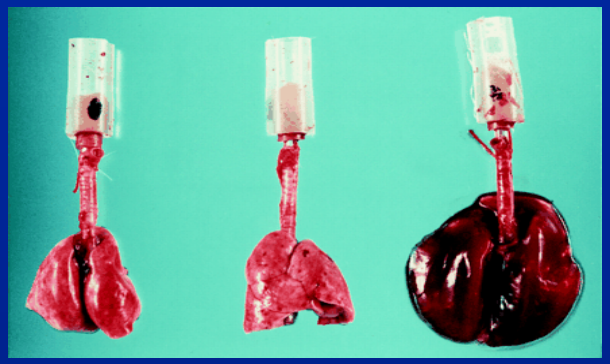

Mechanical Ventilation

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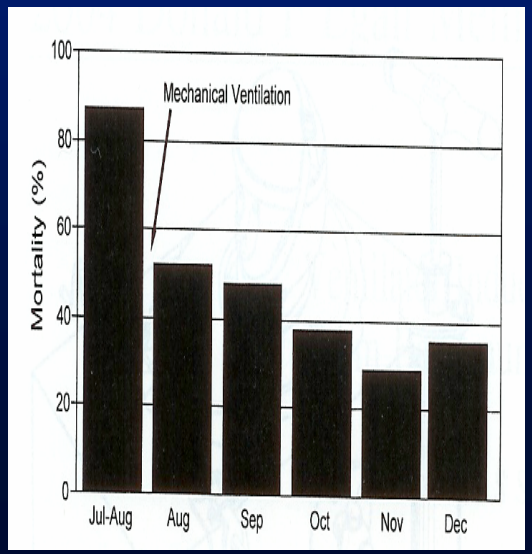
Mechanical Ventilation – Cornerstone of ICU care

- 1928: Drinker-Shaw Iron Lung
- 1950s: Polio epidemic
- 1955: Invasive positive pressure ventilation
- 1973: Intermittent Mandatory Ventilation (IMV)



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

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

Ventilatory requirement is dependent on
metabolic rate, minute volume and dead space

Symptoms/Signs of Hypercapnic Failure

- Tachypnea
- Use of accessory muscles
- Paradoxical motion of abdomen
- Delirium
- Hypercapnia (pC02 >50)
- Insufficient compensation for metabolic acidosis (expect pCO2 to be 100 *[pH-7.00])

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

Symptoms/Signs of Hypoxic Failure

- Tachypnea
- Cyanosis
- Delirium
- Hypoxia (pulse ox ok – ABG better)

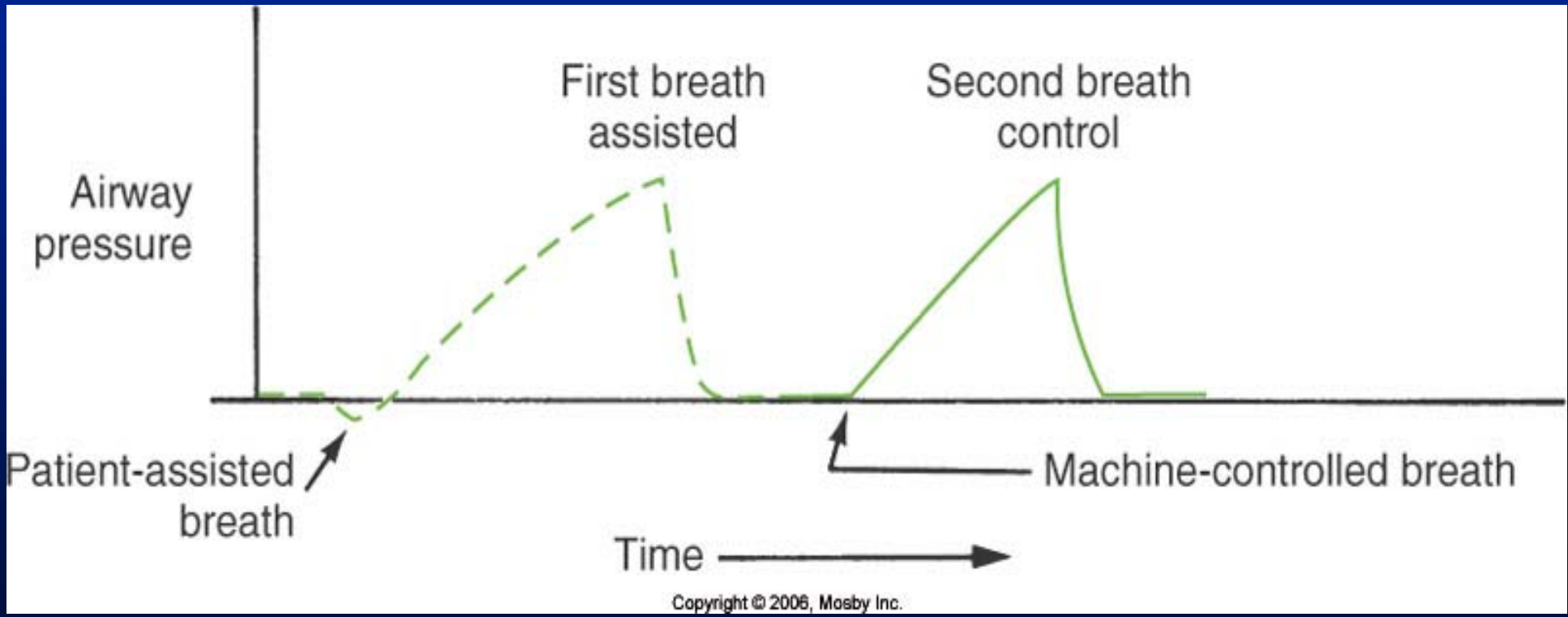
What kinds of MV are there?

