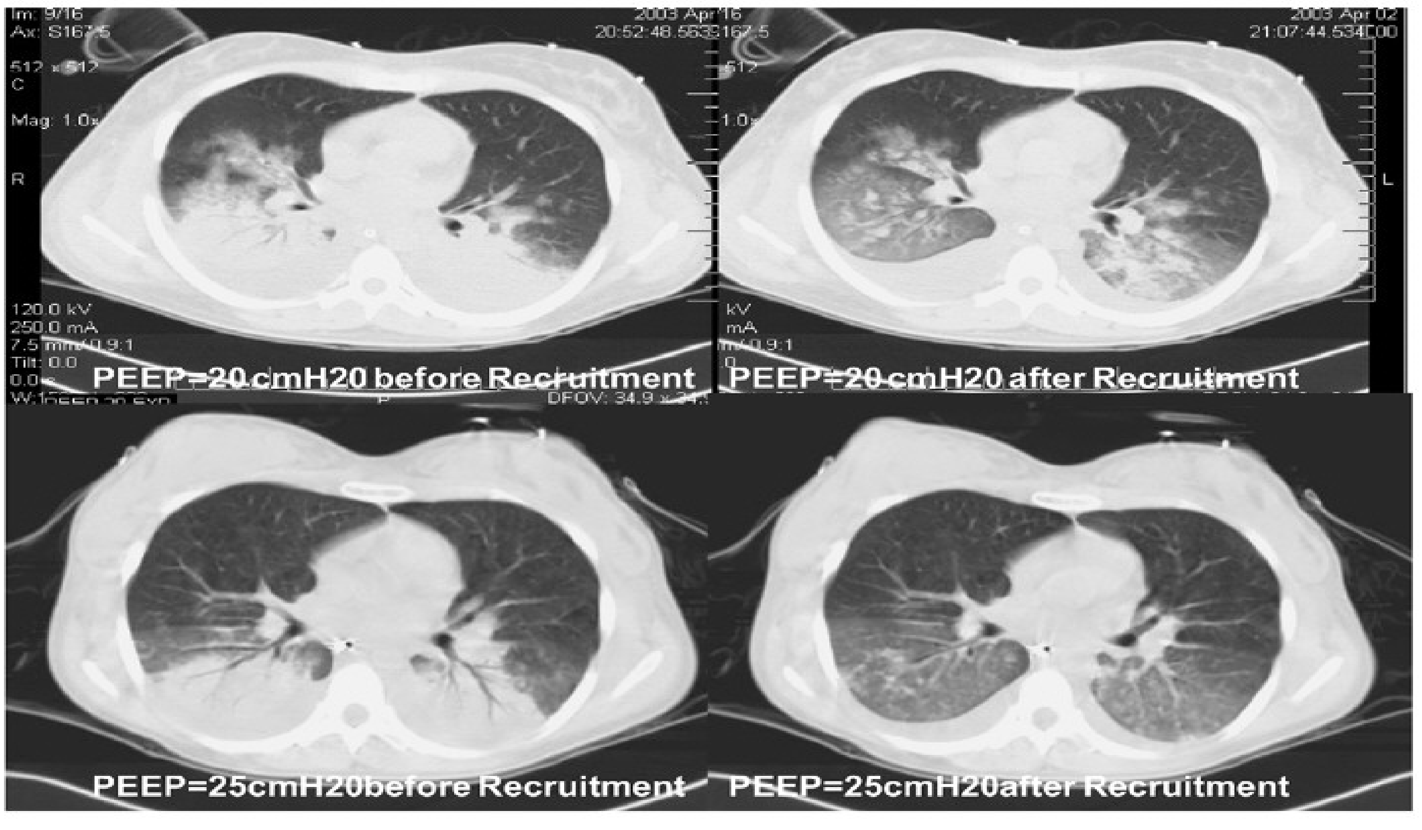
May reduce VILI

Further studies needed

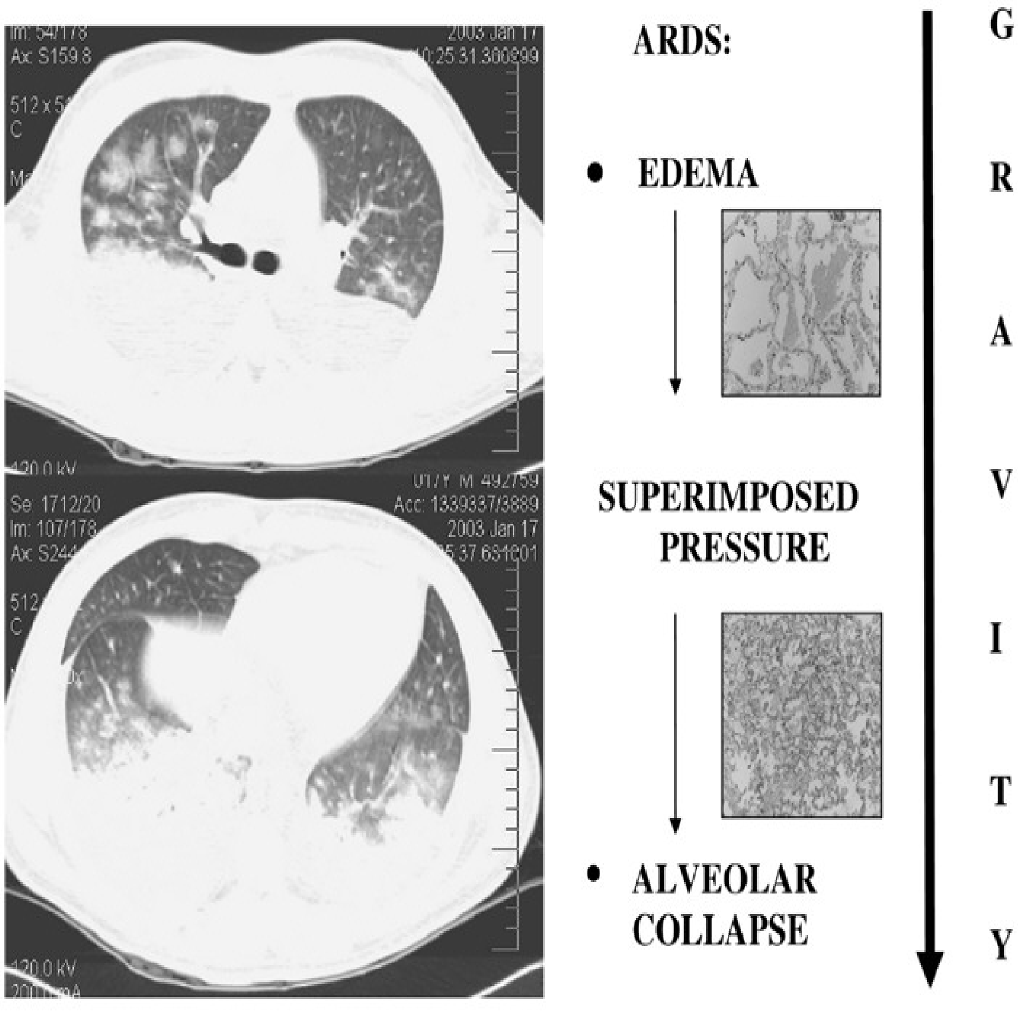


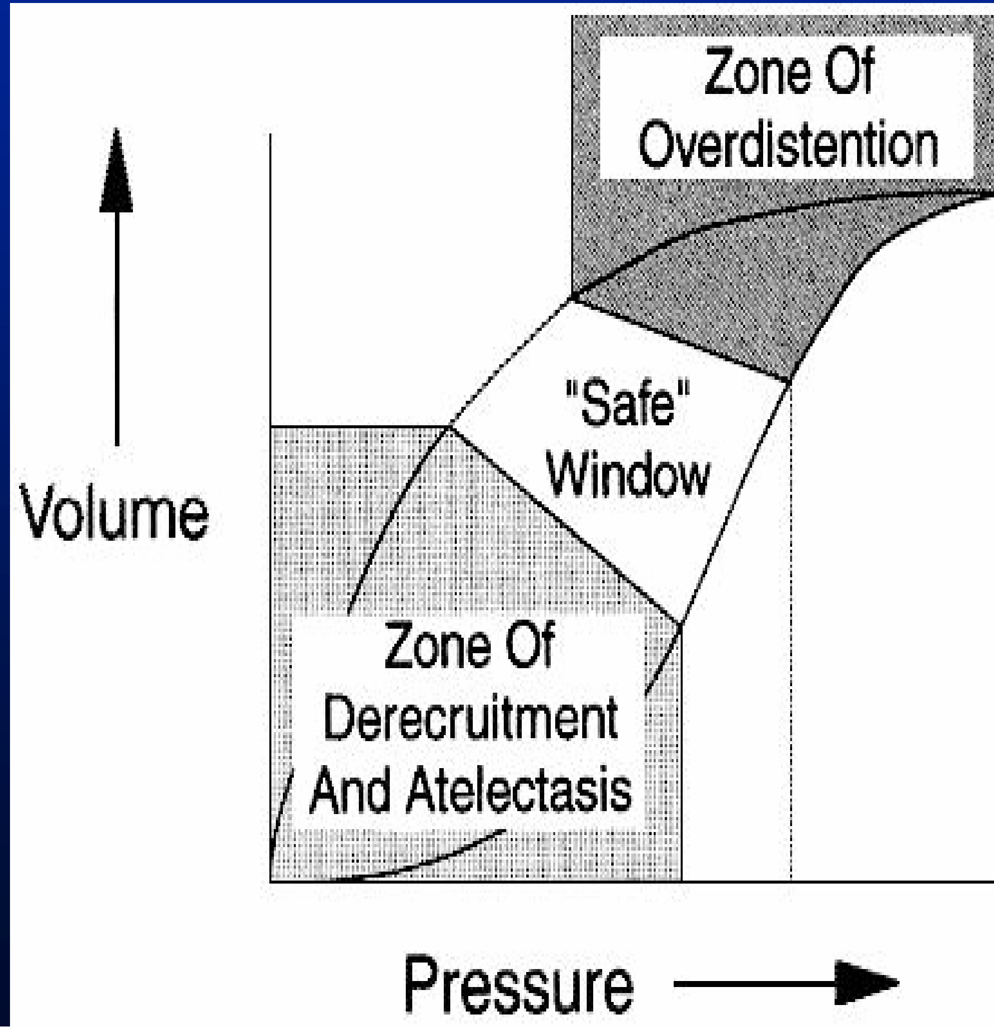
