Acute Respiratory Failure

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Acute Respiratory Failure

Physiologic Classification

	Type 1 Hypoxemic	Type 2 Ventilatory	Type 3 Post-op	Type 4 Shock
Mechanism	Shunt	↓Va	Atelectasis	↓Cardiac Output
Etiology	Airspace Flooding	Increased Respiratory load, Decreased ventilatory drive	Decreased FRC and increased Closing Volume	Decreased FRC and increased Closing Volume
Clinical Setting	Water, Blood or Pus filling alveoli	CNS depression, Bronchospasm, Stiff respiratory system, respiratory muscle failure	Abdominal surgery, poor insp effort, obesity	Sepsis, MI, acute hemorrhage

Respiratory Failure

Physiologic Definition:

Inability of the lungs to meet the metabolic demands of the body

Can't take in enough O_2
or
Can't eliminate CO_2 fast enough to keep up with production

Ventilatory Failure

Inbalance between load on the lungs and the ability of bellows to compensate

Respiratory Failure

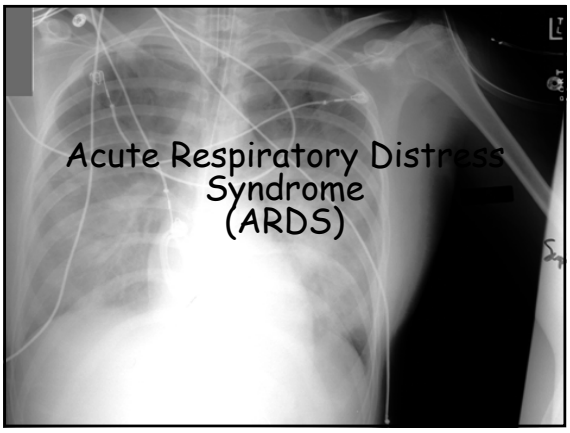
- Failure of Oxygenation: P_aO_2<60 mmHg
- Failure of Ventilation*: P_aCO_2>50 mmHg

*P_aCO_2 is directly proportional to alveolar minute ventilation

Type 1 Respiratory Failure

Acute Hypoxemic Respiratory Failure

- Shunt disease - intracardiac or intrapulmonary
- Severe V/Q mismatch - asthma, PE
- Venous admixture due to low cardiac output states, severe anemia coupled with shunt and/or V/Q mismatch



Causes of ARDS

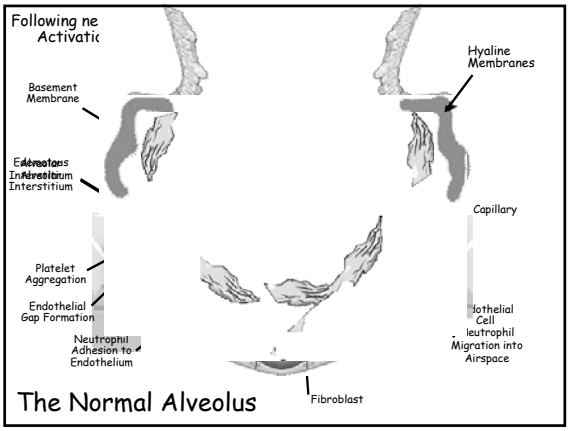
DIRECT LUNG INJURY
- Pneumonia
- Aspiration of gastric contents
- Pulmonary contusion
- Near-drowning
- Inhalation injury (Cl^-, smoke)
- Reperfusion pulmonary edema after lung transplantation or pulmonary embolectomy

INDIRECT LUNG INJURY
- Non-pulmonary sepsis/SIRS
- Severe trauma with shock
- Cardiopulmonary bypass
- Drug overdose (Narcotics)
- Acute pancreatitis
- Massive transfusion (TRALI)
- Drug reaction (ARA-C, nitrofurantoin)
- fat/air/amniotic fluid embolism,bypass

