"ARDS"

More than just Respiratory Distress

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ONLINE FIRST

Acute Respiratory Distress Syndrome

The Berlin Definition

JAMA, June 20, 2012—Vol 307, No. 23

- First described in 1967 as Adult Respiratory Distress Syndrome
  - Acute respiratory distress
  - Cyanosis refractory to oxygen therapy
  - Decreased lung compliance
  - Diffuse infiltrates on chest radiograph
- Berlin Definition (2012)
  - Bilateral infiltrates in chest radiography within 1 week of insult
  - Resp failure that connot be explained by cardiac failure of fluid overload (normal ECHO and/or BNP)

"NON-CARDIOGENIC PULMONARY EDEMA"

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ARDS:Epidemiology

- 200,000 cases per year in the US
- Outcomes:
  - Fatalities:
    - Traditionally 30-50% mortality
    - Majority of deaths due to MSOF
  - Survivors:
    - Most of them will have normal pulmonary function within 5 years

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ARDS etiologies

- Pulmonary
  - Pneumonia
    - Bacterial, viral, fungal, or parasitic
  - Aspiration
  - Contunsion (pulm)
  - Inhalation injury
  - Fat emboli
- Extrapulmonary
  - Sepsis
  - Trauma
  - Toxicology
  - Acute Pancreatitis
  - Cardiopulmonary Bypass

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ARDS for the EMT/Medic:

- Acute respiratory distress (24-48 hrs)
- Cyanosis refractory to oxygen therapy
- Accessory muscle use
- Decreased lung compliance (difficulty in ventilation)
- Diffuse infiltrates on chest radiograph
- PaO2 refractory to oxygen therapy

Progression to ARDS was associated with higher illness severity and **intubation in the prehospital environment** or transferring facility

-Chest, August 2015

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Why ARDS is relevant to EMS…

- ARDS is a major cause of death in:
  - Trauma
  - Burns
  - Infection
  - Shock
  - Aspiration
  - Hemorrhage
  - Near Drowning
  - Overdoses

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Pulmonary Physiology

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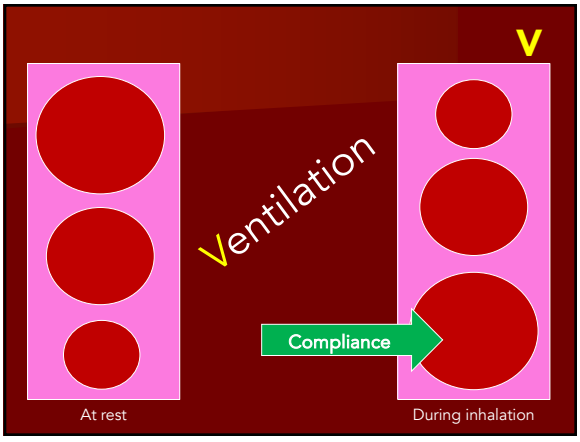

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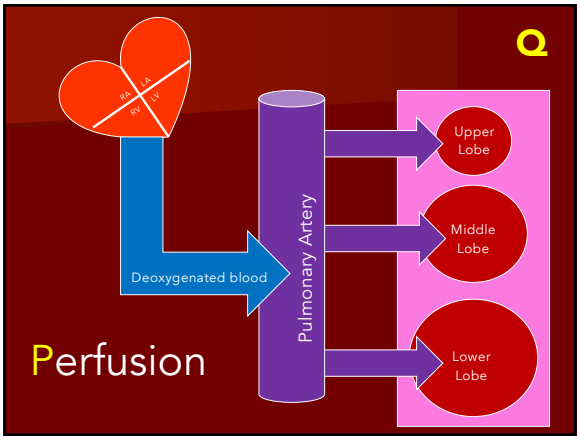

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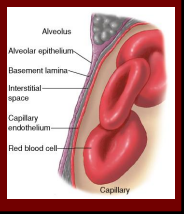
A:a gradient

- Alveolar-arterial oxygen gradient (**A-a gradient, for short**) is one way to assess the integrity of the alveolar-capillary unit and help determine the cause of a person's low PaO2



