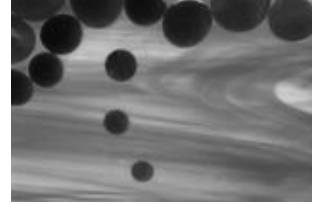


Respiratory Failure Oxygenation vs. Ventilation

Wendy Lawson MPH, RRT, AE-C

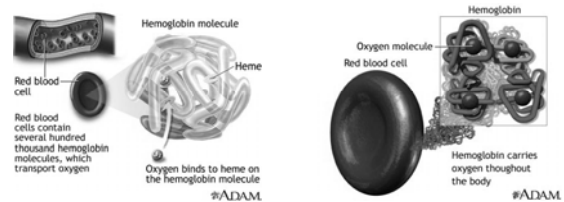
A little review of Oxygenation



What is the difference?

- PaO₂
- SaO₂
- SpO₂
- Why do we care about hemoglobin?

Oxygenation depends on Hemoglobin!

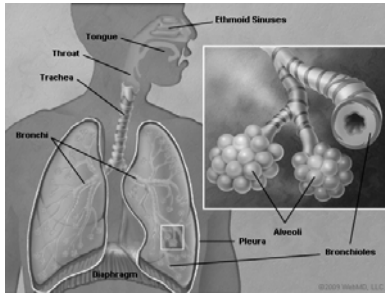


How much O₂ in the blood?

- $CaO_2 = Hb \text{ (gm/dl)} \times 1.34 \text{ ml O}_2/\text{gm Hb} \times SaO_2 + PaO_2 \times (.003 \text{ ml O}_2/\text{mm Hg/dl})$.



A little overview of Ventilation

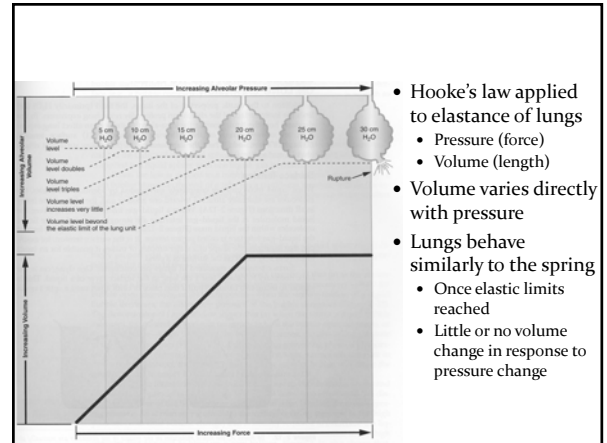
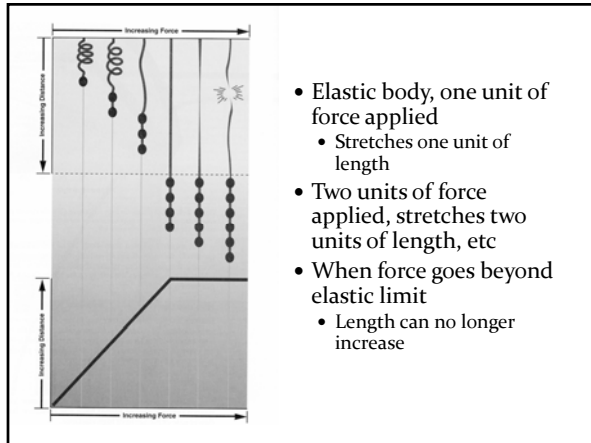


Hooke's Law -- P/V

□ **Elastance:** Ability of matter to return to its original resting position or shape



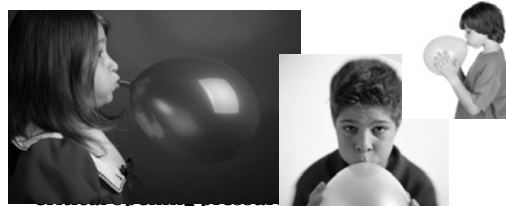
□ Volume varies with pressure
 • ✓ Pressure causes ✓ Volume



Surface Tension

- Holds the liquid surface intact at liquid gas interface
 - Liquid molecules strongly attracted to other liquid molecules within the liquid mass
- Air liquid interface creates high surface tension
 - **Surfactant decreases surface tension**

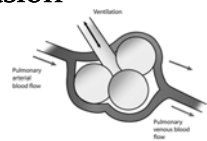
- High pressure is required to expand a collapsed alveolus until its radius is equal to that of the alveolar duct supplying it.