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

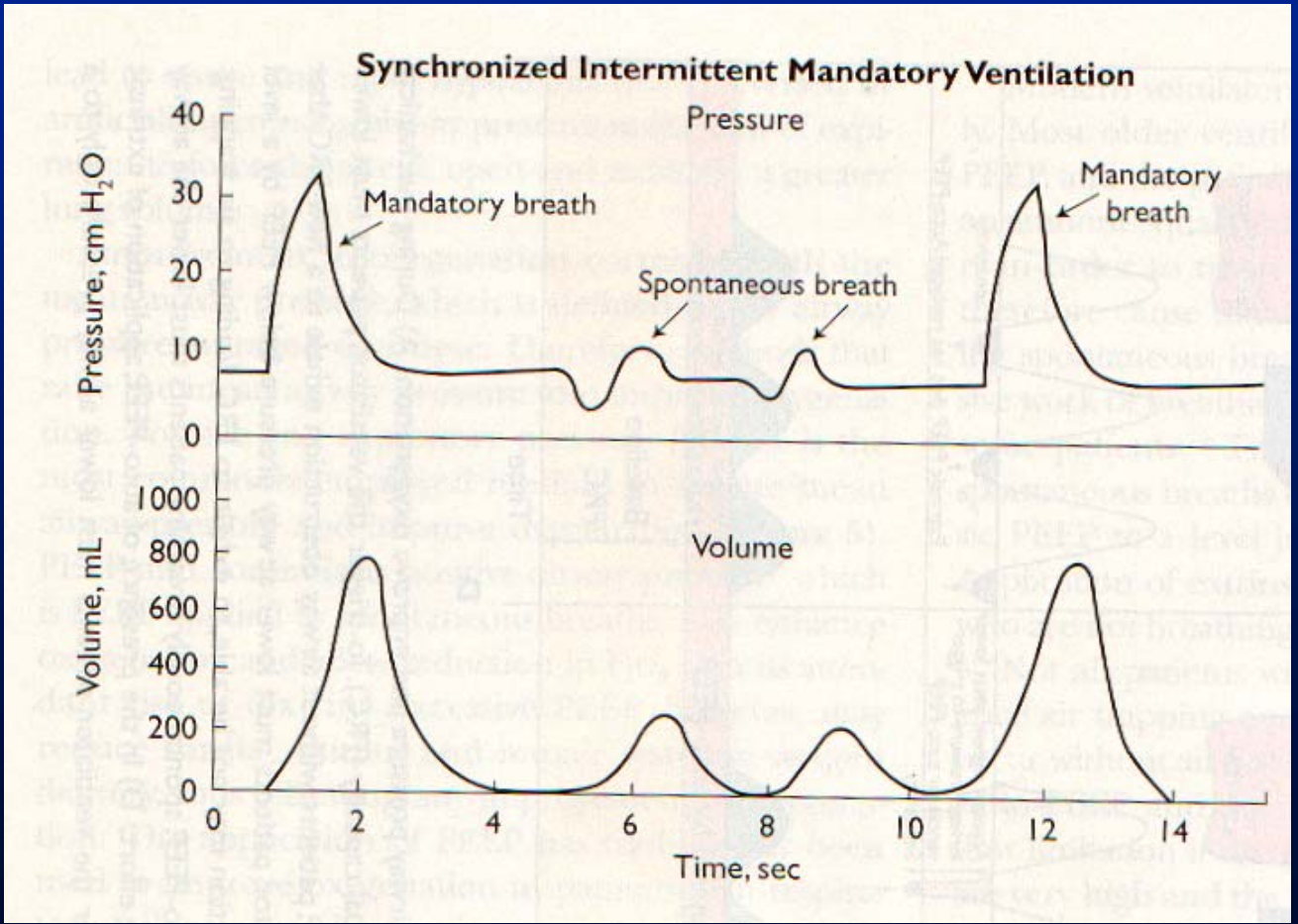
What kinds are there: Triggering

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

Triggering: Assist/Control



Triggering: SIMV

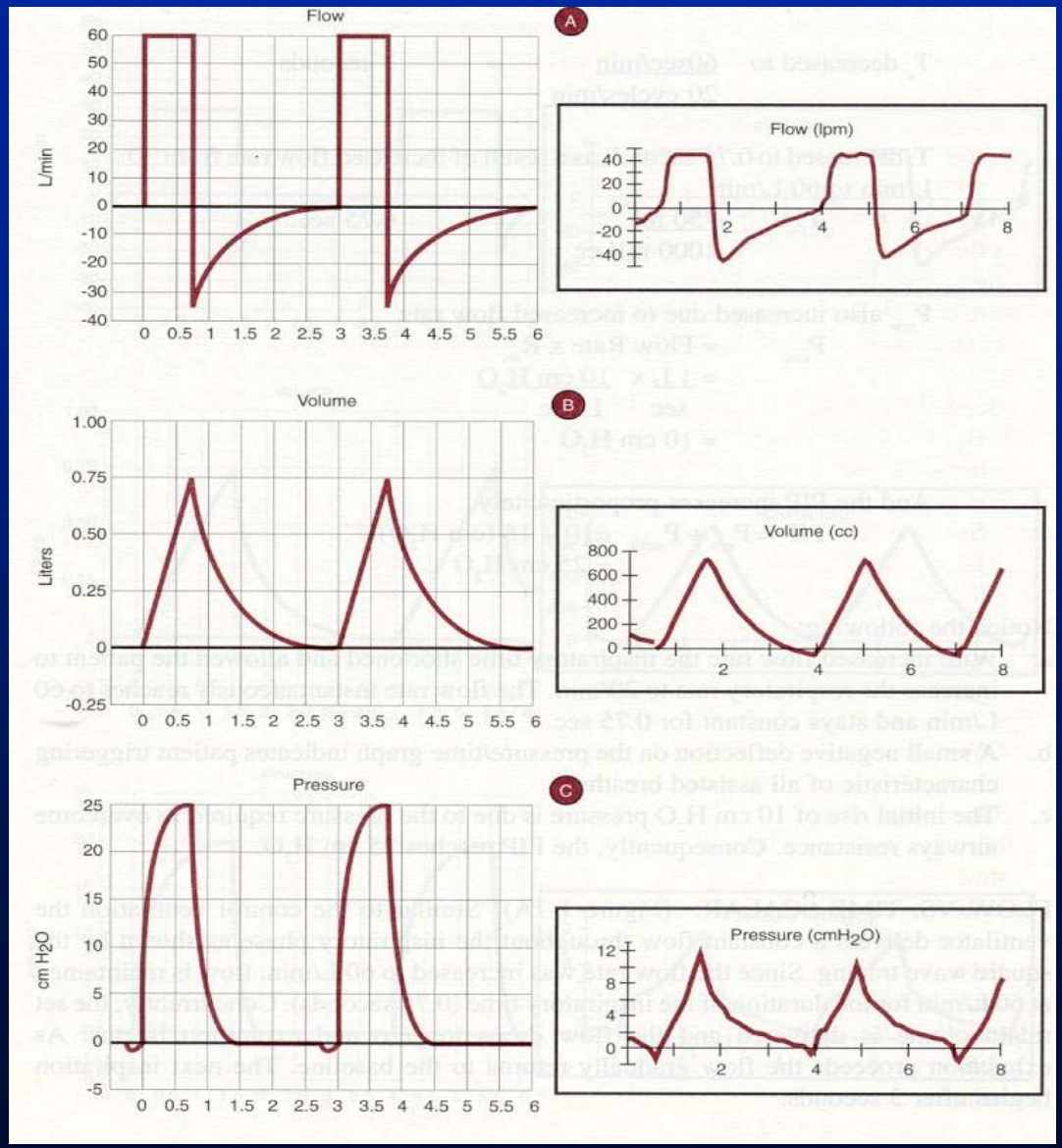


What kinds are there: cycling

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

Cycling: Volume (A/C)

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



Summary of Basic Modes

Mode	Trigger	Cycling	Limits
Assist /Control	Pt or Machine	Volume	Flow
SIMV	Patient Machine	Flow (usually) Volume (usually)	Pressure Flow
Pressure Control	Machine Only	Time	Pressure
Pressure Support	Pt Only	Flow (usually)	Pressure

Volume or Pressure Ventilation?

- **Volume Control (A/C)**
  - **Consistent Tidal Volume**
    - **Ignores changing impedance**
    - **Auto-PEEP from incomplete exhalation**
  - **Variety of flow waves, rates**
  - **How to assess patient effort?**
- **Pressure Support (or PC)**
  - **Alveolar pressure maintained within set limits**
  - **Variable flow rate**
  - **Variable tidal volume**
  - **Reduced WOB**
  - **Variable I-time & pattern (PS)**
  - **Patient effort easier to assess**

Scientific Evidence For Different Modes of Ventilation

- **Extremely poor quality**
  - **Diverse Patient populations**
  - **Study designs (crossover, animal models, theoretical models, small sample sizes)**
  - **Secondary endpoints (WOB)**
- **Recent example: Ortiz et al., *Chest* 2010**
  - **4968 pts/349 ICUs/23 Countries**
  - **SIMV vs A/C**
  - **Arbitrary definition of "simple, difficult, or prolonged" weaning**
  - **Logistic regression: No difference**

Scientific Evidence Summarized:

Dean Hess: 2010

"Many new modes [have been] introduced in recent years…..but have not been subjected to rigorous scientific study. None has been conclusively shown to improve patient outcomes. The Acute Respiratory Distress Syndrome Network study……..is the *only* study of mechanical ventilation ever shown to improve patient outcome"

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

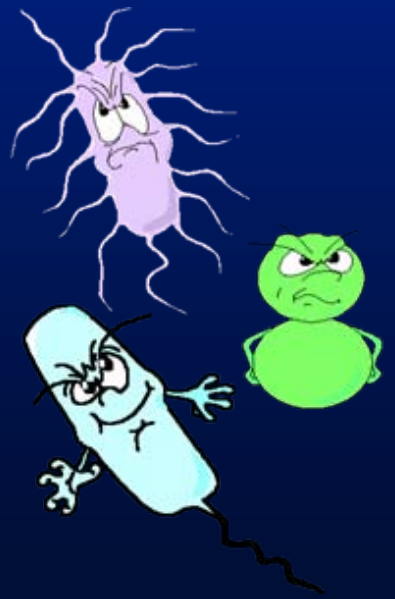
- **Initial full support:**
  - **Goal: ensure adequate ventilation**
  - **Recommend: Assist-Control**
    - **Pt & machine triggered**
    - **Volume cycled – constant volume each breath**
    - **Flow limited – adjust flow for rate and comfort**

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
  - Particular mode of ventilation appears to make little difference
- **Avoid:**
  - Ventilator induced lung injury (VILI)
  - Nosocomial pneumonia
- **Pursue:**
  - Protocol-driven care
  - Appropriate sedation



