Acute Respiratory Failure & ARDS

Nina M. Patel, MD
Assistant Clinical Professor of Medicine
Division of Pulmonary, Allergy & Critical Care
Columbia University, College of Physicians & Surgeons

Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS

Respiratory Failure

- An inability to adequately oxygenate or ventilate
  - $PaO_2 < 60$ mm Hg
  - $PaCO_2 > 45$ mm Hg

Respiratory Failure

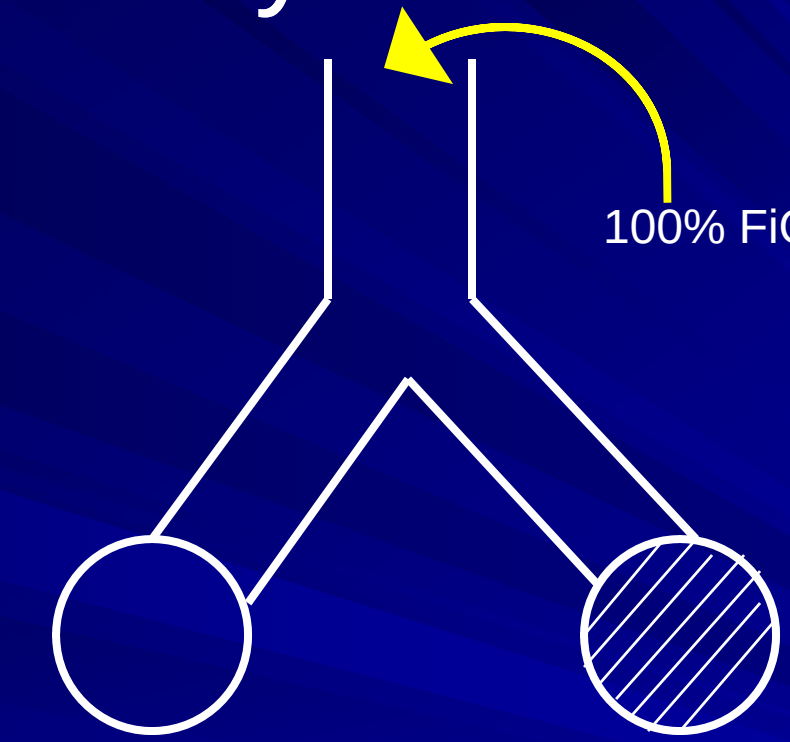
	Type I	Type II	Type III	Type IV
Mechanism	Shunt	Hypoventilation	Atelectasis	Hypoperfusion
Etiology	Alveolar flooding- low or high pressure pulmonary edema	Increased dead space, decreased minute ventilation	Decreased FRC, Increased closing volume	Decreased mixed venous oxgyen
Clinical Scenario	ARDS, CHF, Pneumonia, Alveolar hemorrhage	Airway Obstruction, Impaired Lung or Chest Wall Compliance, Neuromuscular weakness, Impaired CNS drive	Postoperative, Obesity	Shock, MI

From Hall JB, Schmidt GA, Wood LDH (eds): Principles of Critical Care, 3rd ed. New York; McGraw-Hill.

Respiratory Failure- Type I
Acute Hypoxemic Respiratory Failure

- Cardiogenic
  - "High-pressure" edema
- ARDS
  - "Low-pressure"/increased permeability edema
- Focal lung lesions
  - Pneumonia, Contusion
- Alveolar Hemorrhage syndromes
  - Goodpasture's, Wegener's disease
- Miscellaneous

Respiratory Failure- Type I



PAO2= 650 mm Hg

CcO2= 22 mL/100 mL

PvO2= 40 mm Hg

CvO2= 15 mL/100 mL

PaO2= 60 mm Hg

CaO2= 18.5 mL/100 mL

Respiratory Failure- Type I Starling Equation

* $J_v = K_f [(P_c - P_i) - \sigma(\pi_c - \pi_i)]$

K_f= filtration coefficient

P_c= hydrostatic capillary pressure

P_i= interstitial capillary pressure

π_c= oncotic capillary pressure

π_i= oncotic interstitial pressure

σ=reflection coefficient

Respiratory Failure- Type II

$$Pa_{CO2} = \frac{\dot{V}_{CO2} \times k}{\dot{V}_A}$$

- **Pa CO2 rises if:**
  - **CO2 production increases**
  - **Alveolar ventilation decreases**