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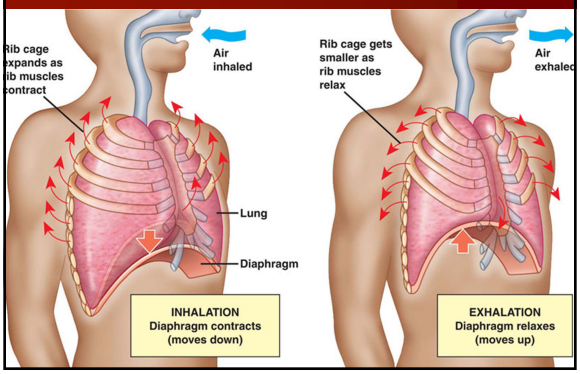
Ventilation -Mechanical



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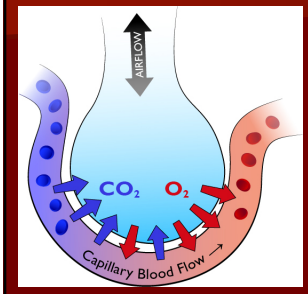
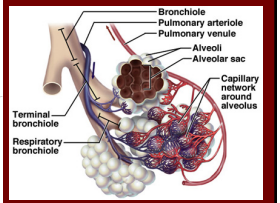
Perfusion- Chemical





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Pathophysiology of ARDS

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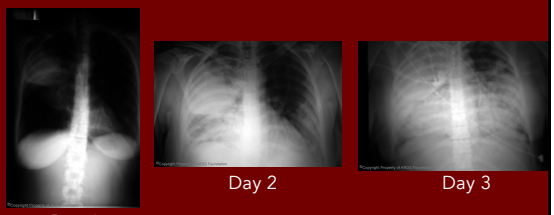
ARDS Pathophysiology

Alveolar Injury → Diffuse alveolar damage → Pro-inflammatory cytokines → PMN recruitment



Day 1 | Day 2 | Day 3

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Why the Lungs?

- Lungs receive entire cardiac output
- Any injury or any substance carried by the blood will end up in the lung
- Intimate contact with the environment
- Can easily develop a "true shunt"
  - Alveoli are NOT VENTILATED but ARE PERFUSED

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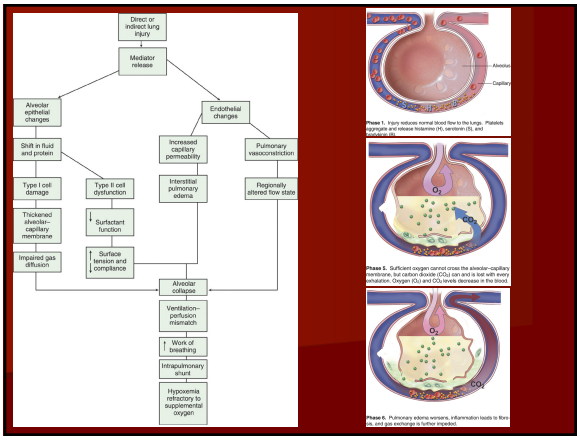

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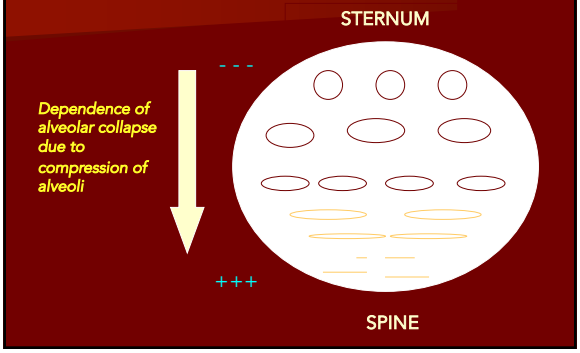
Dependent Alveolar Collapse in ARDS



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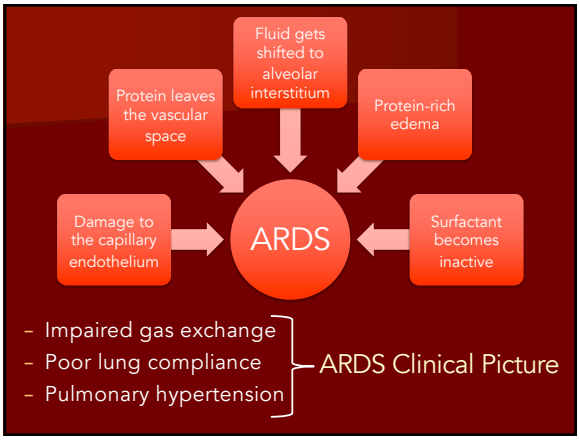