What is A Recruitment Maneuver ???

"…. A sustained increase in airway Pressure (30 – 90 Sec) with the goal to open collapsed lung tissue, *after which sufficient positive end-expiratory pressure (PEEP) is applied to maintain the lungs open."*



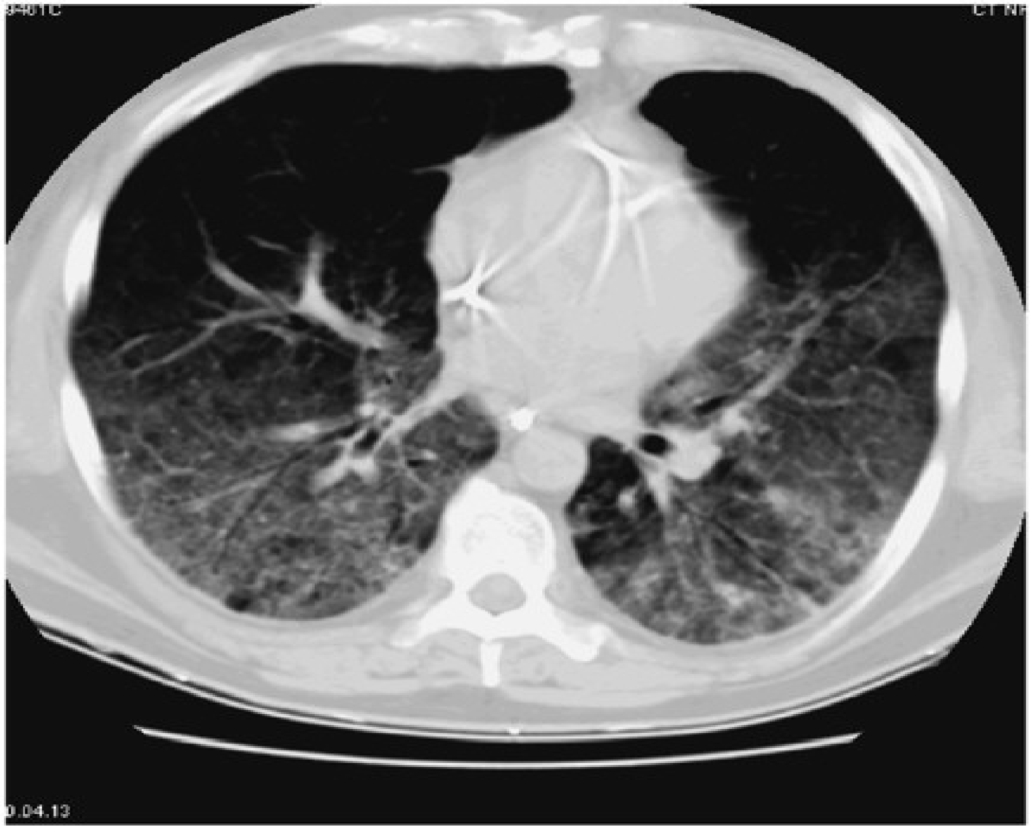
Rational for Recruiting the Lung During LPVS





