Boards and Beyond: Pulmonary

A Companion Book to the Boards and Beyond Website

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**Surfactant**
- Exhale alveoli shrink
- Could collapse atelectasis
- ↓ efficiency gas exchange
- Surfactant allows alveoli to avoid collapse

**Alveoli**
- Small sacs
- Gas exchange
- Surrounded by capillaries

**Mucous**
- Secretions produced by respiratory tract
- Mostly glycoproteins and water
- Secreted by goblet cells in bronchial walls
- Protects against particulates, infection
- Beating cilia move mucous to epiglottis swallowed

**Zones**
- **Conducting Zone**
  - No gas exchange
  - Large airways: nose, pharynx, trachea, bronchi
- **Respiratory Zone**
  - Gas exchange
  - Respiratory bronchioles, alveolar ducts, alveoli

**Pulmonary Anatomy**

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Neonatal respiratory distress syndrome

- Risk factors:
  - Prematurity
  - Maternal diabetes: high insulin levels decrease surfactant production
  - Cesarean delivery: lack of vaginal compression stress leads to reduced fetal cortisol and reduction in surfactant

Surfactant

- Secreted by type 2 pneumocytes
- Mix of lecithins
- Especially dipalmitoylphosphatidylcholine

Fetal Lung Maturity

- Lungs are “mature” when enough surfactant present
- Occurs around 35 weeks
- Lecithin–sphingomyelin ratio (L/S ratio)
- Both produced equally until ~35 weeks
- Ratio >2.0 in amniotic fluid suggests lungs mature
- Preterm delivery: betamethasone used to stimulate surfactant production in lungs

Neonatal respiratory distress syndrome

- Hyaline membrane disease
- Atelectasis
- Severe hypoxemia/pCO2 (poor ventilation)
- Poorly responsive to O2
  - Lungs collapsed (alveoli)
  - Intrapulmonary shunting

Neonatal respiratory distress syndrome

- Many complications
- Bronchopulmonary dysplasia
- Patent ductus arteriosus (hypoxia keeps shunt open)
- Retinopathy of prematurity
  - When infant taken off oxygen
  - Neovascularization in the retina
  - Retinal detachment → blindness

Surfactant

\[
\text{Distending Pressure} = \frac{2 \ast \text{(surface tension)}}{\text{radius}}
\]
Aspiration

- Right lung is more common site of aspiration
  - Right bronchus wider
  - Less angle
  - More vertical path to lung

Aspiration Foreign Body

- If upright
  - Right inferior lobe – lower portion
- If supine (lying flat)
  - Right inferior lobe – superior portion

Diaphragm

- Caval opening
  - T8
  - IVC
- Esophageal hiatus
  - T10
  - Esophagus, Vagus nerve
- Aortic hiatus
  - T12
  - Aorta, thoracic duct, azygous vein

Diaphragm

- Innervated by C3, C4, C5 (Phrenic nerve)
- Diaphragm irritation → “referred” shoulder pain
  - Classic example is gallbladder disease
  - Also lower lung masses
  - Irritation can cause dyspnea and hiccups
- Cut nerve → diaphragm elevation, dyspnea
  - “Paradoxical movement”: Moves up with inspiration
  - Can see on fluoroscopy (“sniff test”)

Muscles of Quiet Respiration

- Diaphragm → inspiration
- Exhalation is passive with normal (“quiet”) breathing

Exercise Breathing

- Inspiration (neck)
  - Scalenus – raise ribs
  - Sternocleidomastoids – raise sternum
- Exhalation (abdomen)
  - Rectus muscle
  - Internal/external obliques
  - Transverse abdominis
  - Internal intercostals
- Use of accessory muscles in respiratory distress
Lung Capacities

Capacity = sum of two volumes

- Total lung capacity
  - Sum of all volumes
  - RV + ERV + IRV + TV
- Inspiratory capacity
  - Most air you can inspire
  - TV + IRV
- Vital capacity
  - Most you can exhale
  - TV + IRV + ERV

RV
ERV
IRV
TV
Lung and Chest Wall

- Lungs tend to collapse
  - Pull inward/recoil
- Chest wall tends to expand
  - Spring outward

Ventilation

- Ventilation = volume x frequency (resp rate)
  - 500cc per breath x 20 breaths per minute
  - 10,000cc/min
- Alveolar ventilation = useful for gas exchange
- Dead space ventilation = wasted ventilation
  - Nose, trachea, other areas with no gas exchange

Dead Space

- Space filled with air but no gas exchange
- #1: Anatomic dead space
  - Volume of conducting portions respiratory tract
  - Nose, trachea
- #2: Physiologic dead space
  - Anatomic PLUS volume of alveoli that don’t exchange gas
  - Insufficient perfusion
  - Apex is largest contributor
- Physiologic dead space increases many diseases

Ventilation

- Total ventilation (TV) = volume/min out each breath
  - *Volume in slightly > volume out due to O₂ uptake
    - Sometimes called minute ventilation
- Alveolar ventilation
  - Fresh air for gas exchange
  - TV minus “dead space”
- Imagine 500cc out per minute
  - 150cc fills dead space
  - Only 350cc available for gas exchange

Measuring Dead Space

- Bohr’s method
- Physiologic dead space ($V_d$) from:
  - Tidal volume
  - $P_{CO_2}$ (exhaled air)
  - $P_{aCO_2}$ (blood gas)

$$V_d = P_{CO_2} - P_{aCO_2}$$

Lung Volumes and Pressures

- Lungs tend to collapse
  - Pull inward/recoil
- Chest wall tends to expand
  - Spring outward
**Lung Compliance**

- For given pressure how much volume changes
- Compliant lung
  - Small amount diaphragm effort
  - Generates small pressure change across lungs
  - Large volume change
  - Easy to move air in/out
- Non-compliant lung
  - Large amount diaphragm effort
  - Big pressure change across lungs
  - Small volume change (lungs stiff)
  - Hard to move air in/out

\[ C = \frac{\Delta V}{\Delta P} \]
Lung Compliance

- Decreased
  - Pneumonia
  - Pulmonary edema
  - Pulmonary fibrosis
- Increased
  - Emphysema (floppy lungs)
  - Aging

\[ C = \frac{\Delta V}{\Delta P} \]

Resistance to Air Flow

- Upper airways about 50% resistance
  - Nose, mouth, pharynx
- Lower airway resistance
  - Highest in medium bronchi (turbulent flow)
  - Lowest in terminal bronchioles - slows laminar flow