Strength/ Drive

Load

CNS Drive
Sedation
Metabolic encephalopathy
OHS

Resistive
Bronchospasm
OSA
Secretions

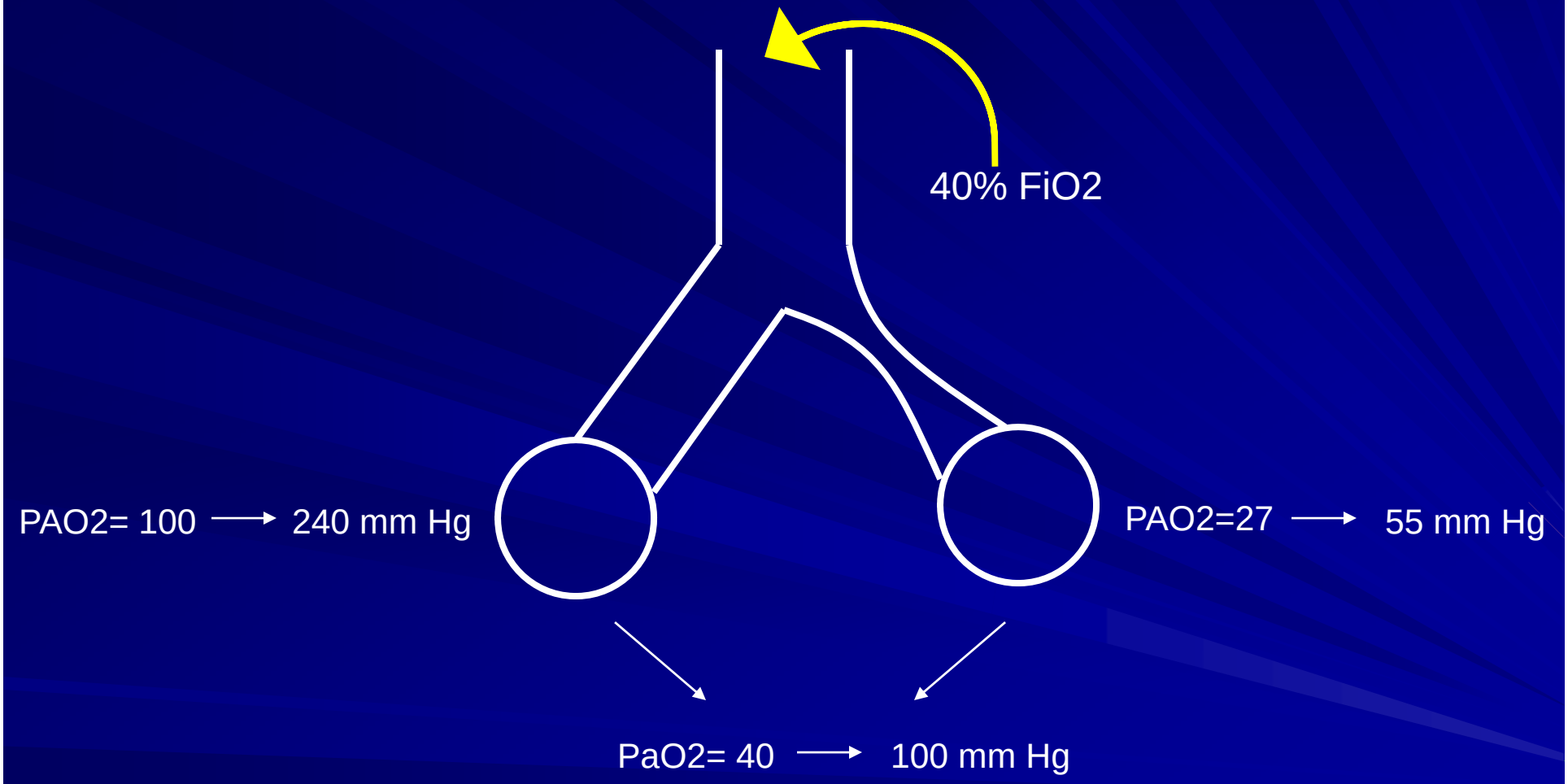
NM Transmission Impaired
ALS
Guillain-Barre Syndrome
Paralytic