Factors effecting the reposnsiveness to a recruitment maneuver:

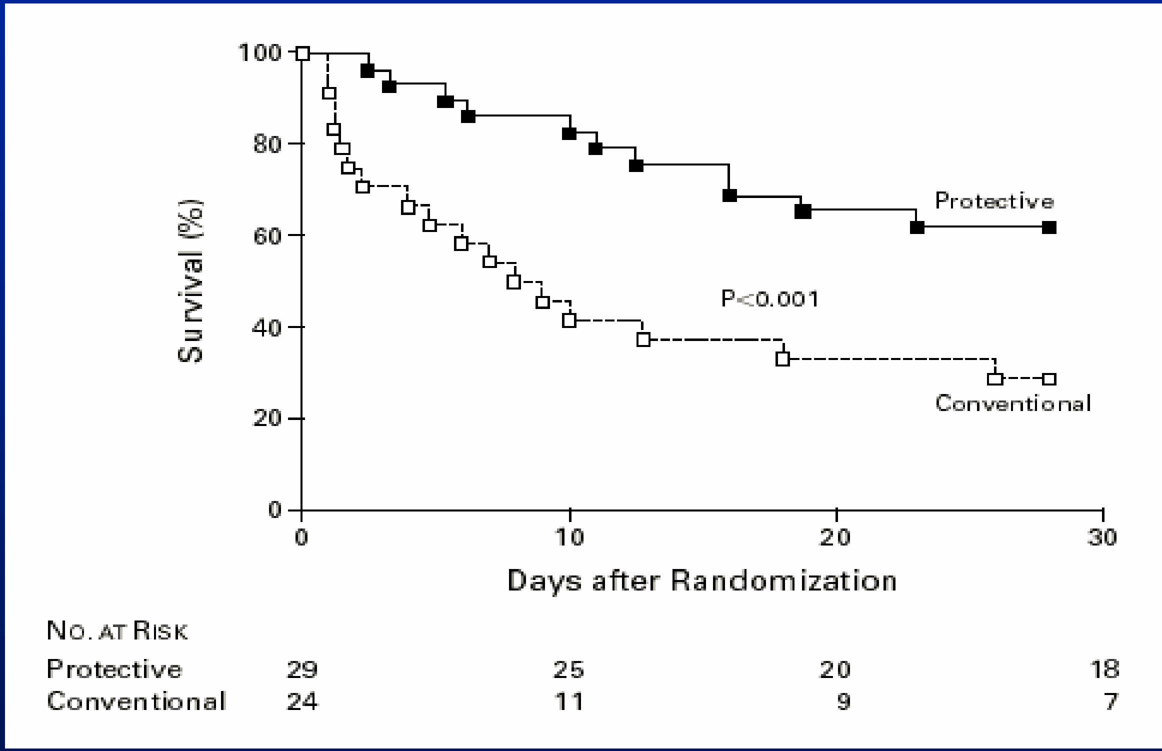
1. TYPE OF ARDS
2. ARDS SEVERITY
3. ARDS TIME
4. MECHANICS OF CHESTWALL



Recruitment Trials

	Amato	ARDSNet	Oczenski
Mode	PCV	Volume-Controlled	PCV
Tidal Volume	6 ml/Kg	4-6 ml/Kg	5-7 ml/Kg
Plat Press	30.1 cm	25-30 cm	29 cm
Static Compl	28.5 cm	35.4 cm	34.1 cm
PEEP	16.8cmH_2O	13.4cm H_2O	15.1 cm H_2O