Acute Respiratory Distress Syndrome (ARDS)

American-European Consensus Definition:*
- Refractory hypoxemia
  P_aO_2/F_TO_2 (P/F ratio)
  <300 for ALI,
  <200 for ARDS
- A disease process likely to be associated with ARDS
- No evidence of elevated left atrial pressure elevation (by clinical exam, echo or PA catheter)
- Bilateral airspace filling disease

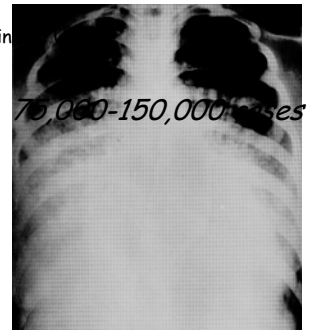
Report of the American-European Consensus conference on acute respiratory distress syndrome: definitions, mechanisms, relevant outcomes, and clinical trial coordination. Consensus Committee.



The Normal Alveolus

Acute Respiratory Distress Syndrome

Each year in

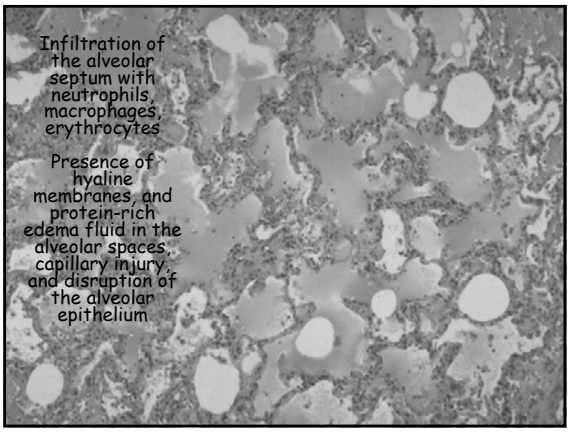


ARDS

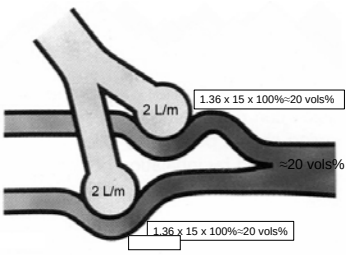
Fundamental Pathophysiology:

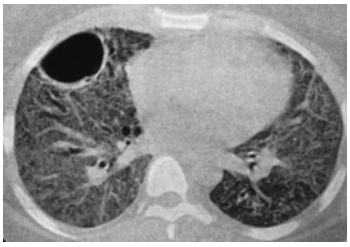
<u>Increased alveolar permeability</u> due to direct neutrophil-mediated injury to the alveolar epithelium

Not a distinct disease - rather a sequelae of activation of lung and systemic inflammatory pathways