Lung & Chest Wall Elastic
Pneumonia
Pulmonary Edema
Pleural Effusion
Ascites

Muscle Weakness
Malnutrition
Fatigue
Electrolyte
Hypoperfusion

Minute Ventilation
Sepsis
Pulmonary Embolism
Metabolic Acidosis

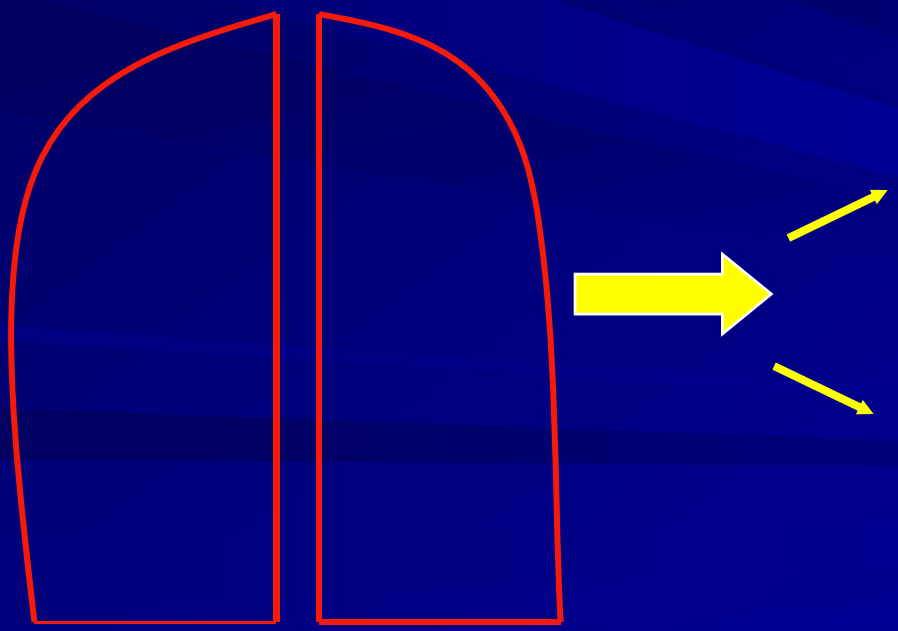
Respiratory Failure- Type II

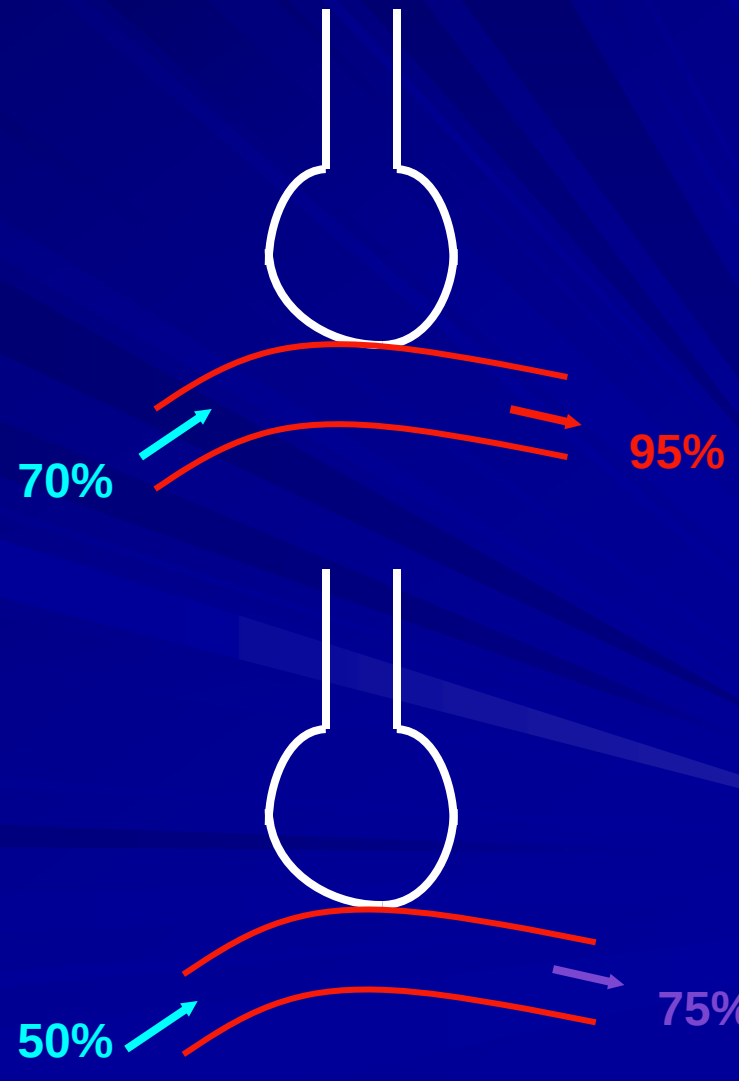


* PaO2 corrects readily with supplemental oxygen

Respiratory Failure- Type IV

- Hypoperfusion
- Cardiac output “steal”





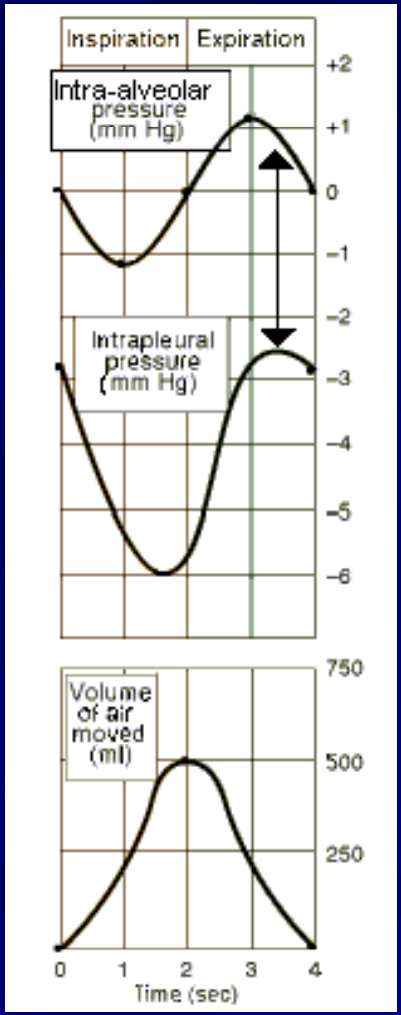
Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS

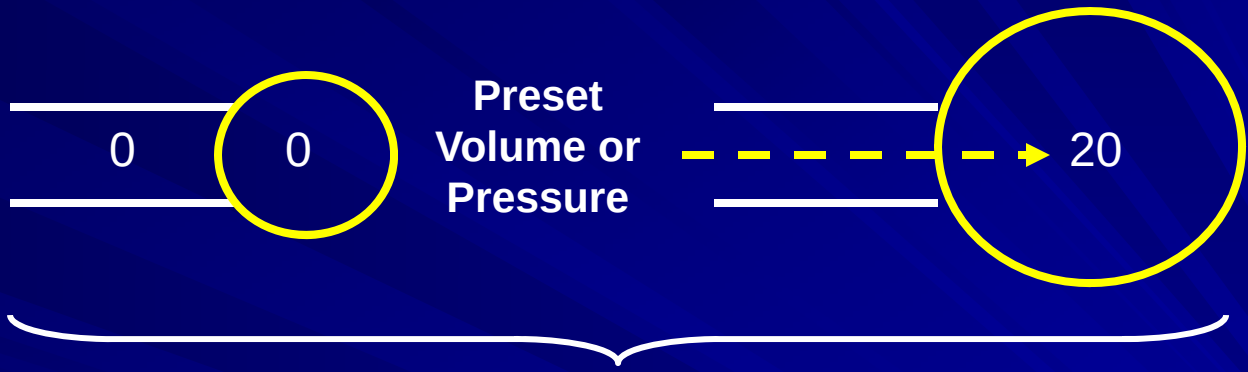
Indications for Mechanical Ventilation

- Inadequate Oxygenation
- Inadequate Ventilation
- Shock
- Airway Protection
- Elective (e.g. Sx)

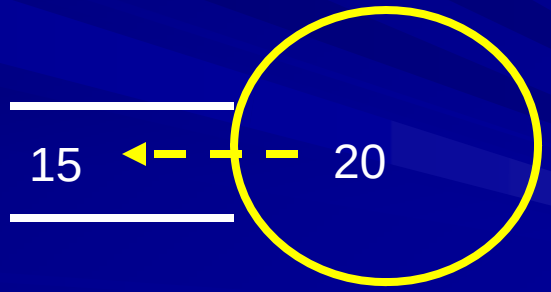
Mechanical Ventilation



Normal Respiration



Inspiration



Expiration

Positive Pressure Ventilation

Principles of Mechanical Ventilation

- Equation of Motion
  - Driving Pressure
    - **= Resistive load + Elastic load**
    - **= Airways Resistance + (lung and chest wall) Elastance**

Mechanical Ventilation

- Ventilation
  - Volume or Pressure Modes
  - Compliance determines:
    - Alveolar pressure
    - Tidal volume
- Oxygenation
  - PEEP & FiO_2

Mechanical Ventilation

- GOALS
  - Maximal Rest
  - Meet minute ventilatory requirements
  - Patient-Ventilator Synchrony
- Avoid
  - Respiratory Alkalosis
  - Barotrauma/Volutrauma
  - Auto-PEEP

Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS

ALI & ARDS Definition

- Acute onset
- Bilateral infiltrates
- PaO_2/FiO_2
  - < 300 mm Hg for ALI
  - ≤ 200 mm Hg for ARDS
- No evidence of pulmonary venous congestion
  - PCWP ≤ 18 mm Hg

Bernard GR, Artigas A, Brigham KL, et al. *AJRCC* 1994;149:818-24.

ALI & ARDS Epidemiology

- 64 to 86.2 cases/100,000 person-years
- ~142,000 - 191,000 annual cases
- Risk factors
  - EtOH abuse
  - Poor nutritional status
  - Increased age
  - Increased APACHE score

Rubenfeld GD, Caldwell E, Peabody E, et al. *NEJM* 2005;353:1685-93.
MacCallum NS; Evans TW. *Curr Opin Crit Care* 2005;11(1):43-9
From Hall, Schmidt & Wood, eds: Principles of Critical Care, 3rd ed. New York, McGraw-Hill 2005.