FIO_2	-------	0.39	0.68
Pre R.M P/F	112	-----	139
Age	33 ±13	53 ±17	66 ± 8
ARDS/Pulm	48%	65%	----
Extra	52%	35%	100%
Sedation/NMB	Yes	No	Yes
R.M. Application	CPAP 40 cm x 40 sec Frequently/daily	35 cm x 30 sec 1 Q.O.D	50 cm x 30 sec once

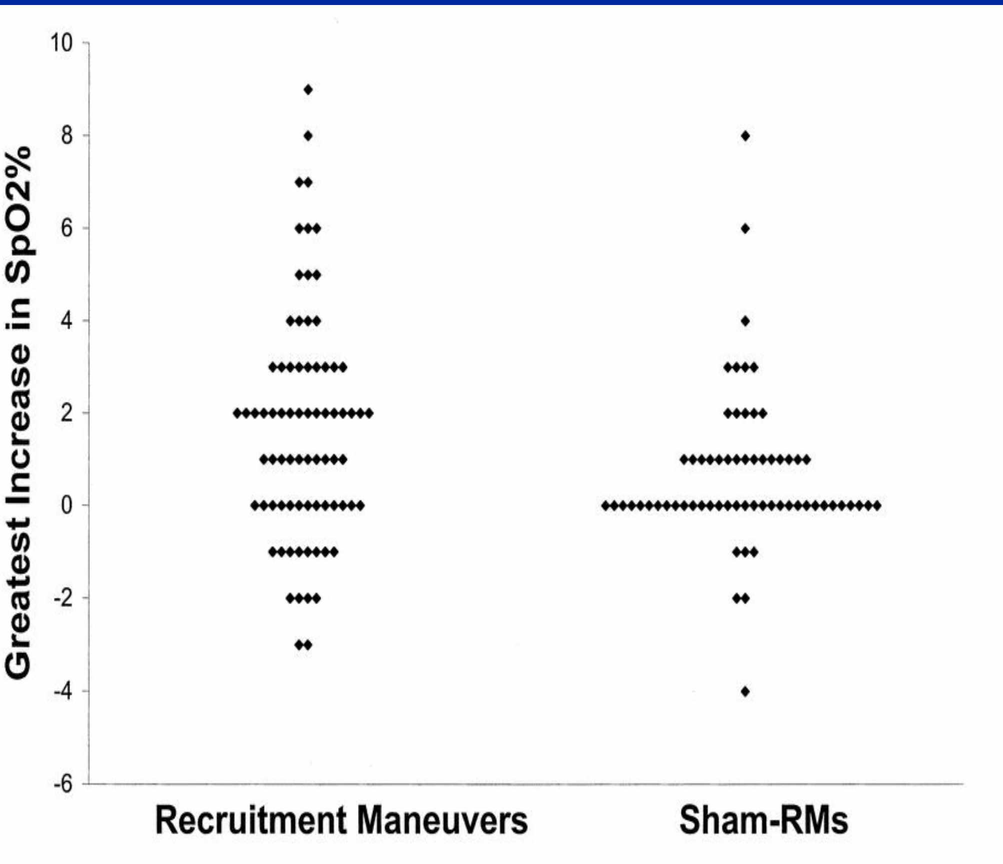
Effect of A Protective-Ventilation Strategy on Mortality in the Acute Respiratory Distress Syndrome