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Factors in normal control of fluid

Capillary	ECF	ICF
At the junction Between the alveloi and capillary	Outside of cells (in between cells)	Inside cells

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Fluid and Electrolytes

- Hydrostatic pressure
  - Due to water volume in vessels
  - Water through the filter…

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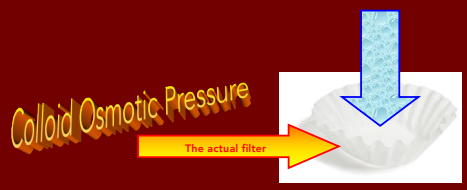
Fluid and Electrolytes

- Colloid osmotic pressure
  - Created by osmotic pressure of blood proteins (albumin)
  - The paper of the filter…



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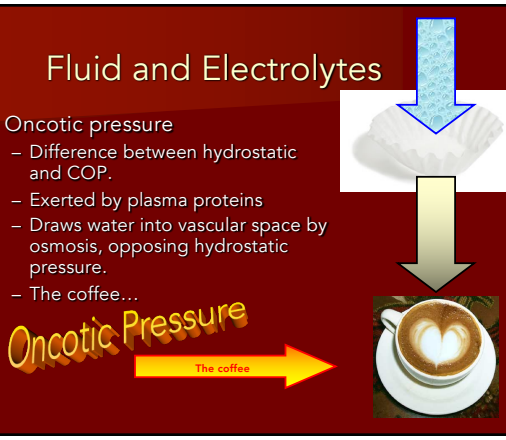
Fluid and Electrolytes

- Oncotic pressure
  - Difference between hydrostatic and COP.
  - Exerted by plasma proteins
  - Draws water into vascular space by osmosis, opposing hydrostatic pressure.
  - The coffee…



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Fluid and Electrolytes

- Hydrostatic pressure
  - Due to water volume in vessels
- Colloid osmotic pressure
  - Created by osmotic pressure of blood proteins (albumin)
- Oncotic pressure
  - Difference between hydrostatic and COP.
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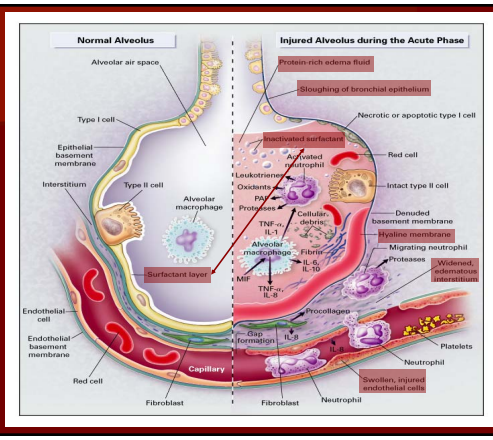

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Complications

- Secondary bacterial infection
  - Sepsis, most common and Assoc. c/ high morbidity and mortality
  - Gram negative bacteria predominate
  - Pulmonary Fibrosis due to secondary infection
- Pneumothorax assoc. c/ ventilator use and PEEP
- Pulmonary Embolism
- Multiple Organ System Failure (MSOF)

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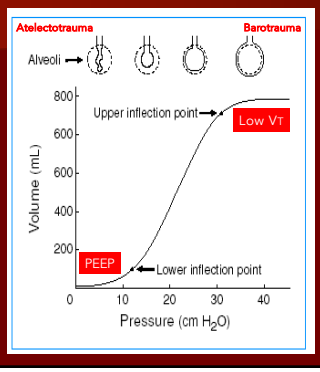
Ventilation strategies



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

- Recommended V_T of 6ml/kg –12ml/kg had been used
- Mortality was 31% vs 39.8%

The Acute Respiratory Distress Syndrome Network
N Engl J Med 2000;342:1301-8

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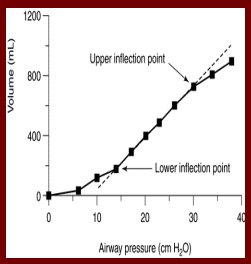
Ventilation with Lower Tidal Volumes

- The goal of providing small tidal volumes is to maintain the patient on the steep, more compliant portion of the curve without exceeding the upper inflection point



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ARDS:Permissive Hypercapnia

- Hypercarbic acidosis
  - Hypoxemia
  - Respiratory failure and arrest
  - Decrease myocardial contractility
  - Cerebral vasodilatation
  - Decrease seizure threshold
  - Hyperkalemia
- Permissive hypercapnia
  - Supplemental oxygen overcomes CO2 induced hypoxia
  - No evolution to respiratory arrest
  - Lack of significant deleterious effects
  - Is hypercarbia beneficial?

