Respiratory Anatomy and Physiology

Ma, Cline, *Emergency Medicine Manual* chapter (Keadey) : Respiratory Distress
Brady (or standard paramedic text) chapter :
Anatomy and Physiology of the Respiratory System

With photos + text modified from Dr. Hubble's review of physiology in "EMC 410 Trauma Management Chapter 18. Airway and Ventilatory Management"

Objectives

Upon completion of this lecture you should be able to discuss :

- A review of the anatomy and physiology of the respiratory system.
- Various factors involved in respiratory function
- Respiratory problems of obstruction and inadequate ventilation

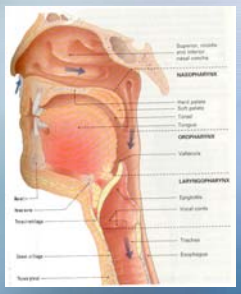
Objectives , cont

- Respiratory distress and the findings of dyspnea, hypoxemia, hypercarbia, and cyanosis
- For each of these, the definition, the clinical features, the assessment and the initial treatment
- A brief introduction to advanced airway control and indications, advantages, and disadvantages

Respiratory Anatomy

Upper Airway
- Mouth and Nose
- Pharynx
- Epiglottis
- Larynx

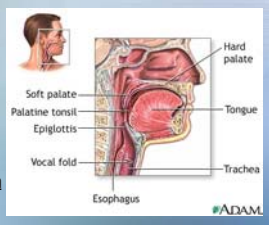
Lower airway
- Trachea below the cricoid
- Bronchi
- Lungs



from Ch 18 Airway...Mgt. -Hubble

Upper Respiratory Anatomy

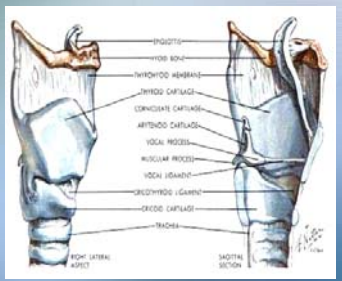
Upper Airway
- Mouth and Nose
- Pharynx
- Epiglottis
- Larynx
- Epiglottis
  - Pyriform fossa



Upper Airway Anatomy

Larynx
- Cords
- Related structures
  - Hyoid bone
  - Epiglottis
  - Thyroid cartilage
  - Cricoid ring

Tracheal rings



Larynx

- Collective term
  - Area between upper and lower airways
  - "Valve-like" doorway to lower airway
  - Extends
    - From epiglottis
    - To the cricoid ring
- At the C 3, 4, 5 level of the neck

Upper Airway Anatomy

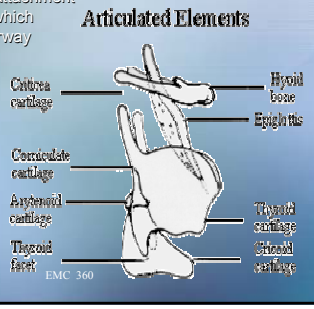
Anatomically and mechanically : two "units"

- ***Jaw-*** tongue-hyoid-epiglottis unit
- ***Laryngeal*** unit

- Jaw-tongue attachment
  - Jaw thrust moves tongue out of airway
- Jaw - hyoid - epiglottis attachment
  - Jaw thrust pulls on the hyoid which in turn pulls the epiglottis out of airway

Jaw Unit

1. The jaw-tongue attachment of unit: Jaw thrust moves ***tongue*** out of airway
2. The jaw - hyoid - epiglottis attachment Jaw thrust pulls on the hyoid which in turn pulls ***epiglottis*** out of airway



Upper Airway Anatomy

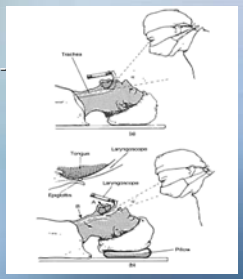
Laryngeal unit

- Thyroid - cords - cricoid attachment
  - cricoid pressure moves trachea, cords into alignment
- Thyroid Cartilage
  - Anterior: attachment of vocal folds
  - Posterior: articulation with cricoid cartilage
- Cricoid Cartilage
  - A complete ring. Articulates with thyroid and arytenoid cartilages
- Arytenoids
  - cartilages which glide along posterior cricoid ; attach to posterior ends of vocal folds.