ARDS Causes

Direct

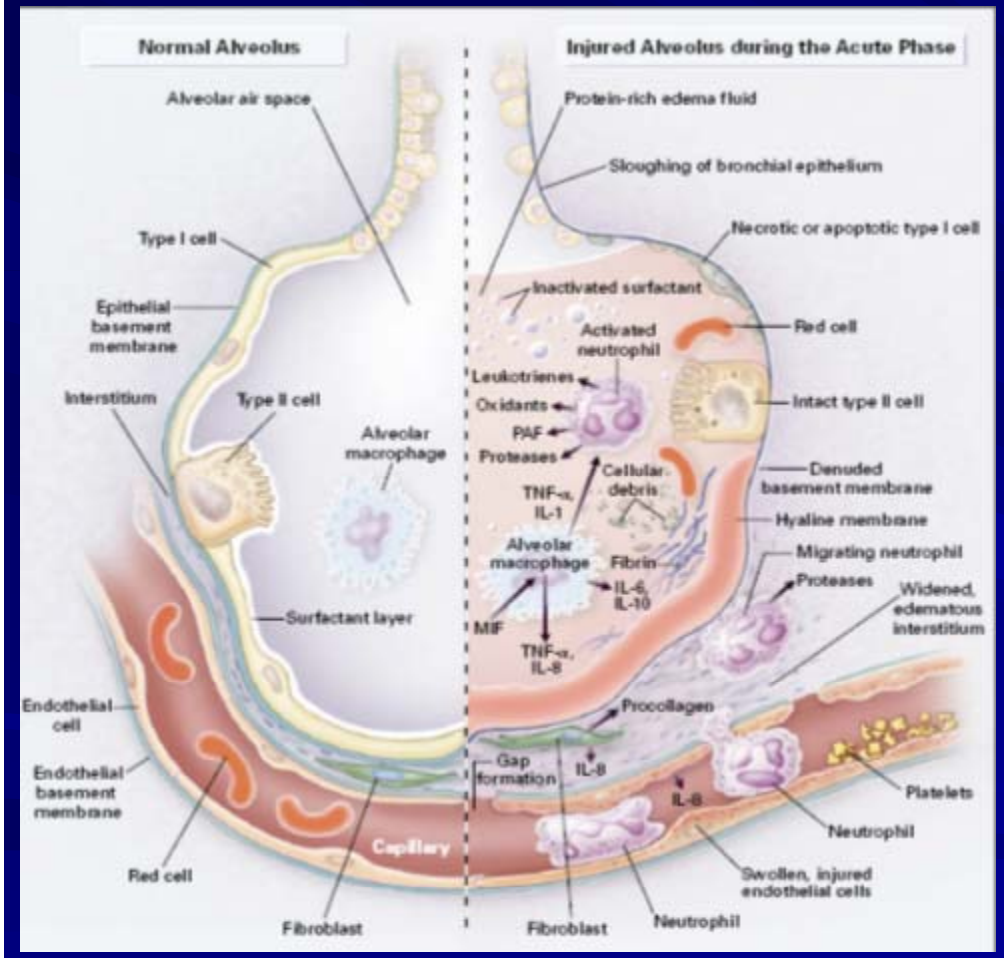
- Pneumonia
- Aspiration
- Inhalational injury (e.g. heroin/crack)
- Lung contusion
- Near-drowning

Indirect

- Sepsis
- Trauma
- Pancreatitis
- Burns
- Air, Amniotic fluid or Fat Emboli
- Drug Reaction
- Transfusion of Blood Products
- D.I.C.

From Hall, Schmidt & Wood, eds: Principles of Critical Care, 3rd ed. New York, McGraw-Hill 2005.

