VENTILATION
Section 2, Part C

DEADSPACE, ALVEOLAR VENTILATION, DIFFUSION

I. Deadspace
A. Normal breathing characteristics
   1. normal frequency of breathing (f) - 11 to 14/min.
   2. VT = 450 to 600 ml
   3. VT - VD = VA

B. Respiratory deadspace
   1. anatomic deadspace - this is the volume of gas that occupies the conducting airway, it
do not mix with alveolar gas
   2. physiological deadspace - this is the volume of gas that is inspired that takes no part in
gas exchange in the lungs
   3. alveolar deadspace - gas that enters the alveoli but takes no part in alveolar gas exchange

C. Calculation of deadspace
   1. anatomical deadspace: \( VD = \frac{(FACO \ V^2 - FECO \ V^2)}{VE} \)
   2. physiological deadspace: \( VD = \frac{(PaCO \ V^2 - PECO \ V^2)}{PaCO} \)

II. Alveolar Ventilation
A. Calculation of air equation
   1. respiratory exchange ratio: \( R = \frac{\dot{V}CO}{\dot{V}O} \)
   2. alveolar air equation:
      \[ PAO = PIO - PACO \times \left[ FIO + \frac{1 - FIO}{R} \right] \]
      or \( PAO = PIO - (PaCO \times 1.2^*) \)
      or \( PAO = PIO - \frac{PaCO}{0.8^*} \)
      * In both equations change number to 1.0 if FIO2 is greater than 0.6.

B. Effects of altering ventilation
   1. hypoventilation - insufficient volume of fresh air enters alveoli
      a. hypoventilation causes hypoxemia, CO2 retention, resp. acidosis
      b. less O2 is added each minute - PAO2, PaO2, O2 content and Hb saturation decrease
      c. less CO2 is removed each minute - PACO2, PaCO2 increase, pH decreases (H+ is
         proportional to CO2 in the blood)
      d. breathing room air - patients become anoxic, hypercarbic, and acidicotic
      e. breathing 100% O2 relieves anoxia but patient still retains CO2
   2. hyperventilation - \( \dot{V}A \) is in excess to what is required to keep the blood within normal
      limits
      a. PACO2 decreases - causes alkalosis
      b. PAO2 increases, PaO2 increases but saturation does not greatly improve
C. Regulation of ventilation
   1. the body is capable of monitoring levels of ventilation and modifying it to meet specific
      metabolic demands
      a. most action occurs by negative feedback system
      b. compensation can occur within limits
   2. effect of hypoxemia
      a. VT increases
      b. reflex from chemoreceptors in carotid and aortic bodies
   3. effect of increase PaCO2
      a. VT and VA increase
      b. reflex from lateral surface of medulla - senses change in [H+]
   4. effect of acidosis
      a. VT and VA increase
      b. both central and peripheral chemoreceptor affected

III. Diffusion
   A. Grahm's Law - the rate of diffusion of a gas through a liquid medium is directly
      proportional to the solubility of the gas and inversely proportional to the square root of
      its density or its gram molecular weight.
      1. passive diffusion - gas moves from high concentration to low conc.
      2. light gases diffuse faster than heavy gases

   3. diffusibility of CO2 = \( \frac{\sqrt{gmw O_2 (32)}}{\sqrt{gmw CO_2 (44)}} \)
   = \( \frac{5.657}{6.633} \)
   = 0.852  gaseous CO2 diffuses faster than O2

   4. diffusibility between gas and tissue must include solubility coef. diffusibility of
      \( CO_2 = \frac{\text{Sol. Coef. CO}_2 x \sqrt{gmw O_2}}{\text{Sol. Coef. O}_2 x \sqrt{gmw CO}_2} \)
      = \( \frac{0.510 x \sqrt{32}}{0.023 x \sqrt{44}} \)
      = \( \frac{0.510 x 5.657}{0.023 x 6.633} \)
      = 19  (CO2 diffuses 19x faster in a liquid/air than O2)

   5. Fick's law of diffusion -

B. Diffusion path
   1. respiratory epithelium of alveoli
   2. interstitial layer
   3. endothelial cells of capillary
   4. plasma
   5. RBC

C. Surface area
   1. 50 - 70 m² is exposed to 60-100 ml of blood per second
D. Factors determining diffusion of O2
1. PA-vO₂ or driving pressure
2. length of diffusion path
   a. alveolar wall may thicken
   b. interstitial edema
   c. intra-alveolar edema
3. area for diffusion may decrease (exercise will increase area)
   a. emphysema
   b. bronchiolar obstruction
   c. pulmonary embolism
4. characteristics of alveolar-capillary and RBC membrane

E. Pulmonary diffusing capacity (D) - ability of the A-C membrane to transfer gases
1. \( \text{DO}_2 = \text{ml of O}_2 \text{ transferred from alveoli to blood/min.}/\text{PAO}_2 - \text{PvO}_2 \)
   a. \( \text{DO}_2 = \text{ml O}_2/\text{min.}/\text{mmHg} \)
2. CO is usually used to measure D of gases in the lungs

F. Measuring DLCO - single breath (SB) test
1. patient inspires a gas mixture of CO and He from RV
2. breath is held for 10 sec. then end tidal gas sample is obtained and measured for P\text{CO}
   and P\text{He}
3. CO leaves the alveoli and enters the blood, the larger the diffusing capacity, the greater
   the amount of CO that enters the blood
4. CO attaches to Hb and only the CO that does not diffuse through the membrane is
   exhaled and then measured
5. three measurements are required
   a. ml of CO transferred, %CO at beginning, %CO at end
   b. mean P\text{CO}, very small - usually neglected
   c. PACO - uneven in steady state due to absorption of CO
6. Krogh equation -
   \[ \text{DLCO} = \frac{\dot{V}_A \times 60}{(P_B - PH_2O) \times t} \times \log \frac{\text{FIACO}}{\text{FEACO}} \]
7. normal values: greater than 15 ml CO/min./mmHg \( (DLO_2 = 1.23 \text{DLCO}) \)

G. Factors affecting D
1. body size
2. age
3. lung volume
4. exercise
5. body position

H. Laboratory diagnosis
1. DLCO is normally compared to O₂ saturation of Hb
   a. decreasing DLCO is only one factor to lower O₂ sat.
   b. DLCO may be low while O₂ saturation is normal
2. if other factors are excluded, may describe quantity or quality of A-C membrane
3. CO₂ is rarely affected