- when critical opening pressure is exceeded, rapid expansion of the alveolus occurs

Ventilation and Perfusion

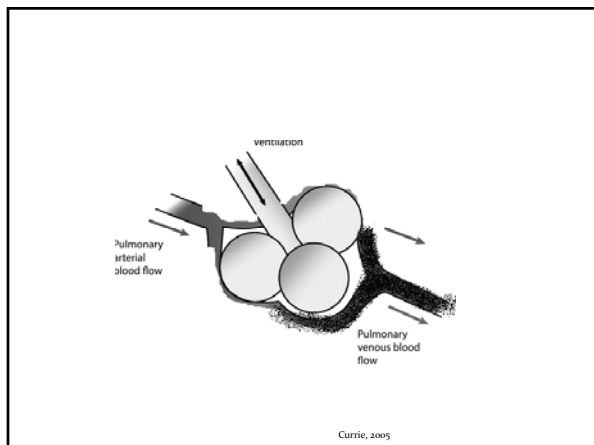
- **Ventilation = gas exchange**
- **Perfusion = blood flow**



- **Ventilation (V) / Perfusion (Q) Ratio**
 - Normal alveolar minute ventilation is 4 liters per minute
 - Normal cardiac output is 5 liters per minute
 - $4\text{ L} / 5\text{ L} = 0.8$ **Normal V/Q Ratio**

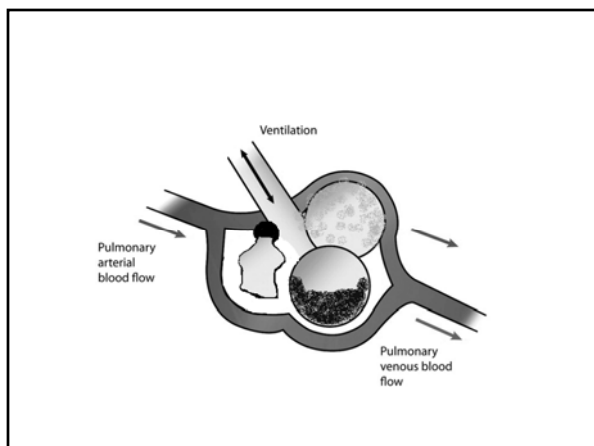
Ventilation and Perfusion

- High V/Q Ratio (> 0.8) = **Deadspace**
 - Oxygenated cells aren't being picked up and distributed
 - Caused by anything that could decrease blood flow to the lung
 - pulmonary embolism,
 - shock,
 - decreased cardiac output/index,
 - excessive PEEP



PHYSIOLOGY

- Low V/Q ratio (< 0.8) = **Shunt**
 - Circulating blood is not being oxygenated properly
 - Ex: pulmonary edema, pneumonia, ARDS, asthma, emphysema, mucous plugs, tumor
 - Two types of shunt
 - Anatomic - ASD, VSR
 - Physiologic - atelectasis, pulmonary edema



Respiratory Failure

Definition

- Respiratory Failure is a syndrome, rather than a disease, in which the respiratory system fails in one or both of its gas exchange functions: oxygenation and CO₂ removal.
 - Chest Wall
 - Airway
 - Alveolar-capillary units
 - Pulmonary circulation
 - Nervous system, CNS or Brain stem

Epidemiology

- Incidence: approx. 360,000 U.S. cases per year
- 36% die during hospitalization
- Morbidity and mortality rates increase with age and presence of comorbidities

Classification

- Type I or Hypoxemic (PaO₂ < 60): *Failure of oxygen exchange*
 - Increased shunt fraction (Q_s/Q_t)
 - Alveolar flooding
 - Hypoxemia refractory to supplemental oxygen
- Type II or Hypercapnic (PaCO₂ > 45): *Failure to exchange or remove carbon dioxide*
 - Decreased alveolar minute ventilation (VA)
 - Often accompanied by hypoxemia that corrects with supplemental oxygen

Classification

- Acute
 - Develops over minutes to hours
- Chronic
 - Develops over several days or longer
- Acute on Chronic
 - I.E. acute exacerbation of advanced COPD