Protecting the Lung

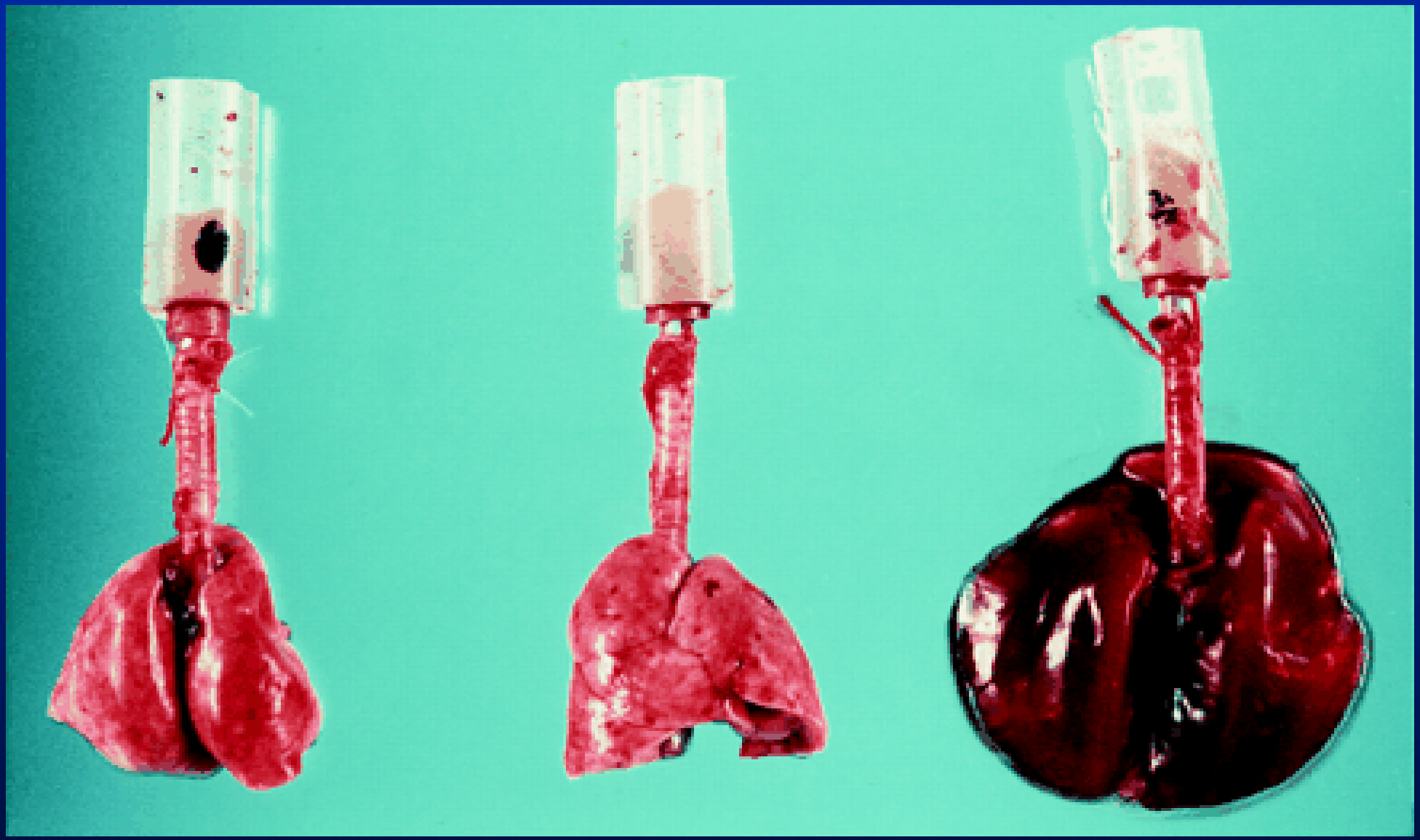
Two types of Ventilator-Induced Injury (VILI)

Barotrauma: too much pressure

Volutrauma:

repetitive opening closing

regional overdistention



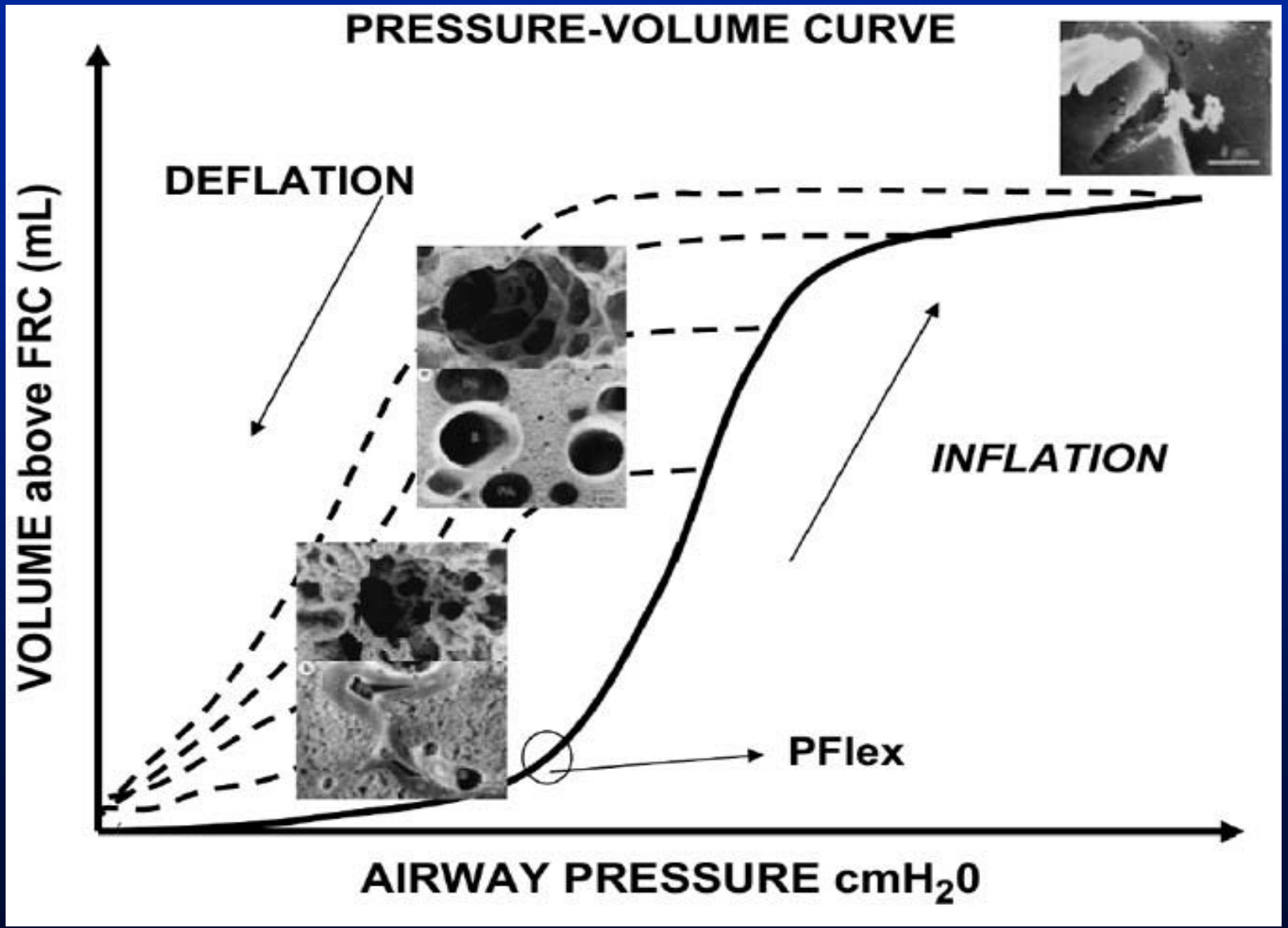
Normal
Lung

PIP 45 cm H_20
5 Min

PIP 45 cmH_20
20 Min

Dreyfuss Am Rev. Respir Dis 1985

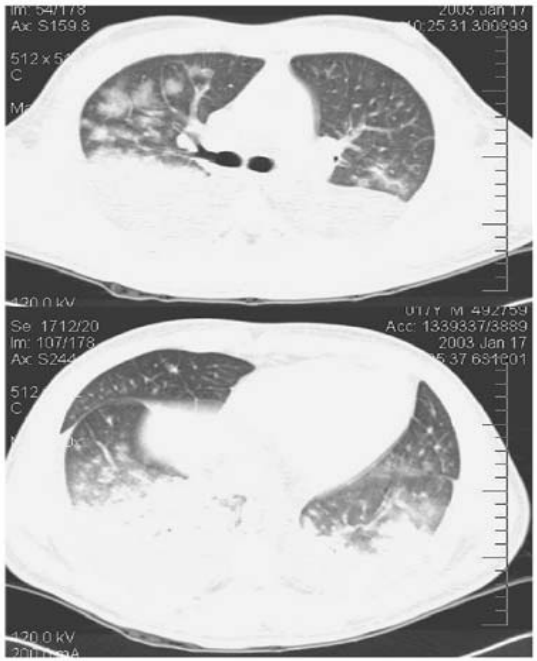
Pressure/volume curve: Inflation vs Deflation