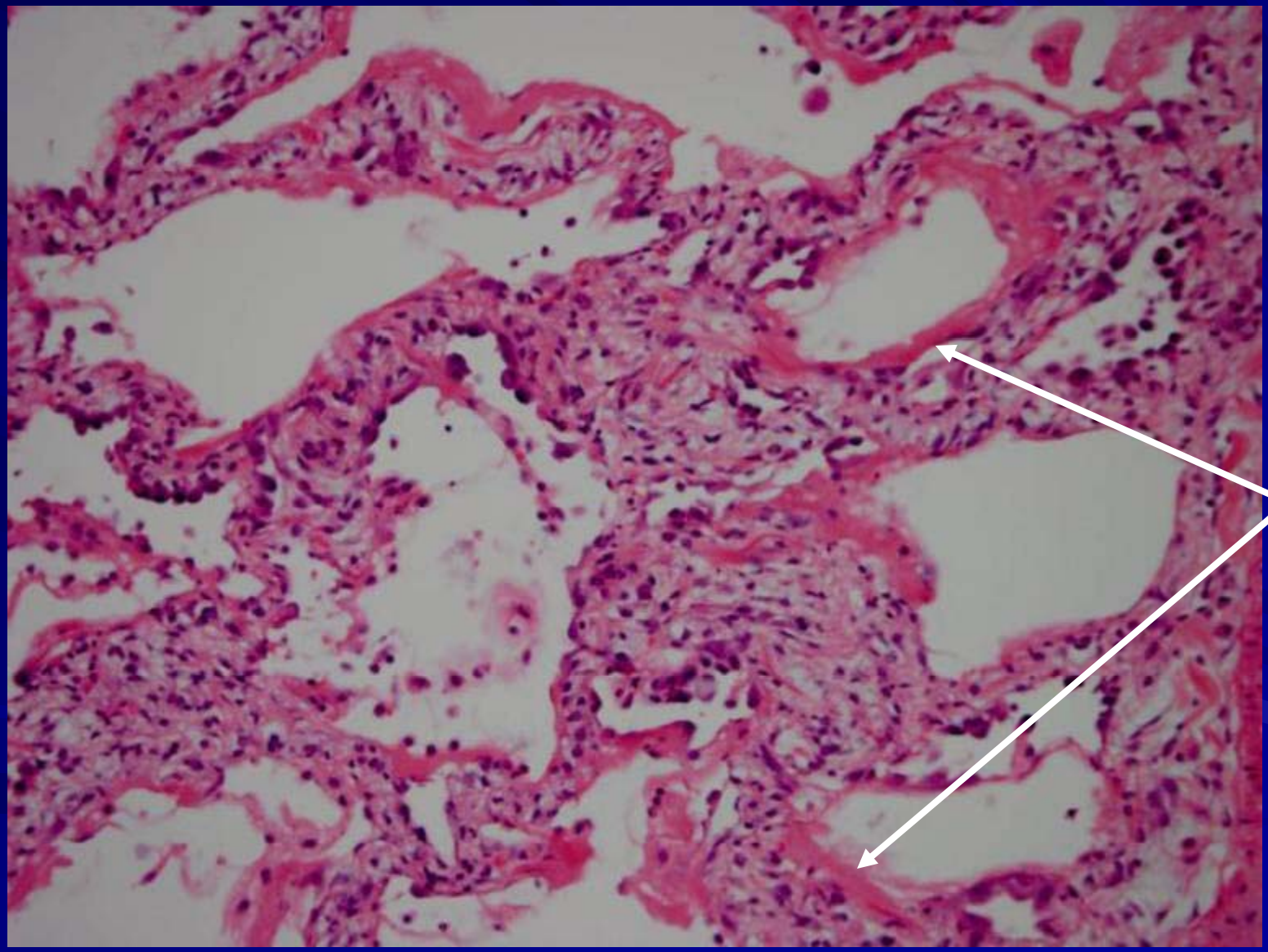
ARDS- Basic Pathophysiology



- Alveolar flooding
  - ↑ permeability alveolar-capillary barrier
  - Endothelial & epithelial injury
  - Surfactant depletion
- Inflammatory injury
  - TNFα, IL1, IL6
- Coagulation abnormalities

Ware LB, Matthay MA. *NEJM* 2000;342(18):1334-1349.

ARDS- Histopathology



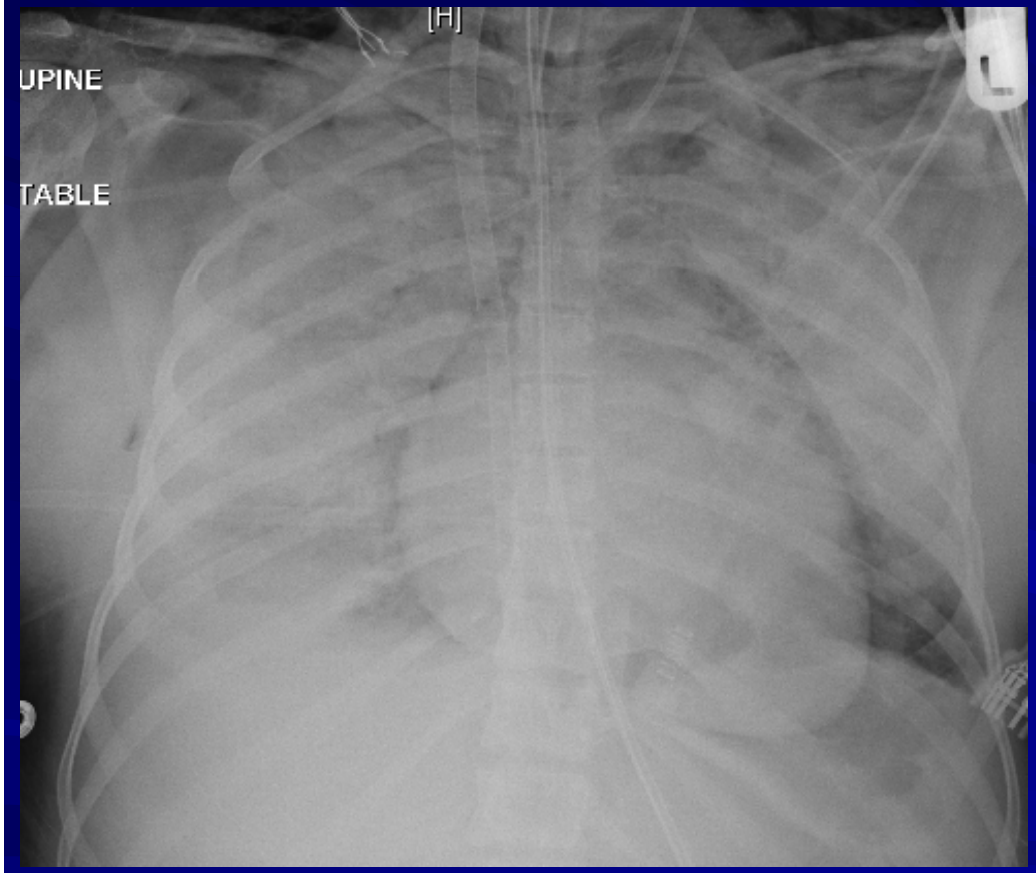
Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS

ARDS- Clinical Presentation

- History:
  - Acute onset: 4-48 hrs
- Symptoms:
  - Tachypnea, Dyspnea
- Exam
  - Severe, refractory hypoxemia
  - Diffuse “wet” crackles on lung exam

ARDS- Radiographically



- Bilateral infiltrates
- Consolidation
  - May be patchy
  - Often dependent
- Kerley B lines absent
- +/- pleural effusions & atelectasis