Optimizing Laryngeal Visualization

Optimized Visualization for ET intubation:

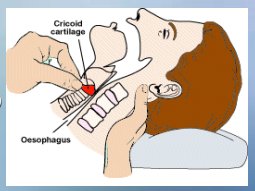
- Positioning:
  - Oral-pharyngeal-laryngeal axes alignment
- External pressure:
  - *by the operator*



Laryngeal "BURP"

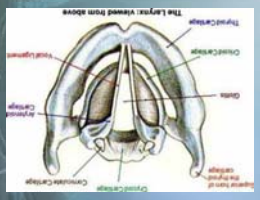
Optimized Visualization for ET intubation:

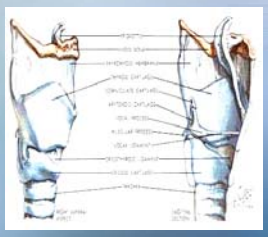
- Positioning
- External pressure:
  - Laryngeal unit is "BURP" Backward (posterior), Upward (toward the operator) and Rightward Pressed
  - *by the operator*



Laryngeal Orientation

and see video at : https://www.entusa.com/larynx_photo.htm (requires high speed)

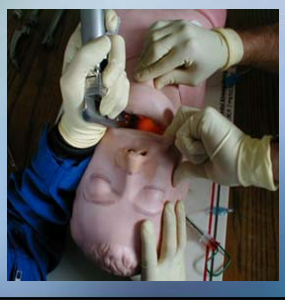




Cricoid Cartilage Pressure

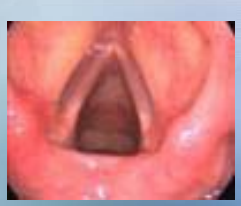
Cricoid pressure:

- Moves the whole cricoid - cords - thyroid unit
- Thus moving the trachea and cords into alignment



Vocal Cords

- "A" shaped cords wide open
- Epiglottis is pinned (out of view) , anteriorly
- Esophagus
  - Obscured by the posterior pharynx-hypopharyngeal tissue



Larynx

Innervation - vagus nerve (2 branches)

- Superior Laryngeal Nerve (from high in neck)
  - Sensation : glottis and supraglottis
  - Motor : to the cricothyroid muscle, which tenses the vocal folds
- Recurrent Laryngeal Nerve
  - Sensation : subglottic area
  - Motor : to intrinsic muscles of the larynx.
  - This branch comes off the vagus in the mediastinum, then turns back up into the neck

Anatomy of Upper Airway

Trachea

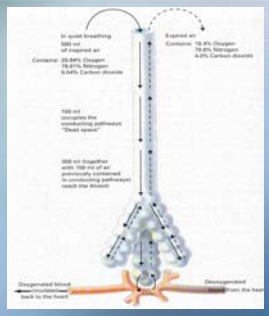
- Bifurcates at the carina
  - Carina lies just posterior to the Angle of Louis (or the sternomanubrial joint)
  - From the incisors, average patient's ET tube should measure less than 22cm (carinal tracheal bifurcation is 18 to 22 from the incisors)
- Left bronchus is angulated (45°)
- Right bronchus can be thought of as "in line" (25°) with the upper trachea and pharynx

Anatomy of Lower Airway

- Bronchi
  - Become smaller and increasingly muscular as they divide [site of reactive airway disease]
- Lungs
  - 300 million alveoli with a surface area of 70 M^2
  - Visceral pleura lines the lungs
  - Parietal pleura lines thoracic cavity, adhering to the internal ribs and to the diaphragm
  - Pleural fluid (minimal) bathes space between visceral and parietal pleura [potential space for pleural fluid]

Physiology of Respiration

- Tidal Volume (TV)
  - 500mL
- Dead space
  - 150mL
- Inspired gas
  - (O2 [21%],N,CO2)
- Exhaled gas
  - (O2,N,CO2 [4%])
- Alveolar gas exchange
  - Inspired (350) + old dead space (150)

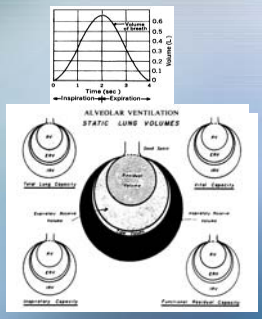


Chap. 18 - Hubble

Tidal Volume (TV)

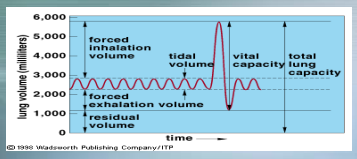
Tidal Volume (TV) :

- The amt of air that moves in and out during each ventilatory cycle
- "stroke volume of lungs"
- Part of inspired air remains unavailable to the alveoli : called dead space because it remains outside the area of gas exchange



from: D Penny Pulmonary Physiology

Physiology of Respiration



- ***Inspir Reserve Vol (IRV)***: can be forcibly inhaled following normal inspir.
- ***Expir Reserve Vol (ERV)*** : can be forcibly exhaled following normal expir.
- ***Vital Capacity (VC)*** : maximal volume of air that can be forcibly exhaled after a Maximal Inspiration. VC = TV + IRV + ERV.
- ***Residual Volume (RV)*** : air remaining in the lungs after a Max Expiration
- ***Functional Residual Capacity (FRC)*** : volume of air remaining in the lungs at the end of a normal expiration. FRC = RV + ERV.
- ***Total Lung Capacity (TLC)*** : vol in the lungs at the end of a Max Inspiration. TLC = FRC + TV + IRV = VC + RV
- ***Minute Volume*** : the volume of air exhaled per minute