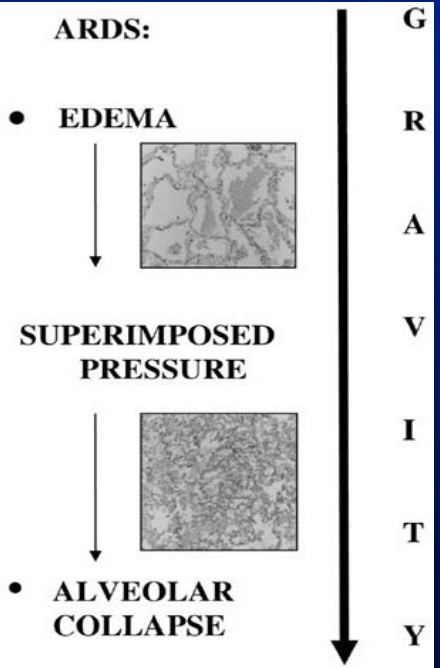


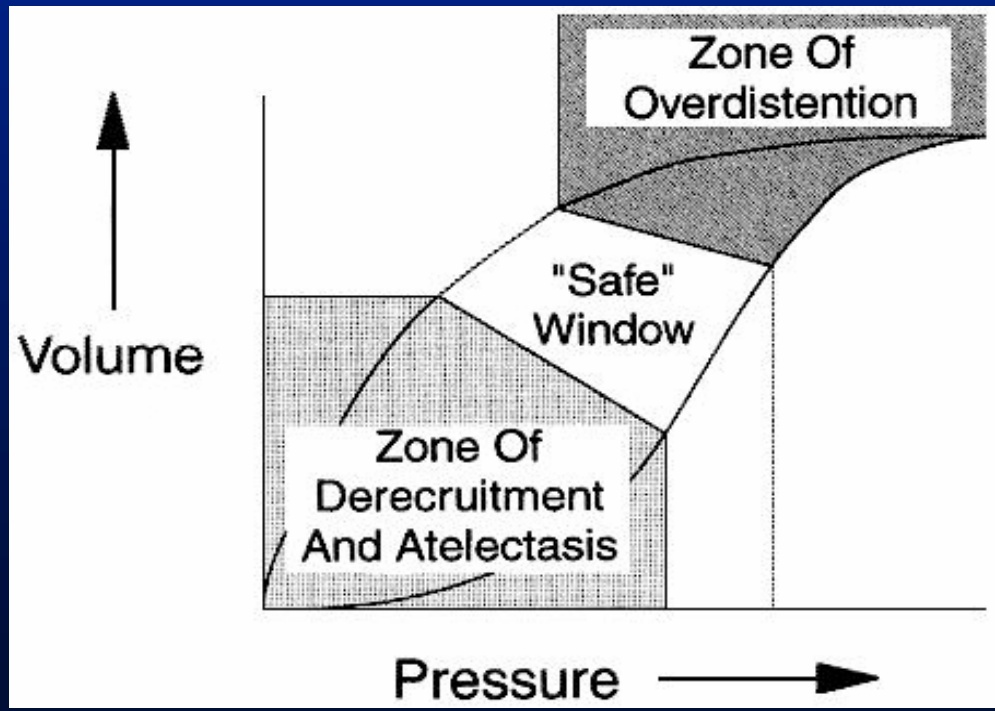
The Acutely Injured Lung (ALI/ARDS)