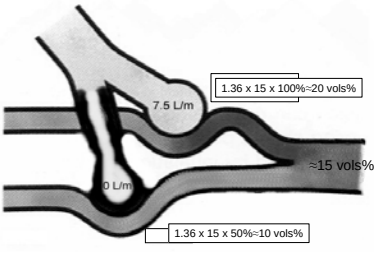


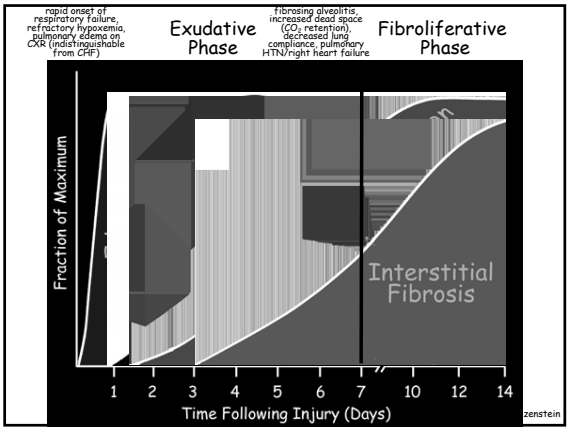
Optimal V/Q matching





Shunt





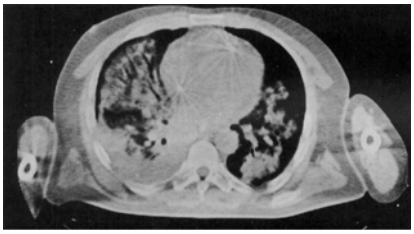
Severe Hypoxemia

Therapeutic Goals

Maintain reasonable oxygen delivery

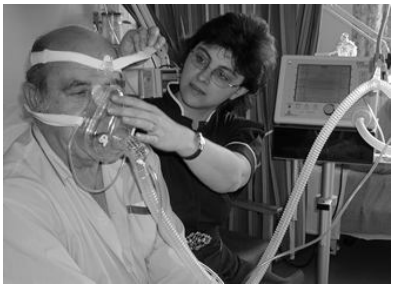
Find & fix the primary cause

"Baby Lungs"



FRC can be reduced by 80% or more in ARDS

Gattinoni, et. al. Anesthesiology, 74:15-23, 1991.

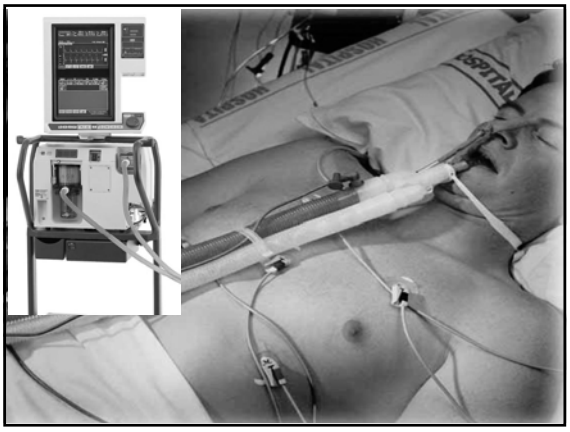


ARDS Network Trial

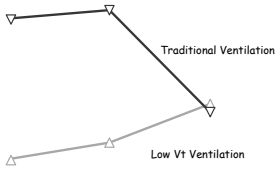
Day 1 Ventilatory Characteristics

	Low V_t Group n=432	Traditional V_t Group n=429
V_t:	6.2 ± 0.9	11.8 ± 0.8
PEEP:	9.4 ± 3.6	8.6 ± 3.6
F_iO_2:	0.56 ± 0.19	0.51 ± 0.17
P_{plat}:	25.7 ± 7	33 ± 9
P_{peak}:	32.8 ± 8	39 ± 10
P_aO_2/ F_iO_2 :	158 ± 73	176 ± 76
P_aCO_2:	40 ± 10	35 ± 8
pH:	7.38 ± 0.08	7.41 ± 0.07

NEJM 342:1301-1308, 2000

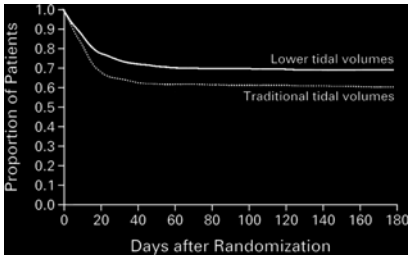


ARDS Network Trial: Oxygenation



Ventilation with low tidal was associated lower P/F ratios on days 1 & 3

ARDS Network Trial

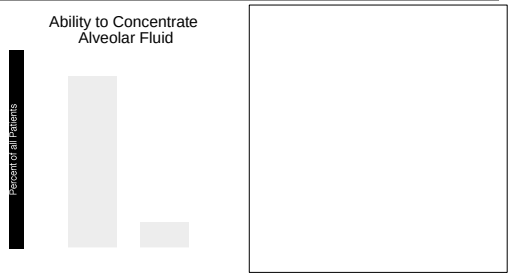


Mortality: 39.8 % in traditional tidal volume group, 31% in low tidal volume group (P=0.007)