ARDS- Radiographically

ARDS- Differential Diagnosis

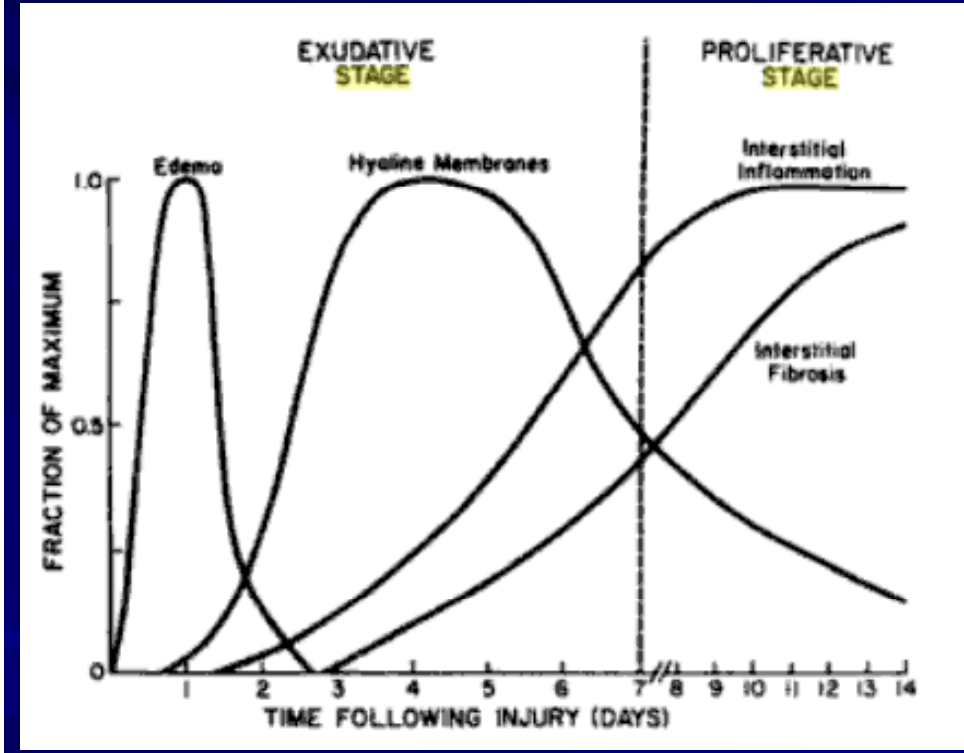
- Congestive heart failure
- Diffuse alveolar hemorrhage
- Acute eosinophilic PNA
- Acute interstitial PNA

- Less commonly:
  - Pulmonary alveolar proteinosis
  - Hypersensitivity pneumonitis
  - Cryptogenic organizing PNA

ARDS- Dx Evaluation

- Basic Labs (CBC, BMP)
- Chest X-ray
- ECG & Echocardiogram
- Bronchoalveolar lavage

ARDS- Clinical Course

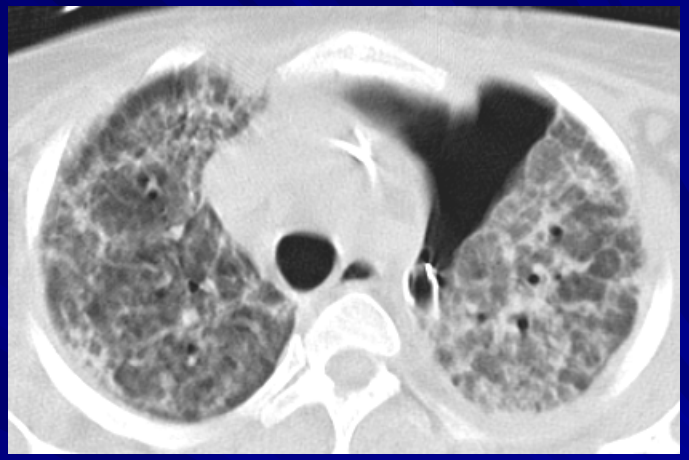


- Exudative Stage
  - Refractory hypoxemia
  - Intrapulmonary shunt
  - Decreased compliance
- Proliferative Stage
  - Increased dead space & V_E
  - Pulmonary HTN
- Resolution

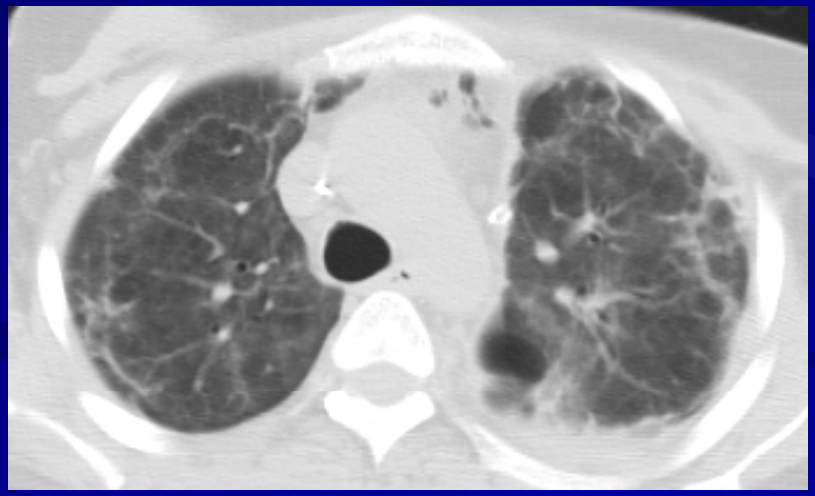
From Katzenstein AA, Askin FB: Surgical Pathology of Nonneoplastic Lung Disease, 2nd ed. Philadelphia,Saunders 1990.

ARDS- Clinical Course

Exudative



Fibroproliferative



Resolution

Objectives

- Define respiratory failure & discuss types of respiratory failure
- Brief introduction to mechanical ventilation
- Define ARDS, its epidemiology & basic pathophysiology
- Discuss clinical aspects of ARDS
- Discuss treatment of ARDS