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

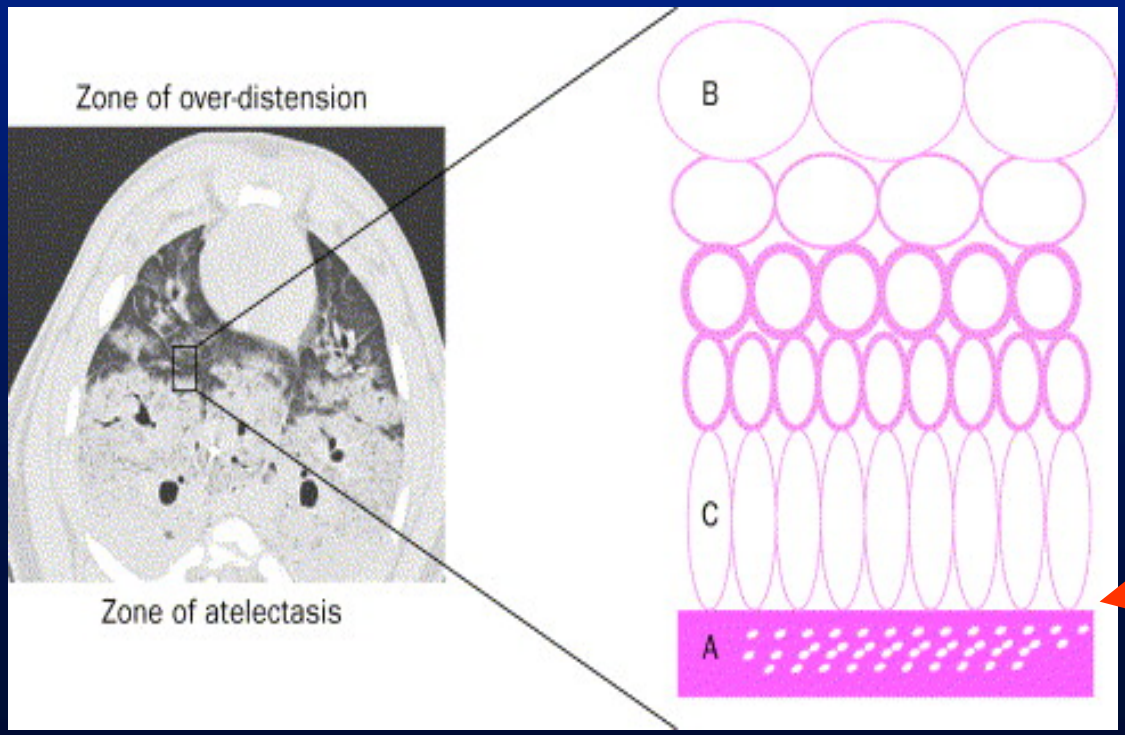






Lung Recruitment

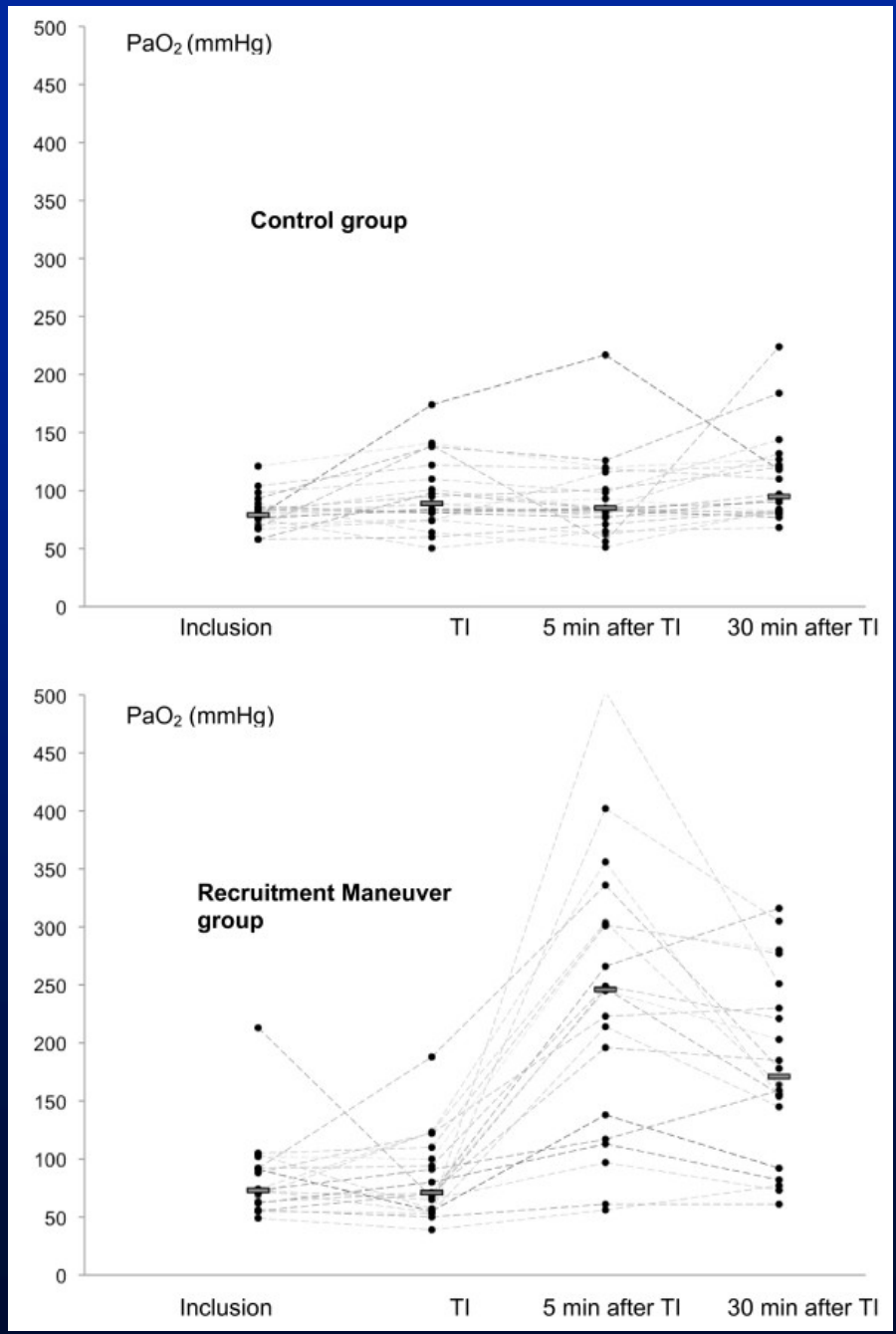
Recruitment = "…. A sustained increase in airway Pressure (30 – 90 Sec) with the goal to open collapsed lung Tissue"



Potential pressures of > 140 cm H_20

Does Recruitment Help?

- Constantin et al., Crit Care 2010
- Prospective, Randomized studies
- Patients enrolled promptly after intubation for hypoxia
- “Recruitment” = CPAP 40 for 30 seconds
- Did not change PEEP (5 cm water)



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

Many questions Remain

Which patients will benefit??

ARDS $_{PULM}$

ARDS$_{EXtraPULM}$

Post R.M. PEEP

Optimal Duration of R.M.

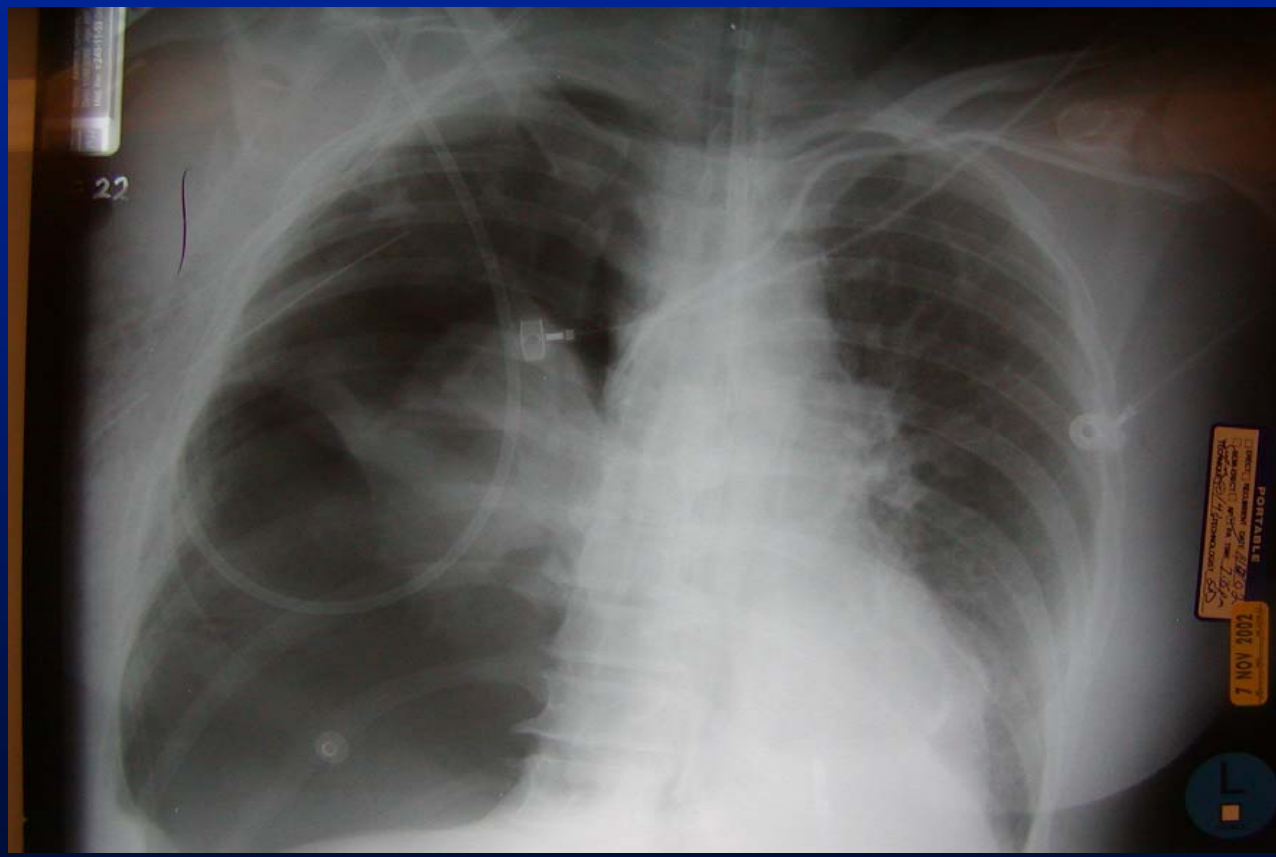
Routine use or only during Hypoxic events

Contraindications:

Pneumonia ??