Also: @ 28 days: more ventilator free days (12 vs. 10), more days without organ failure (15 vs 12), higher rate of liberation from ventilation rate (65.7% vs 55%)

NEJM 342:1301-1308, 2000

Pulmonary Edema Clearance Correlates with Outcome in Patients with Acute Lung Injury



Patients with intact active Na^+ transport had better survival (20% vs 62%) and shorter duration of mechanical ventilation

Ware, Am J Resp Crit Care Med. 163:1376-1383, 2001

Permissive Hypercapnea

Low tidal volume mechanical ventilation are usually associated with low alveolar minute ventilation which results in high P_aCO_2

- High P_aCO_2 is well tolerated*
- P_aCO_2 should be allowed to rise slowly
- Contraindications: increased ICP, active myocardial ischemia/severe RV or LV failure, severe metabolic acidosis
- Bicarb infusion may be used if pH<7.10

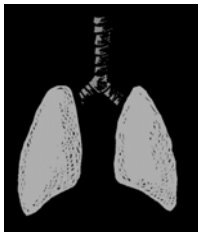
High P_aCO_2 is preferable to flogging the lungs to "normalize gases"

*Multu, Schwartz, Factor, Crit Care Med, 30:477-480, 2002
*Tuxen, Am J Resp Crit Care 150:870-90, 1994

Pulmonary Edema

Not just due to fluid leaking into alveoli

It's also a problem with fluid clearance



Pulmonary Edema Accumulation

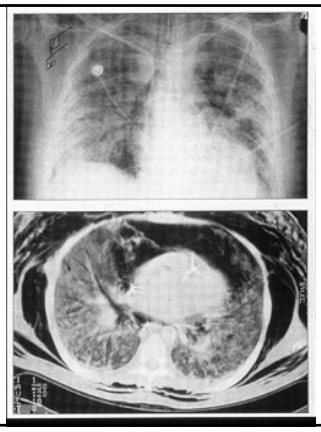
Starling's Equation

$$Q_E = K_F \left[(P_{mv} - P_{is}) - \sigma (\pi_{mv} - \pi_{is}) \right]$$

Hydrostatic Gradient pushing fluid out of the capillary

Oncotic Forces pulling fluid back into the capillary

Fluid movement across a semipermeable membrane is governed by opposing hydrostatic and oncotic pressure gradients

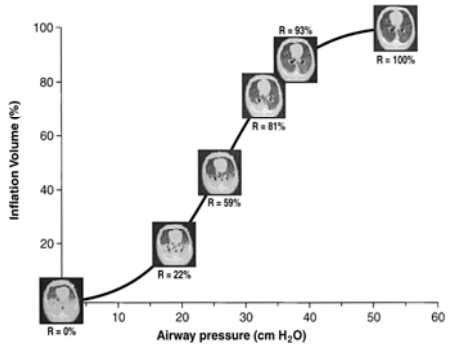


Reduce further edema accumulation

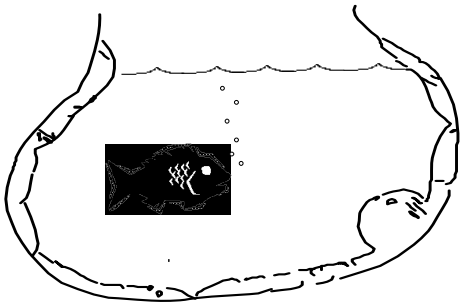
Reduce pulmonary vascular hydrostatic pressures to limit edema accumulation

"Keep-em-Dry"

Diuresis, Phlebotomy, Venodilators



What happens to alveoli in ARDS?