*"We hypothesized that by **preventing the persistent collapse** of recruitable units & reducing cyclic lung reopening and stretch during mechanical breaths ,would result in lower rates of pulmonary complications and mortality…"*

Amato et al N Engl

Effects of recruitment maneuvers in patients with ALI/ARDS Ventilated with High PEEP (ALVEOLI STUDY)



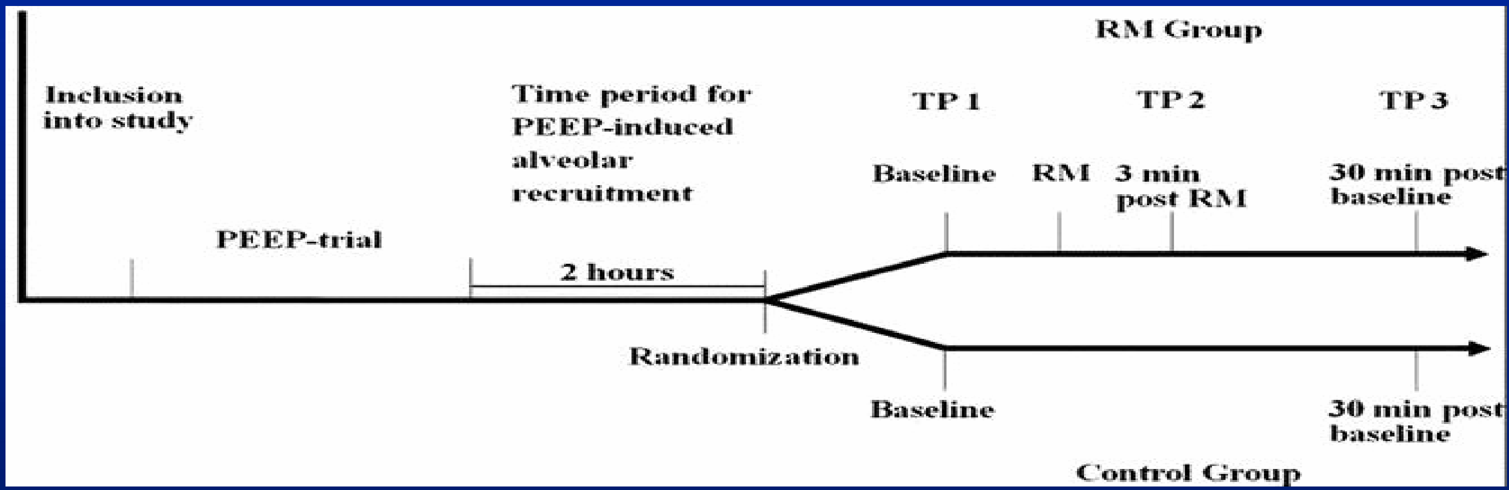
Step Changes	After RMs	After Sham RMs
−4	2	0
−3	0	1
−2	5	4
−1	18	12
0	41	49
+1	6	8
+2	1	1
Totals		
Improved	25	17
Unchanged	41	49
Worse	7	9

34%

IO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.8	0.9	1.0	1.0	1.
EEP	5	8	10	12	14	14	16	16	18	20	20	20	20	20	20	22	24

Brower et al Crit Care Med 2003 Vol. 31

Recruitment Maneuvers after a Positive End expiratory Pressure Trial do not Induce Sustained Effects in Early Adult Respiratory Distress Syndrome



Pao_2/FIO_2 (mm Hg)	*Baseline*	*3 min post-RM*	*30 min post-Baseline*
RM group	139 ± 46	246 ± 111	138 ± 39

Post- Recruitment Strategy: Maintain pre - recruitment level PEEP

Oczenski et al: Anesthesiology 2004; 101:620-5

Recruitment Maneuvers Conclusion

<u>Many questions Remain</u>

Which patients will benefit??

$\text{ARDS}_{\text{PULM}}$

$\text{ARDS}_{\text{EXtraPULM}}$

Post R.M. PEEP

Optimal Duration of R.M.

Routine use or only during Hypoxic events

Contraindications:
Pneumonia ??
Unilateral Dz process
*Acute hypoxia without **CXR***