Unilateral Dz process

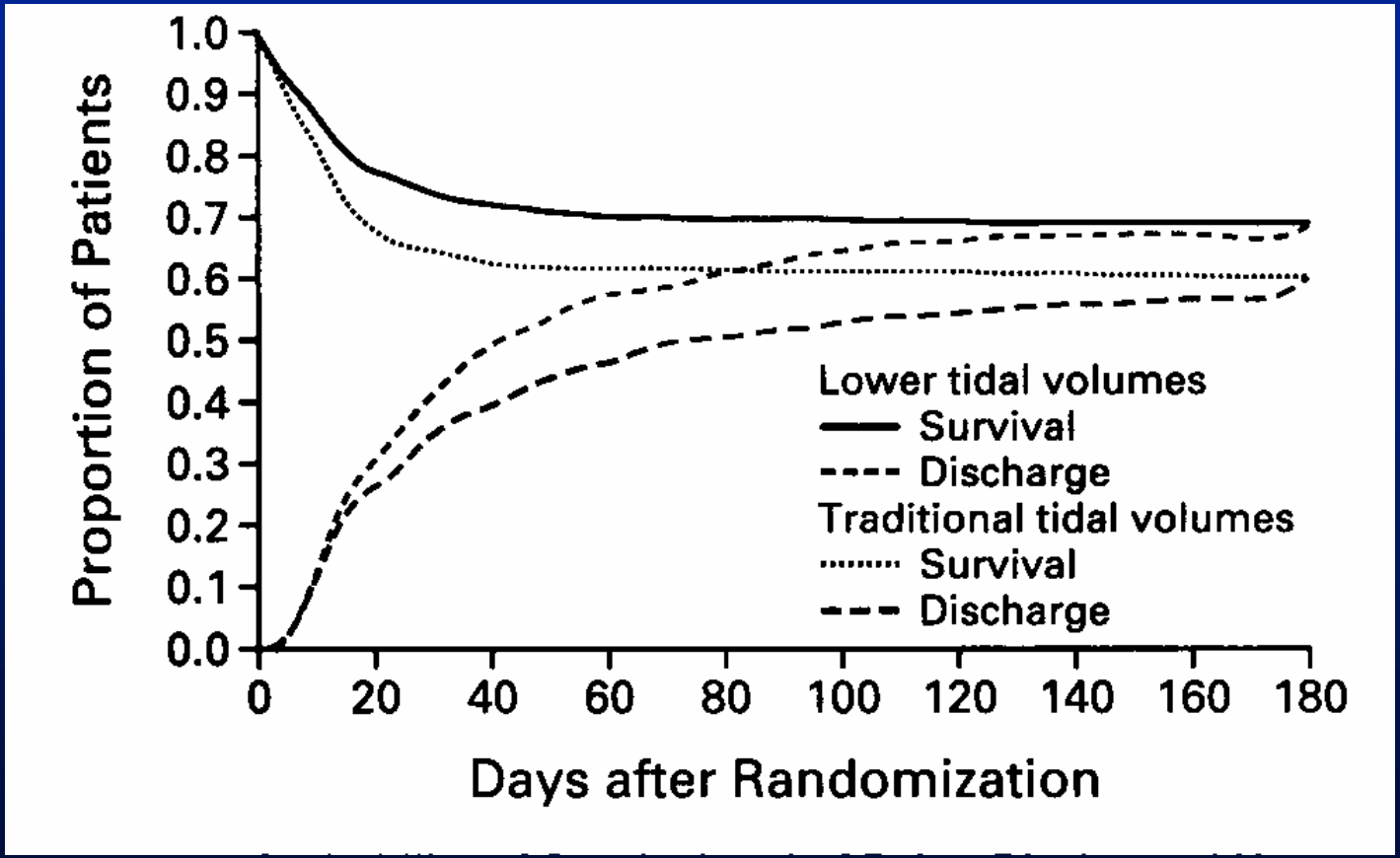
Acute hypoxia without ***CXR***



Overall Strategy for MV

Ventilatory Parameter	Traditional	Lung-Protective
Inflation Volume	10-15 ml/kg	5-7 ml/kg
End-insp. pressure	Peak Pr<50cm water	Plateau Pr<30
PEEP	PRN to keep FiO2<0.6	5-15 cm of water
ABG	Normal, pH 7.36-7.44	Hypercapnia allowed, pH 7.2-7.4
Recruitment Maneuvers?	No	Yes

Lung Protection Improves Survival



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

When and how do I “wean” MV?

- **Better term: Withdrawal of mechanical ventilatory support**
- **Principles:**
  - **Work every day**
  - **Don’t work too hard**
  - **No scientific evidence supporting any given mode**
    - **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**

Are SBTs Beneficial?

- Robertson et al., 2008
  - 488 SICU patients
  - Routine SBTs initiated at beginning of study
  - Comparison of first and last two months
- Observed
  - Decreased days on ventilator
  - Decreased ICU stay
  - No change in reintubation rate

Determinants of Ventilator Dependence

- Gas Exchange
- Respiratory muscle “pump failure”
  - Diminished CNS drive
  - Phrenic nerve dysfunction
  - Muscle weakness
    - Hyperinflation
    - Malnutrition
    - Acidosis/medications
  - Increased load: poor compliance, increased CO_2 production, dead space
- Anxiety

Predicting Successful Liberation from MV

Tobin: “A number of indices….have been proposed as predictors of weaning outcome. However, none….have ever been subjected to prospective investigation but have been passed on from one review article to another”

The Evidence: Discontinuation of Mechanical Ventilation

Parameter	Threshold	PPV	NPV
PaO2/FiO2	200	0.59	0.53
Minute Ventl.	<10L/min	0.50	0.40
Vital capacity	10ml/kg	0.82	0.37
Rate/Tidal Volume (Rapid, Shallow Breathing Index)	<105/min/L	0.78	0.95

Tobin and Alex, in "Principles of Mechanical Ventilation", 1994

For the Severely Hypoxic Patient

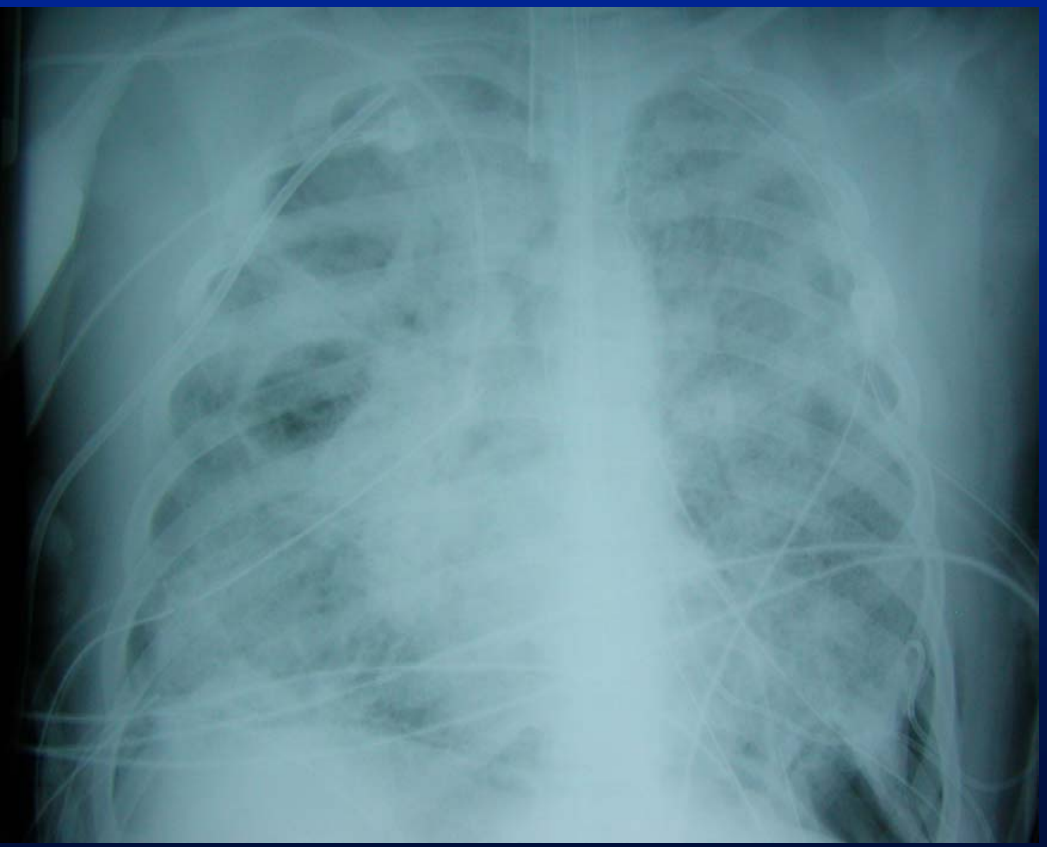
- Corticosteroids for Late ARDS
- Prone ventilation