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Permissive Hypercapnia

- Patients from the low tidal volume trial
- Hypercapnic acidosis was associated with reduced 28-day mortality in the 12 mL/kg VT group after controlling for comorbidities and severity of lung injury.
- These results are consistent with a protective effect of hypercapnic acidosis against ventilator-associated lung injury that was not found when the further ongoing injury was reduced by 6 mL/kg predicted body weight tidal volumes.

Kregenov et al: Hypercapnic acidosis and mortality in ALI
Critical Care Medicine 2006;34:1-7

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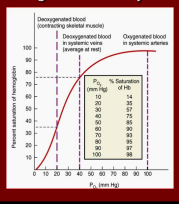
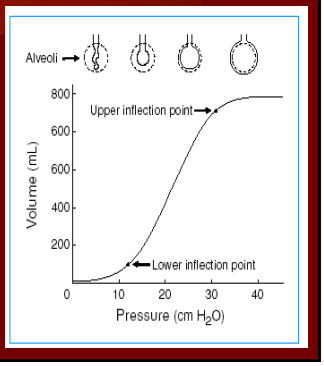
"Optimal" PEEP

- PEEP should be high enough to shift the end-expiratory pressure above the lower inflection point by 2-3 cm H2O (usually 12-15 cm H2O)
  - maximal alveolar recruitment
  - Decreases injury by repeated opening and closing of small airways

Keep PaO_2 above 88%





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ARDSnet

NIH NHLBI ARDS Clinical Network
Mechanical Ventilation Protocol Summary

INCLUSION CRITERIA: Acute onset of
1. $PaO_2/FiO_2 \leq 300$ (corrected for altitude)
2. Bilateral (patchy, diffuse, or homogeneous) infiltrates consistent with pulmonary edema
3. No clinical evidence of left atrial hypertension

PART I: VENTILATOR SETUP AND ADJUSTMENT
1. Calculate predicted body weight (PBW)
   Males = 50 + 2.3 [height (inches) - 60]
   Females = 45.5 + 2.3 [height (inches) -60]
2. Select any ventilator mode
3. Set ventilator settings to achieve initial V_T = 8 ml/kg PBW
4. Reduce V_T by 1 ml/kg at intervals ≤ 2 hours until V_T = 6ml/kg PBW.
5. Set initial rate to approximate baseline minute ventilation (not > 35 bpm).
6. Adjust V_T and RR to achieve pH and plateau pressure goals below.

OXYGENATION GOAL: PaO_2 55-80 mmHg or SpO_2 88-95%
Use a minimum PEEP of 5 cm H_2O. Consider use of incremental FiO_2/PEEP combinations such as shown below (not required) to achieve goal.

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

Higher PEEP/lower FiO2

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

FiO_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0	
PEEP	18	20	22	22	22	24	

PLATEAU PRESSURE GOAL: ≤ 30 cm H_2O
Check Pplat (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or V_T.
If Pplat > 30 cm H_2O: decrease V_T by 1ml/kg steps (minimum = 4 ml/kg).
If Pplat < 25 cm H_2O and V_T< 6 ml/kg, increase V_T by 1 ml/kg until Pplat > 25 cm H_2O or V_T = 6 ml/kg.
If Pplat < 30 and breath stacking or dys-synchrony occurs: may increase V_T in 1ml/kg increments to 7 or 8 ml/kg if Pplat remains ≤ 30 cm H_2O.