Positive End-Expiratory Pressure (PEEP)

- Beneficial Effects
  - Increases FRC, Cl, P_aO_2
  - Recruits Atelectatic Units
  - Decreases Qs/Qt
  - Allows Reduction in F_iO_2
- Detrimental Effects
  - Barotrauma - Volutrauma
    - Alveolar Overdistention
  - Hemodynamic Derangements

What happens to alveoli in ARDS?

Edema accumulates in alveoli

Diluting & disaggregating surfactant

Surface tension increases

Alveoli collapse

Alveolar collapse decreases FRC and contributes to hypoxemia

PEEP

Oxygen is:
- A) good for you
- B) bad for you
- C) all of the above

F_IO_2>0.6 for 24 hours or more may cause lung injury

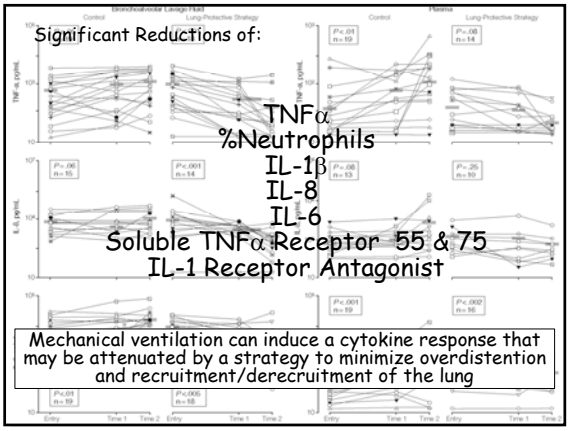
PEEP recruits collapsed alveoli,
improves FRC and
improves oxygenation

An essential therapy for patients with ARDS

ARDS Network Trial

The standard of care

Assist Control
V_t 6 cc/kg ideal body weight
PEEP of ≈8-10



Significant Reductions of:

TNFα
%Neutrophils
IL-1β
IL-8
IL-6
Soluble TNFα Receptor 55 & 75
IL-1 Receptor Antagonist

Mechanical ventilation can induce a cytokine response that may be attenuated by a strategy to minimize overdistention and recruitment/derecruitment of the lung

Cause of Death in ARDS Patients?

Generally not due to respiratory failure

The lung is not just an innocent bystander - it functions as an immunomodulatory organ that may participate in the systemic inflammatory response that leads to multiple organ system dysfunction syndrome

Biotrauma

Does Mechanical Ventilation Contribute to MSOF?

Ranieri, et al.*: randomized prospective study of the effects of mechanical ventilation on bronchoalveolar lavage fluid and plasma cytokines in patients with ARDS (primarily non-pulmonary causes).

Controls (n=19): Rate 10-15 bpm, V_t targeted to maintain $PaCO_2$ 35-40 mmHg (mean: 11 ml/kg), PEEP titrated to SaO_2 (mean: 6.5), P_{plat} maintained <35 cmH_2O

Lung protective ventilation (n=18): Rate 10-15 bpm, V_t targeted to keep P_{plat} less than upper inflexion point (mean: 7 ml/kg), PEEP 2-3 cmH_2O above LIP (mean: 14.8)

Plasma and BALF levels of Il-1β, IL-6, IL-8, TNFα, TNFα-sr 55, TNFα-sr 75, IL-1ra, measured within 8 hrs of intubation and again @24-30 hours & 36-40 hours after entry

*Ranieri, et al. Effect of mechanical ventilation on inflammatory mediators in patients with acute respiratory distress syndrome: a randomized controlled trial. JAMA 282:54-61, 1999.

Goals for Management of ARDS

The American-European Consensus Conference on ARDS, Part 2

- Ensure appropriate O_2 delivery to vital organs
- Minimize oxygen toxicity/tolerate mediocre ABG's
- Reduce edema accumulation
- Minimize airway pressures
- Prevent atelectasis/Recruit alveoli
- Use sedation and paralysis judiciously

Am J Resp Crit Care Med 157:1332-47, 1998.

Survival from "pure" ARDS

1979: 20-50%

2002: 50-90%