EMC 360

Alveolar Ventilation

- Tidal volume of air : 500 mL / breath
- Dead space air which stays in bronchi: 150 mL
- Actual air ventilating the alveoli : 500-150 = 350 ml
- Respiratory minute volume (rest): (if RR: 12)
  - 500 x 12 = 6000mL/min or 6.2 L
- Minute volume does not reflect how much air is actually reaching the alveoli
- Alveolar ventilation (rest):
  - 350 x 12 = 6000mL/min or 4.2 liters/min
- Minute volume does not equal alveolar ventilation

EMC 360

Tidal Volume

- Amount of air that is measured between a normal [not forced] inspiration and a normal [not forced] expiration

EMC 360

Vital Capacity

- Amount of air that is measured between a full [forced] inspiration and a full [forced] expiration

EMC 360

Respiratory Flow

- Determinants of flow :
  - Lung compliance
  - Airway resistance
- Flow :
  resistance to flow through a tube is inversely proportional to the fourth power of the radius
  $F = \frac{1}{r^4}$
- Surfactant :
  - lung secretion that contributes to lung tissue elasticity
- Stretch receptors :
  - on the visceral pleura
  - on bronchi al and bronchiolar walls
  - provide feedback to respiratory center in the medulla

Respiratory Pathology and Definition of Respiratory Terms

Dyspnea : the subjective feeling of "shortness of breath," or difficult or labored breathing (66% will have CP dz)

Common causes:
- COPD
- CHF
- Coronary ischemia
- Pneumonia
- Hyperventilation syndrome

Life threatening causes:
- FBAObstruction
- Tension pneumothorax
- Pulmonary Embolism
- Pneumonia
- CNS / N-M (GBS; botulism)

Hypoxia

Hypoxia
- Inadequate delivery of O2 to tissues

Hypoxemia
- Low (inadequate) circulating O2
- pO2 less than 60 mmHg

Hypoxemia causes:
- Hypoventilation
  - → CO2 retention
  - CO2 displaces O2
- R to L Shunt
  - Areas of lung are ventilated (V) , but not perfused (Q) [shock]
- V / Q mismatch
  - Areas of lung are perfused (Q), but not ventilated (V) [pnthx]
- Diffusion abnormality
- Low inspired O2 [high altitude]

Diffusion

Normal diffusion
- Movement of molecules through a membrane from an area of greater concentration to an area of lesser concentration
- Lung is very efficient at distributing gas to a very large, thin (very thin [0.5 micron]) diffusion membrane that has a very good blood supply
  - the entire cardiac output

Diffusion Abnormalities

Determinants of diffusion
- Ficks formula applied to diffusion of gases in lung:
  Flow = Area of lung x driving P / thickness of membrane
- Abnormal A – C membrane (alveolar – blood barrier) impairs O2 movement [pneumonia]

- www.keele.ac.uk/.../ histologyimages/t94.jpg

Respiratory Terms

- Hemoglobin:
  - transport protein that carries O2
- FiO2
  - forced inspired O2 concentration
- Hypercapnea
  - ↑ pCO2
- Asphyxia
  - inadequate respiration causing decreased O2 and increased CO2
- Polycythemia
  - excess of red blood cells
- Hemoptysis
  - → expectoration of blood
- Orthopnea
  - supine dyspnea
- PND
  - attack of dyspnea at night [left CHF]

And More Respiratory Terms

- Cor pulmonale:
  - hypertrophy of the right ventricle
  - resulting from "stiff lung" disorders such as COPD
  - right CHF
    - JVD
    - Pedal edema
- ARDS
  - pulmonary disorder in which fluid accumulates not in the alveolar space, but in the interstitial space
- Cyanosis
  - bluish discoloration of skin or mucus membranes due to increase in reduced hemoglobin in blood
  - directly related to poor ventilation

Cyanosis

Not a *sensitive* indicator of true arterial oxygen level

- Highly subjective

Causes [tissue hypoxia]

- Peripheral
  - Shock
  - Cold extremities
- Central (best observed under tongue)
  - Abnormal hemoglobin (Co-Hb)
  - Hypoxemia
    - Hypoventilation
    - Ventilation / Perfusion mismatch
    - Right to Left shunting (congenital heart disease)

Summary

We have discussed :

- A review of the anatomy and physiology of the respiratory system. And we've briefly addressed :
  - Determinants of flow
  - Vital Capacity (VC)
    - Inspir Reserve Vol (IRV)
    - TV
    - Expir Reserve Vol (ERV)
  - Residual Volume (RV)
  - Functional Residual Capacity (FRC)
  - Total Lung Capacity (TLC) and
  - Minute Volume
- Respiratory pathophysiology of inadequate ventilation
- Respiratory distress , dyspnea, and the findings of hypoxemia, hypercarbia, and cyanosis