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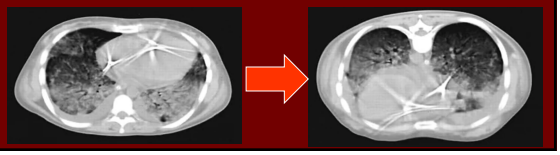
The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 JUNE 6, 2013 VOL. 368 NO. 23

Prone Positioning in Severe Acute Respiratory Distress Syndrome

- 28 day mortality
  - Prone: 16%
  - Supine: 32.8%



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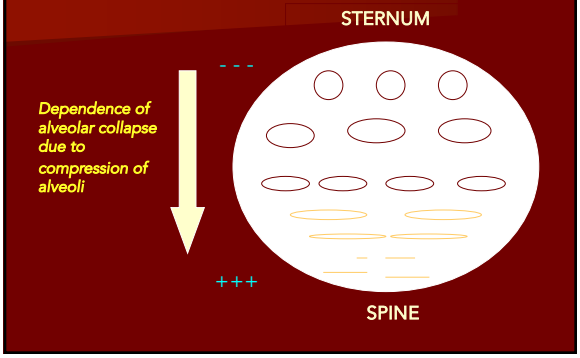
Dependent Alveolar Collapse in ARDS



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PaO_2 ↑ by > 20% in 70% of the study population

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Fluid Balance

- Fluid and hemodynamic management
  - Optimal fluid management is controversial
    - There is data supporting fluid restriction as a mean to minimize lung edema
    - However maintenance and preservation of oxygen delivery may require fluid administration
  - Euvolemia, judicious use of vasopressors
  - Effects of ventilation in circulation
- Avoid blood and blood products if at all possible
  - RBC's and FFP increase incidence of ARDS by 40%
  - Platelets double the risk

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The NEW ENGLAND JOURNAL of MEDICINE

N ENGL J MED 354;24 WWW.NEJM.ORG JUNE 15, 2006

ORIGINAL ARTICLE

Comparison of Two Fluid-Management Strategies in Acute Lung Injury

- 1000 patients
- Mortality at 60 days was similar between groups and demonstrated no statistically relevant differences
- Conservative fluid replacement showed better
  - Oxygenation index
  - Lung injury score
  - ventilator free days and
  - days not spent in the ICU
- Fluid balances were similar among the groups

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[Original Research **Critical Care**] CHEST 2015; 147(6):1510-1522 CHEST

The Use of Inhaled Prostaglandins in Patients With ARDS

A Systematic Review and Meta-analysis

Brian M. Fuller, MD, MSCI; Nicholas M. Mohr, MD; Lee Skrupky, PharmD, BCPS; Susan Fowler, MLIS; Marin H. Kollef, MD, FCCP; and Christopher R. Carpenter, MD

- Inhaled nitric oxide
  - Most ARDS/ALI patient may have mild to moderate pulmonary HTN
  - Improvement in oxygenation was small and not sustained
  - No change on mortality or duration of mechanical ventilation
  - May be used as "rescue" therapy but NO EVNIDENCE of reduced mortality

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[Original Research **Critical Care**] CHEST 2015; 147(6):1510-1522 CHEST

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- Inhaled Prostaglandins
  - Increasing frequency despite lack of research
  - Huge meta analysis suggest there are benefits which include improved oxygenation and decreased PAP BUT SIGNIFICANT HYPOTENSION
- Surfactant
  - Successful in neonatal respiratory distress syndrome

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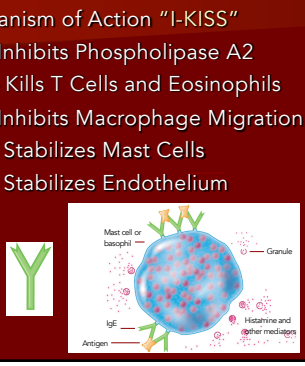
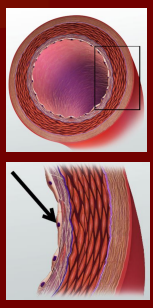
Steroids

- Mechanism of Action "I-KISS"
  - I – Inhibits Phospholipase A2
  - K – Kills T Cells and Eosinophils
  - I – Inhibits Macrophage Migration
  - S – Stabilizes Mast Cells
  - S – Stabilizes Endothelium





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ARDS: Treatment

- Glucocorticoids
  - No benefits in acute phase
  - Some evidence of improvement during proliferative phase *(Meduri et al JAMA 1998;280:159-165)*
    - Methylprednisolone 2mg/kg initially for 32 days
    - Improvement in Lung injury scores, MOSD scores and mortality
    - Benefits may be noticed by day 3
  - High risk of infection

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The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 APRIL 20, 2006 VOL. 354 NO. 16

Efficacy and Safety of Corticosteroids for Persistent Acute Respiratory Distress Syndrome