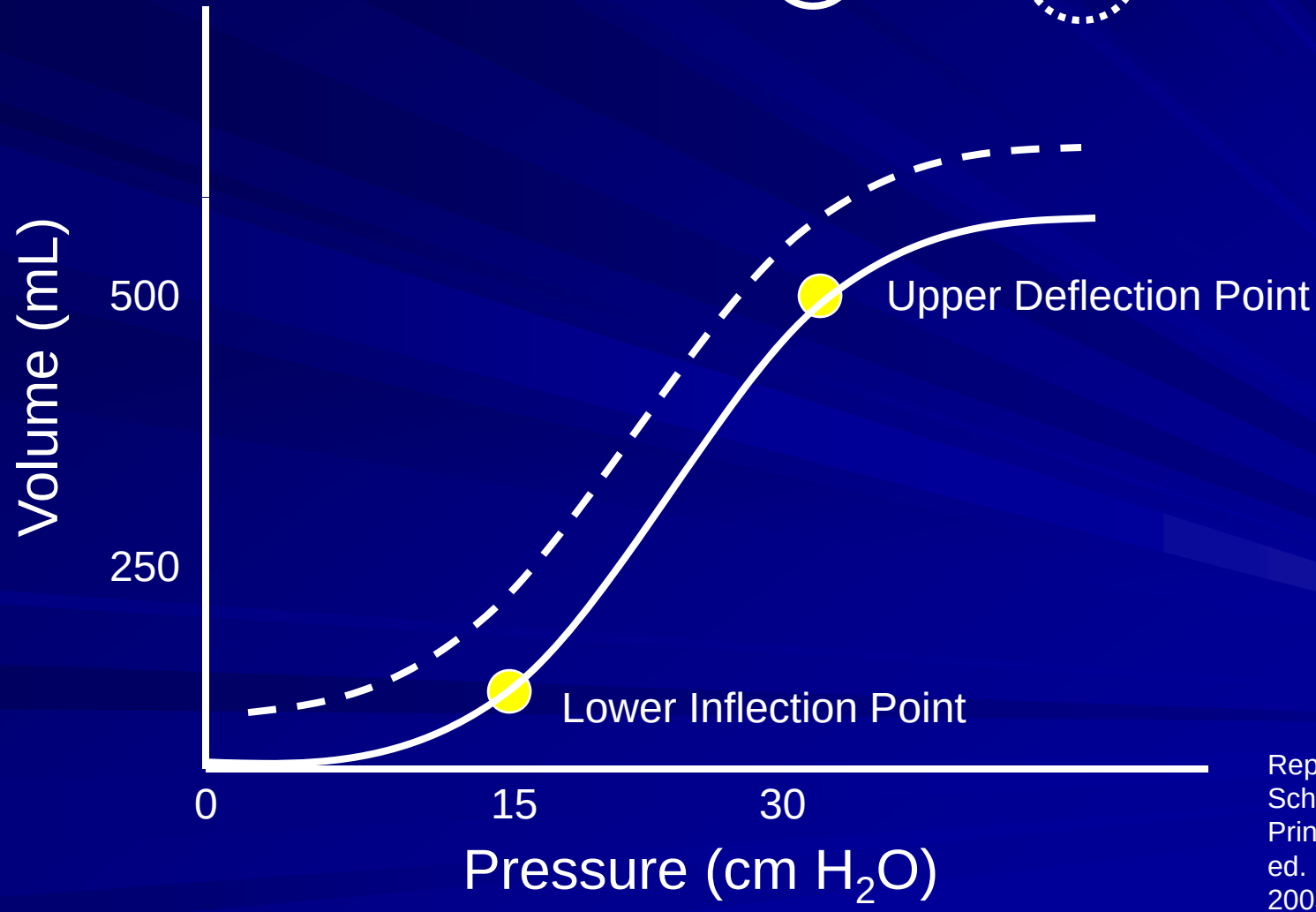
ARDS- Treatment

Treat the Underlying Cause!!!

ARDS- Treatment

- Maintain “adequate” oxygenation
  - O_2Sat ~ 88-90%
- Avoid “toxic” F_IO_2 exposure
- **Lung protective ventilation**

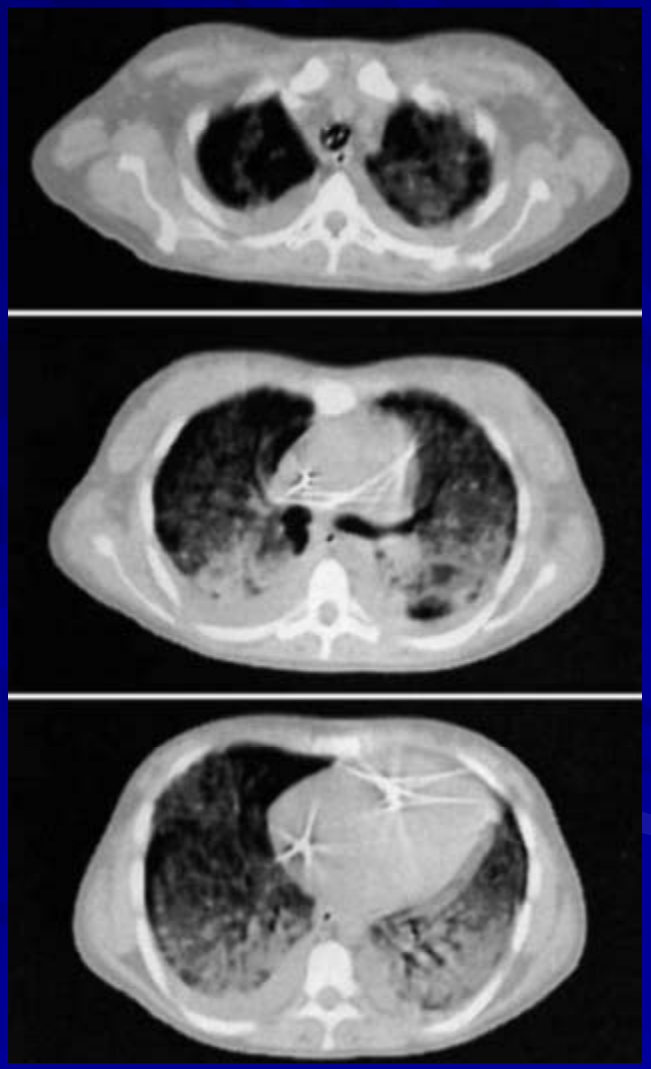
ARDS- PEEP & Oxygenation



Reproduced from Hall, Schmidt & Wood, eds: Principles of Critical Care, 3rd ed. New York, McGraw-Hill 2005.