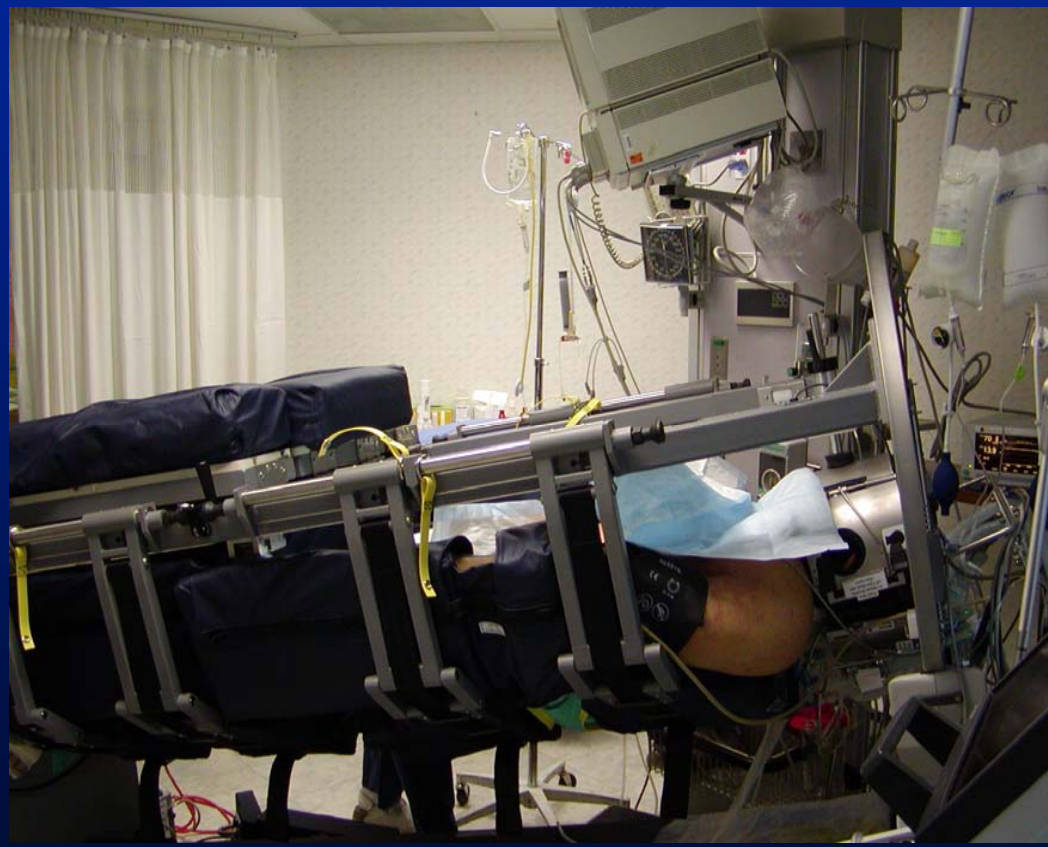
Steroids: The LaSRS Trial

- 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

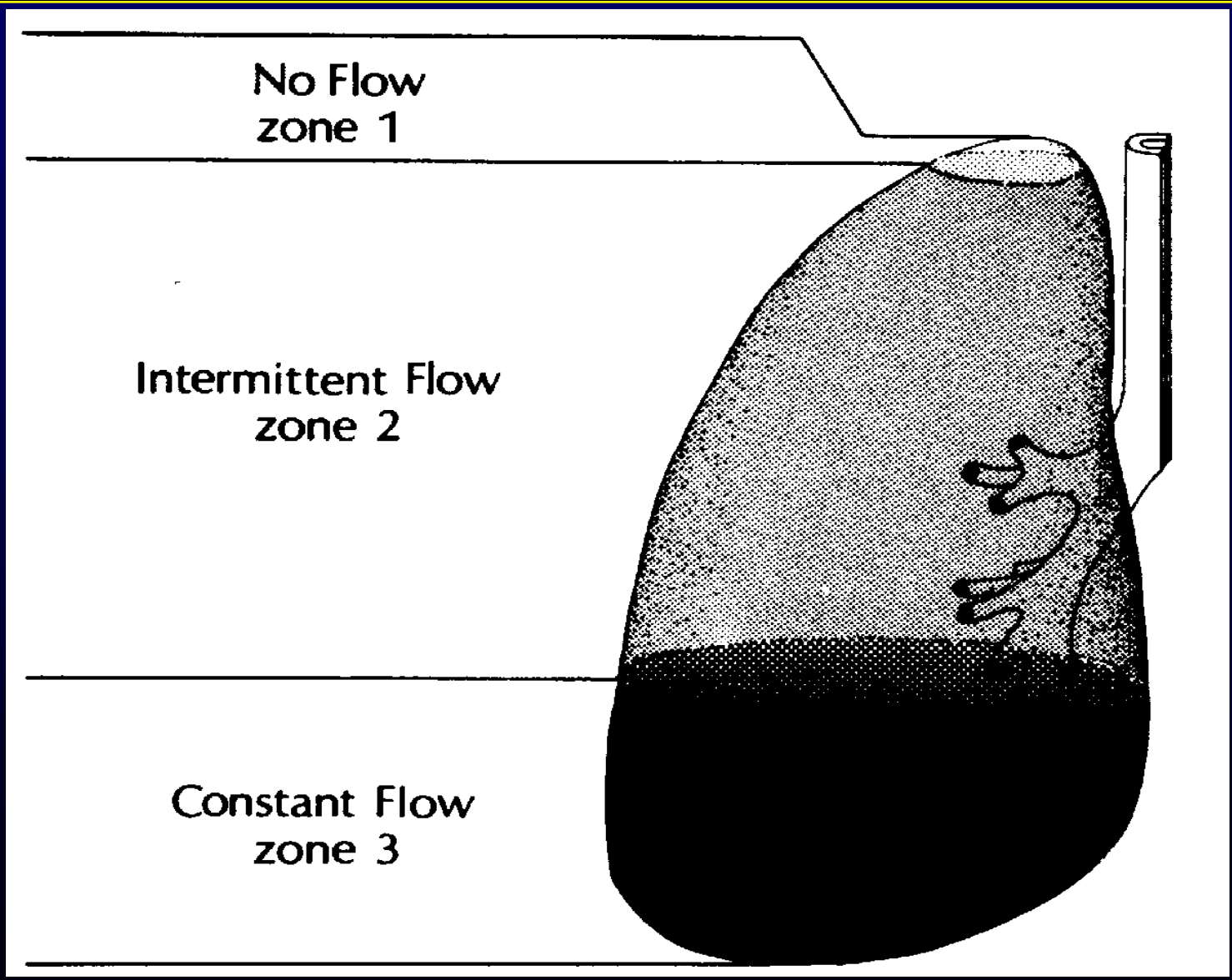
NEJM 354(16): 1671-84, 2006

Should we be Pronating Patients?