- 180 patients
- Mortality at 60 days
  - 28.9% mortality in the placebo group and 29.2% in the methylprednisolone group
  - Methylprednisolone **increased the number of ventilator free and shock free days** during the **first 28 days** in association with an improvement in oxygenation, respiratory system compliance and blood pressure with fewer vasopressor days
  - But methylprednisolone was associated with a **significant increase 60-180 days mortality** in patients **enrolled at least 14 days** after the onset of ARDS

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Boyle et al. Critical Care (2015) 19:109
DOI 10.1186/s13054-015-0846-4

CRITICAL CARE

RESEARCH Open Access

Aspirin therapy in patients with acute respiratory distress syndrome (ARDS) is associated with reduced intensive care unit mortality: a prospective analysis

Andrew J Boyle[1,2*], Stefania Di Gangi[3], Umar I Hamid[1], Linda-Jayne Mottram[2], Lia McNamee[2], Grania White[2], LJ Mark Cross[1,2], James J McNamee[2], Cecilia M O'Kane[1] and Daniel F McAuley[1,2]

- ASA therapy in the prehospital and in-hospital setting led to reduced ICU mortality – LOS and overall mortality were not impacted.

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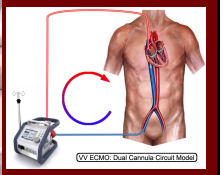
ECMO
Extracorporeal Membrane Oxygenation



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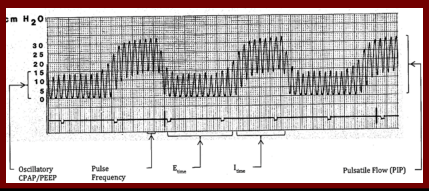
AARC Journal 2015 Pulmonary

Use of HFPV for Adults with ARDS: The Protocolized Use of High-Frequency Percussive Ventilation for Adults with Acute Respiratory Failure Treated with Extracorporeal Membrane Oxygenation

Andrew J. Michaels, Jon G. Hill, Bernie P. Sperley, Brian P. Young, Tawyna L. Ogston, Connor L. Wiles, Peter Rycus, Tanya R. Shanks, William B. Long, Lori J. Morgan, and Robert H. Bartlett

- Subphysiologic tidal volumes at super fast rate (200-900 / minute)



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Critical Care Medicine
Issue: Volume 24(8), August 1996, pp 1396-1402
Copyright: © Williams & Wilkins 1996. All Rights Reserved.
Publication Type: [Pediatric Critical Care]
ISSN: 0090-3493
Accession: 00003246-199608000-00020
[Pediatric Critical Care]

Predicting outcome in children with severe acute respiratory failure treated with high-frequency ventilation

Sarnaik, Ashok P. MD FCCM; Meert, Kathleen L. MD; Pappas, Michael D. MD; Simpson, Pippa M. PhD; Lieh-Lai, Mary W. MD; Heidemann, Sabrina M. MD

- Significant improvement in pH, PaCO2, PaO2 and PaO2/FiO2 occurred within 6 hours after institution of HFV
- The improvement in gas exchange was sustained
- In patients with potentially reversible underlying diseases resulting in severe acute respiratory failure that is unresponsive to conventional ventilation, high frequency ventilation improves gas exchange in a rapid and sustained fashion.

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ARDS specific ventilation

1. small tidal volumes (6 mL/kg predicted body weight) and
2. maintaining a plateau pressure of ≤30 cm

Airway Pressure Release Ventilation (APRV) *may* decrease the peak airway pressure, improve alveolar recruitment, increase ventilation of the dependent lung zones and improve oxygenation

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APRV (bi-level) settings?

- **P-High**
  - Transitioning from volume-cycled ventilation: set equal to plateau pressure.
  - Transitioning from pressure-cycled ventilation: set equal to peak pressure.
  - Often start ~25 cm.
- **P-Low**
  - Set to zero.
- **T-High**
  - Set to 5 seconds.
- **T-Low**
  - Set to 0.5 seconds initially.
  - Adjust to achieve an end-expiratory flow equal to 75% of the peak expiratory flow rate
- **FiO2**
  - Start high, titrate down ASAP.

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Prognosis

- > 50%-60% mortality
  - Last decade 40%
- Many patients have little or no permanent sequelae
- Early Detection Most Important

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The End!

wkrost@gwu.edu

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