ARDS- “Volutrauma”

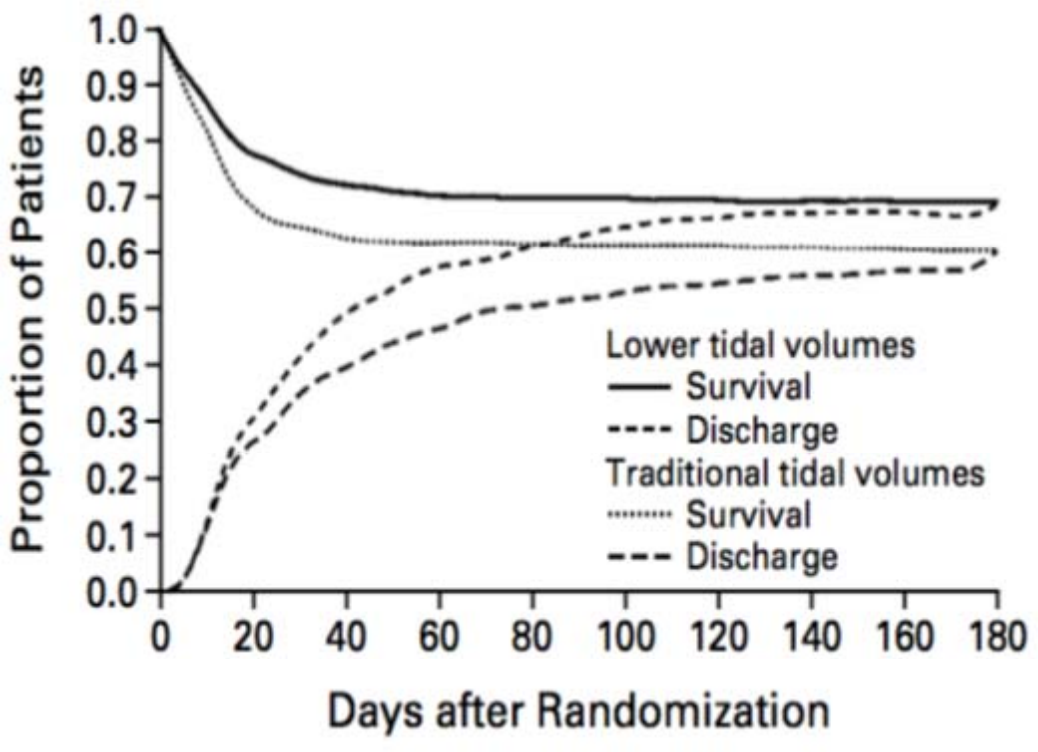
- High-tidal volumes lead to ALI
- “Baby Lungs”



Gatinnoni L, Pesenti A. *Inten Care Med* 2005 31:776-784

From Hall, Schmidt & Wood, eds: Principles of Critical Care, 3rd ed. New York, McGraw-Hill 2005.

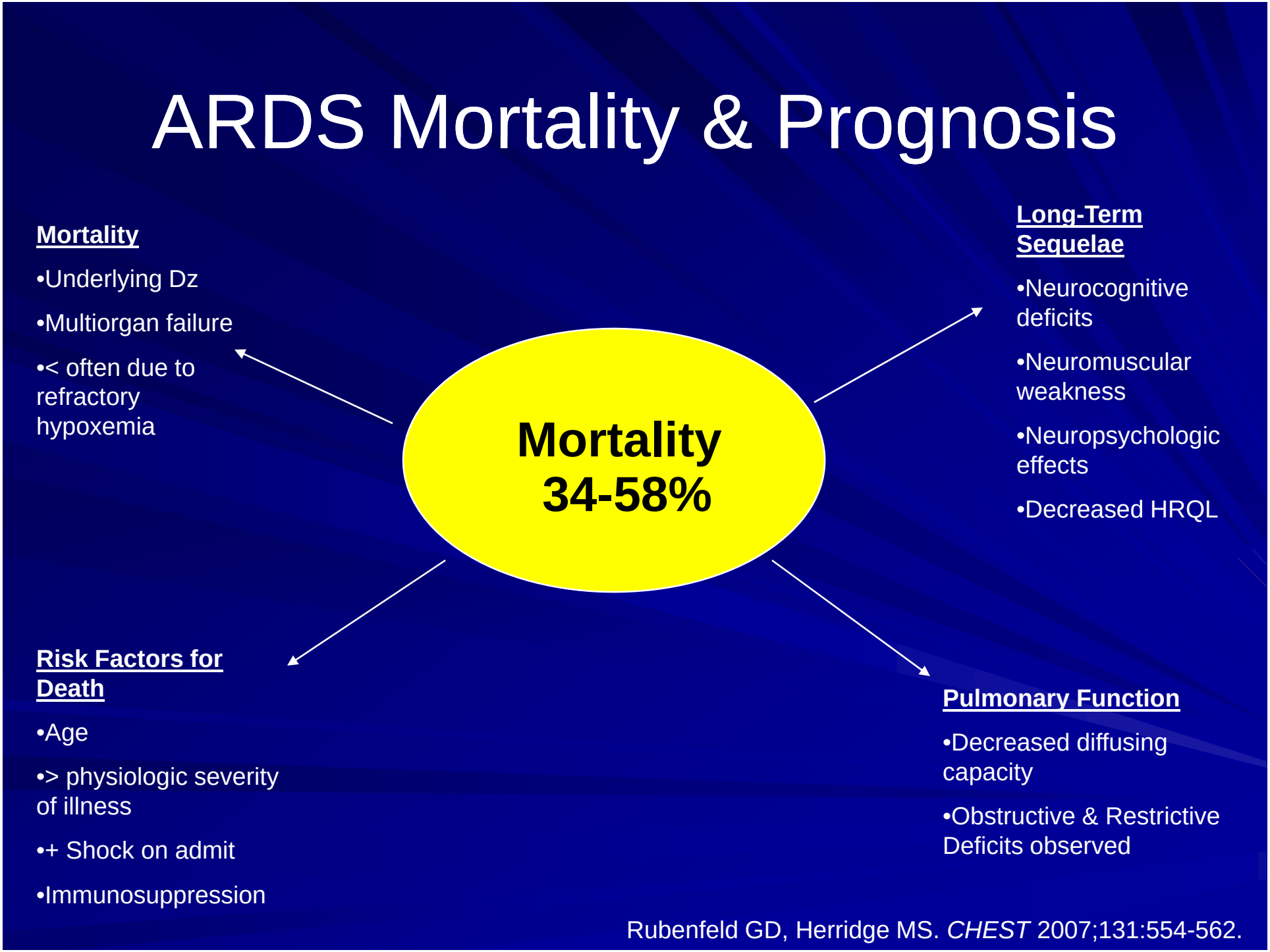
ARDS- Low tidal volume ventilation



- 9% reduction in mortality
- Lower IL-6 levels
- > days without nonpulmonary organ failure

ARDS Network. *NEJM* 2000;342:1301-8

ARDS Mortality & Prognosis



Rubenfeld GD, Herridge MS. *CHEST* 2007;131:554-562.

Thank you

Questions. . .?