RSPT 1307: RESPIRATORY PHYSIOLOGY
VENTILATION
Section 2, Part B

LUNG VOLUMES AND SUBDIVISIONS

Definitions:

volume - refers to one of the four primary (non-overlapping) subdivisions of TLC
capacity - is two or more volumes measured by pulmonary function tests
resting midposition - (REL) all forces of the lung are balanced. Work must be done to move air in either direction. May change as quality or quantity of lung tissue change or as muscular strength changes.

I. Lung Volumes

A. Tidal volume (VT) - the volume of gas added to and then removed with each breath
   1. averages 500 to 600 ml
   2. composed of alveolar gas (VA) plus deadspace gas (VD) -
   3. factors causing VT to increase
      a. increased metabolic rate -
      b. exercise
   4. VT x f = VE ($\dot{V}$) in L(BTPS)/min.

B. Expiratory reserve volume (ERV) - maximum volume of air that can be exhaled from REL
   1. ERV reflects thoracic and abdominal muscle strength
   2. thoracic mobility also determines ERV

C. Residual volume (RV) - volume of gas remaining in the lungs after forced expiration
   1. smallest volume both lungs can contain if the lungs and thorax are intact
   2. reflects the balance of elastic forces in the lung and thorax
   3. also reflects the volume of extrapulmonary structures

D. Inspiratory reserve volume (IRV) - maximum volume of gas that can be inhaled at the end of spontaneous inspiration -
   1. if REL is constant, IRV decreases as VT increases
   2. the volume of IRV is determined by-

II. Lung Capacities

A. Inspiratory capacity (IC) = VT + IRV - the maximum amount of air inhaled from REL

B. Functional residual capacity (FRC) = ERV + RV - the amount of air in the lungs at REL
   1. the size of the FRC determines the fluctuations of O2 and CO2 in alveolar gas
   2. a large FRC buffers alveolar changes

C. Vital capacity (VC) = IRV + VT + ERV - the maximum volume exhaled after the deepest inspiration
   1. inspiratory VC may be used for patients with chronic obstructive diseases
   2. in 1846 Hutchinson made the first study of VC using a large cross-section of people and observed:
      a. VC increases with height
      b. decreases with age
      c. that males have larger VC's as compared to females of corresponding age, height (some over lap)

D. Total lung capacity (TLC) = RV + ERV + VT + IRV - the maximum volume of gas the lungs can hold

III. Change in Lung Volume and Subdivisions

A. Body position affects lung volume
  1. supine -
    a. VC - usually dec.
    b. REL shifts
    c. FRC decreases, IRV, IC increases
  2. standing upright -
    a. FRC and ERV increase
    b. IRV may decrease

B. Normal breathing causes pulmonary circulation to fluctuate -
  1. thoracic blood volume increases with inspiration and decreases with exhalation
  2. Muller maneuver -
  3. Valsalva maneuver -

C. Age will cause changes in lung volume
  1. as a person ages, the elastic recoil of the lung dec.
    a. REL moves up -
    b. RV and FRC may increase
  2. VC decreases slightly with age

D. RV/TLC ratio
  1. range - 15% in young to 30% in elderly
  2. RV/TLC increase in patients with COPD
  3. restrictive lung disease -
  4. thoracic deformities -

IV. Measurement of Lung Volume and Subdivisions

A. Direct measurements -
  1. measured by spirometry

B. Indirect measurements -
  1. Helium dilution
  2. Nitrogen washout
  3. plethysmograph
  4. chest films

RV AND CYCLIC PROCESS OF VENTILATION

I. Residual Volume (RV)

A. Significance - prevents drastic rise and fall of O_2 and CO_2 with each breath

B. Measurement
  1. He dilution
  2. N_2 washout
  3. planimetry
  4. plethysmography
  5. example - open circuit N_2 washout
    a. principle - volume of the lungs is unknown, but FN_2 = 80%
    b. method - patient breathes 100% O_2 through a one-way valve, (no gas is rebreathed), all gas is collected and final FN_2 is measured

c. technique - 40,000 ml of gas at end of test
FN_2 (final) is 5%
therefore, 2000 ml of N_2
N_2 only represents 0.8 to total volume
total volume = 2500 ml

the volume in the lung at the beginning of the test is measured, test began at REL (FRC); FRC - ERV = RV

C. Changes in FRC or RV
1. increase FRC represents hyperinflation
 a. structural changes - COPD and aging process
 b. partial airway obstruction - mostly expiratory
 c. lung compensation for loss of tissue
2. decrease in FRC
 a. parenchymal changes - fibrosis, hyaline membrane
 b. restrictive defects
3. importance of FRC and RV
 a. small FRC allows too large a fluctuation of PaO_2 during respiratory cycle
 b. large FRC does not allow for rapid exchange of $PaCO_2$ when needed

II. Cyclic Process of Ventilation

A. Changes in alveolar gas tensions
1. begin at end inspiration
 a. PAO_2 and $PACO_2$ are equal to pulmonary blood (O_2 = 100, CO_2 = 40)
 b. anatomical dead space is filled with end-tidal or alveolar gas (O_2 = 100, CO_2 = 40)
2. inspiration
 a. VD moves back into alveoli, O_2 consumption and CO_2 elimination continues
 b. oxygen initially falls (98) and CO_2 rises (41) until new air enters alveoli

B. Alveolar ventilation
1. gas exchange occurs only in resp. bronchioles, alveoli, and alveolar sacs and not in the conducting airways
2. at end expiration, conducting airways are filled with alveolar gas this is the first gas to enter the alveoli during the next inspir. the deadspace gas does not affect the O_2 and CO_2 partial pressures
3. if VT = 450 (ml) and VD = 150 then only 300 ml of fresh gas enters the alveoli
4. alveolar ventilation (VA) only refers to fresh air entering the alveoli

C. Deep breathing allows a greater part of VT to enter alveoli
1. VD is generally fixed and does not change with depth of inspir.
2. shallow breathing allows less of VT to enter alveoli
3. example A allows 40% of VT to enter alveoli
 example B allows 70%
 example C allows 85%

D. The amount of O_2 supplied and CO_2 removed is important
1. if the amount is decreased - hypoventilation occurs
2. if the amount is increased - hyperventilation occurs
 a. normal 150 lb. male consumes approx. 250 ml O_2/min. requires a $\dot{V}A$ = 4.3 L/min.
 b. amounts depend on metabolic activity