Pathophysiology: Mechanisms

- Hypoxemic Failure
 - Ventilation/perfusion (V/Q) mismatch
 - Shunt
 - Exacerbated by low mixed venous O₂
- Hypercapnic Failure
 - Decreased Minute Ventilation relative to demand
 - Increased dead space ventilation

Pathophysiology: Etiology

- Nervous System Failure (Type II)
 - Central Hypoventilation
 - Neuropathies
- Muscle (pump) failure (Type II)
 - Muscular dystrophies
 - Myopathies
- Neuromuscular transmission failure (Type II)
 - Myasthenia gravis
- Airway Failure (Type II)
 - Obstruction
 - Dysfunction

Pathophysiology: Etiology

- Chest Wall and Pleural space failure (Type II)
 - Kyphoscoliosis
 - Morbid obesity
 - Pneumothorax, Hydrothorax Hemothorax
- Pulmonary Vasculature failure (Type I)
 - Pulmonary embolism
 - Pulmonary hypertension
- Alveolar unit failure (Type I)
 - Collapse
 - Flooding: edema, blood, pus, aspiration
 - fibrosis

Causes

- Type I Respiratory Failure
 - Pneumonia
 - Cardiogenic pulmonary edema
 - Edema due to increased hydrostatic pressure
 - Non-cardiogenic pulmonary edema
 - Pulmonary edema due to increased permeability
 - Acute lung injury (ALI)
 - Acute Respiratory distress syndrome (ARDS)
- Pulmonary Embolism
- Atelectasis
- Pulmonary fibrosis

Causes

- Type II respiratory failure
 - Central hypoventilation
 - Asthma
 - Chronic obstructive pulmonary disease (COPD)
 - Hypoxemia and hypercapnia often occur together
- Neuromuscular and chest wall disorders
- Obesity Hypoventilation syndrome

Cases and Diagnosis

References

- Currie, D. (2005). *The pulmonary ventilation and perfusion page*. Retrieved March 10, 2006 from <http://faculty.you.edu/currie/pulmperfus.htm>
- Demmons, R. (2000). *Pass CCRN* (4th ed.). St. Louis, MO: Mosby, Inc.
- Markou, N., Myrianthefs, P., & Baltopoulos, G. (2004). Respiratory failure: An overview. *Critical Care Nurse Quarterly*, 24(4), 353-379.
- Acute Respiratory Distress Syndrome Network. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. The Acute Respiratory Distress Syndrome Network. *N Engl J Med*. May 4, 2000;342(18):1301-8. [L](#)
- [Best Evidence] Pina J, Badia JR, Adhikari NK, et al. Has mortality from acute respiratory distress syndrome decreased over time? A systematic review. *Am J Respir Crit Care Med*. Feb 1 2009;179(3):220-7. [L](#)
- Khan NA, Palepu A, Norena M, et al. Differences in hospital mortality among critically ill patients of Asian, Native Indian, and European descent. *Chest*. Dec 2008;134(6):1217-22. [L](#)
- Moss M, Manning DM. Race and gender differences in acute respiratory distress syndrome deaths in the United States: an analysis of multiple-cause mortality data (1979-1996). *Crit Care Med*. Aug 2002;30(8):1679-85. [L](#)
- [Best Evidence] Peek GJ, Elbourne D, Mugford M, Tiruvoipati R, Wilson A, Allen E, et al. Randomised controlled trial and parallel economic evaluation of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR). *Health Technol Assess*. Jul 2009;14(3):1-46. [L](#)
- [Best Evidence] Girault C, Briel A, Benichou J, Hellot MF, Dachraoui F, Tamion F, et al. Interface strategy during noninvasive positive pressure ventilation for hypercapnic acute respiratory failure. *Crit Care Med*. Jan 2009;37(1):22-31. [L](#)
- [Best Evidence] Briel M, Meade M, Mercat A, Brower RG, Talmor D, Walter SD, et al. Higher vs lower positive end-expiratory pressure in patients with acute lung injury and acute respiratory distress syndrome: systematic review and meta-analysis. *JAMA*. Mar 3 2009;301(9):969-75. [L](#)
- Brochard L, Mancebo J, Wysocki M, et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. *N Engl J Med*. Sep 28 1995;333(13):817-22. [L](#)