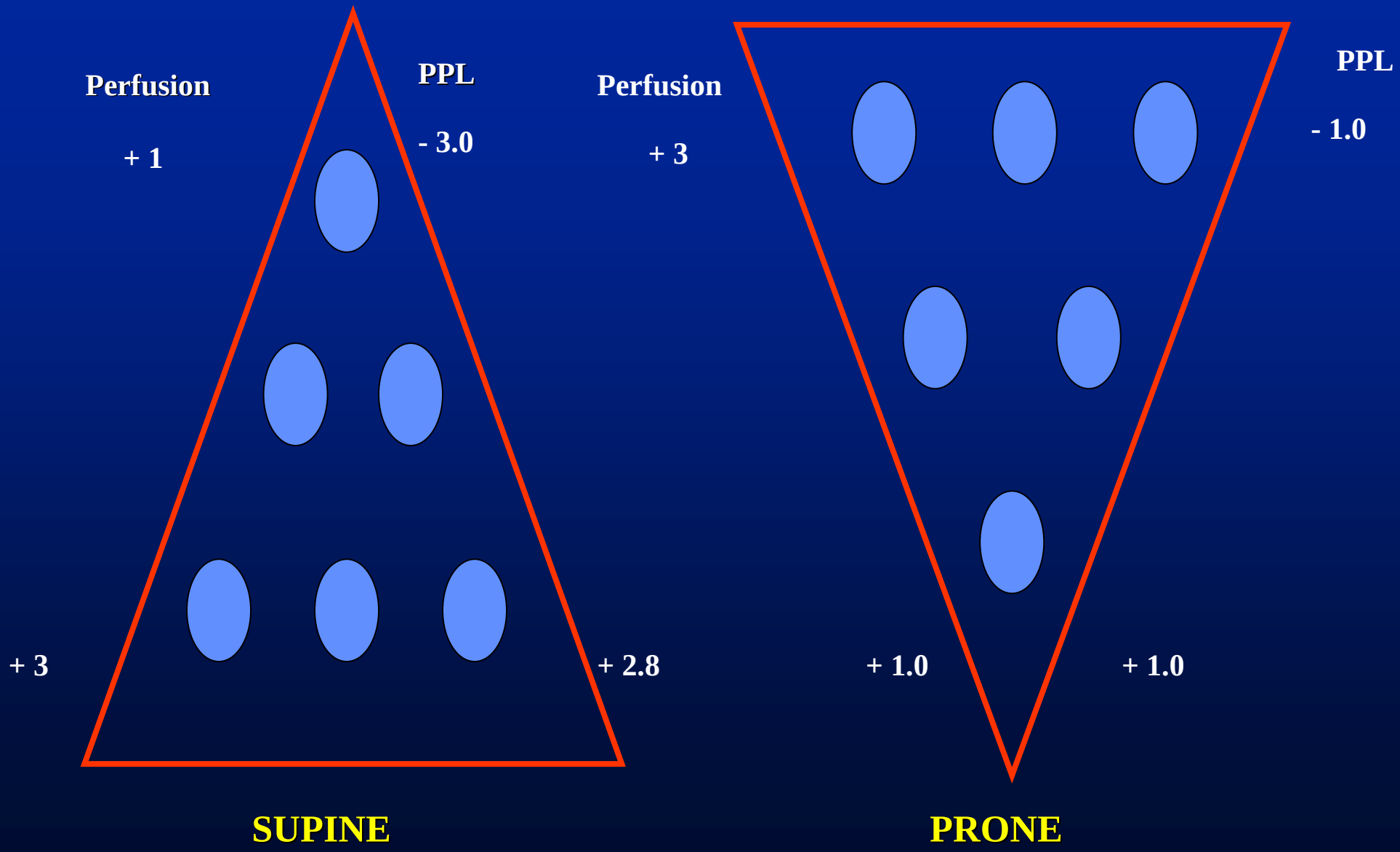




Normal Distribution of Pulmonary Perfusion in the Standing Human
Note the Profound Effect of Gravity on Blood Flow Through the Lung



Mechanism of Improved Gas Exchange with Prone Positioning

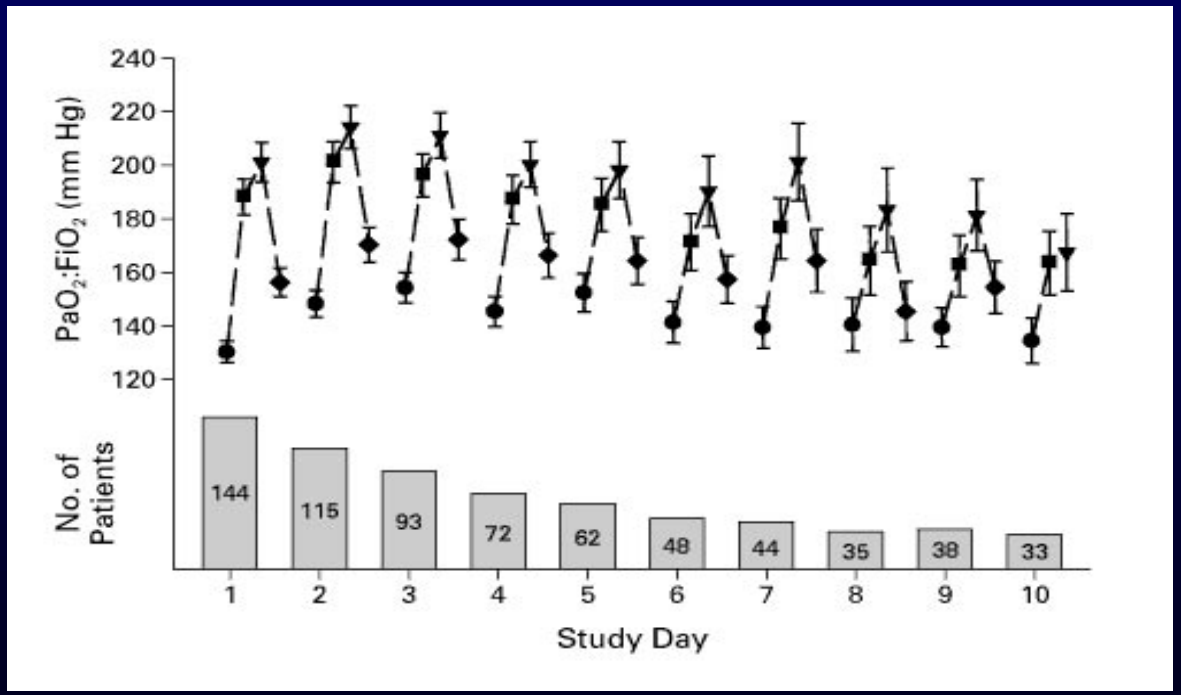


PaO_2/FIO_2 Response

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

Prone Position for ARDS

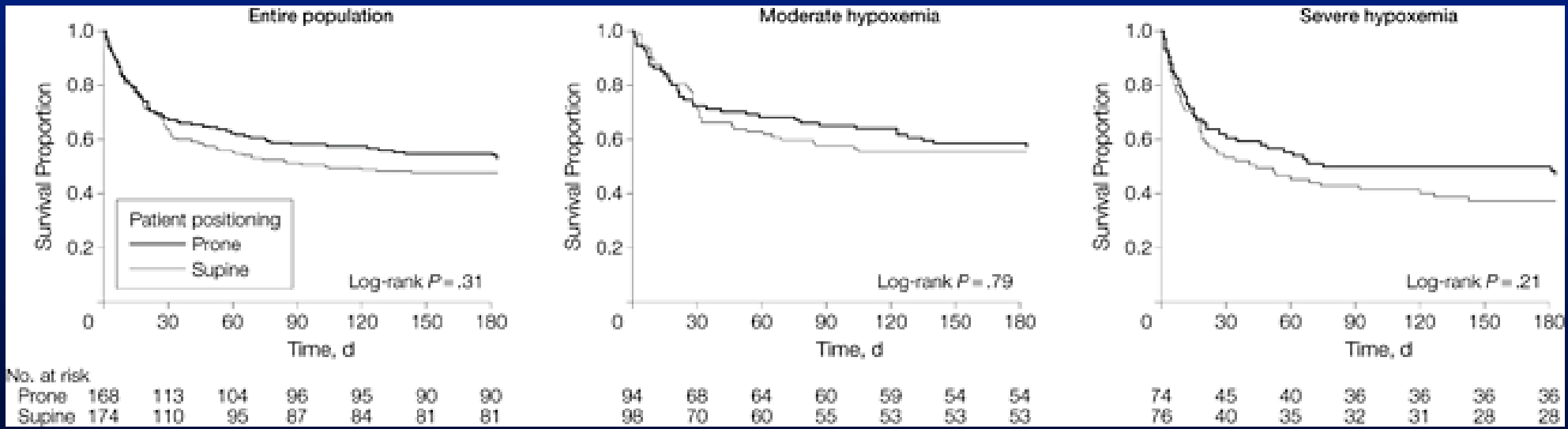


- 152 supine; 152 prone ARDS
- No difference in ICU mortality : 50.7 % vs. 48.0%
- Improved am PaO_2 in prone Pt.
- More pressure sores in prone

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

Prone Positioning in Patients With Moderate and Severe Acute Respiratory Distress Syndrome: A Randomized Controlled TrialPaolo Taccone, MD; Antonio Pesenti, MD; Roberto Latini, MD; Federico Polli, MD; Federica Vagginelli, MD; Cristina Mietto, MD; Luisa Caspani, MD; Ferdinando Raimondi, MD; Giovanni Bordone, MD; Gaetano Iapichino, MD; Jordi Mancebo, MD; Claude Guérin, MD; Louis Ayzac, MD; Lluis Blanch, MD; Roberto Fumagalli, MD; Gianni Tognoni, MD; Luciano Gattinoni, MD, FRCP; for the Prone-Supine II Study Group

JAMA. 2009;302(18):1977-1984.



Summary and Conclusions

- Ventilator modes are simple
- Ventilator modes do not determine outcome
- You should know how a mode you are using triggers, cycles and limits each breath
- Avoid high stretch and high pressure on the lung
- Regular spontaneous breathing trials improve outcome
- Prone ventilation and other recruitment maneuvers improve hypoxia but may not improve outcome

Thank You

JJ