Basic Terms & Concepts of Mechanical Ventilation

Chapter 2
Spontaneous Ventilation

- Movement of air in and out of the lungs
- Muscles of inspiration contract – expand the thorax
- Passive exhalation
- Air flow due to pressure gradients – high to low pressure
- No gas flow present when pressures across the gradient are equal
Respiration

- Movement of gas molecules across a membrane
  - Internal – cellular level
  - External – a-c membrane
Pressure Equivalents

- Ventilating pressures use cmH2O
- 1 mmHg = 1.36 cmH2O
- Pressures are referenced from atmospheric pressure – baseline value of zero
- May also see kilopascals used 1kPa = 7.5mmHg (SI units)
- $P_{aw0}$: zero*
- $P_{bs}$: zero*
- $P_{pl}$: -5cmH2O -10cmH2O
- $P_{A}$: +1cmH2O -1cmH2O

*unless pressure applied
Pressure Gradients Matching

- Transairway Pressure
- Transthoracic Pressure
- Transpulmonary Pressure
- Transrespiratory Pressure

1. \( P_A - P_{bs} \)
2. \( P_{aw} - P_A \)
3. \( P_A - P_{pl} \)
4. \( P_{awo} - P_{bs} \)
Mechanics of Spontaneous Ventilation

Inspiration

- Airflow in
- Lungs
- Intrapleural space (Pressure below ambient)

Exhalation

- Airflow out
- Lungs

Pressure (cm H₂O)

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Lung Characteristics: Compliance

- Relative ease with which a structure distends
  - opposite of elastance
- Used to describe the elastic forces that oppose lung inflation
- \( \Delta V / \Delta P = L/cmH2O \)
- 50-170ml/cmH2O normal
- 35/40 -100ml/cmH2O intubated patient
- Static Compliance
- Dynamic Compliance
Clinical Rounds 2-1

If compliance is normal at 0.1L/cmH2O, calculate the amount of pressure needed to attain a tidal volume of 0.5L (500ml).

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

\[ 0.5 / 0.1 = 5 \text{ cmH2O} \]

A Palv change of 5cmH2O would be needed to achieve a 0.5L tidal volume in a person with normal lung compliance.
Lung Characteristics: Resistance

- Frictional forces associated with ventilation
  - Anatomic structures
  - Tissue viscous resistance
- Ability of air to flow depends on
  - Gas viscosity
  - Gas density
  - Length and diameter of the tube
  - Flow rate of the gas through the tube
- Raw = $\frac{P_{TA}}{\text{flow}}$ cmH2O/L/sec
  - $P_{TA} \approx P_{IP} - P_{plat}$
  - Assumes constant flow
- Normal 0.6-2.4 cmH2O/L/sec
- Intubated patients 5-7cmH2O/L/sec (and higher!)
Clinical Rounds 2-2

An intubated 36y.o. woman is being ventilated with a volume of 0.5L (500ml). The PIP is 24cmH2O, Pplat is 19cmH2O and the baseline pressure is zero. The inspiratory gas flow is constant at 60L/min (1L/sec). What are the static compliance and airway resistance? Are these normal values?

Compliance : 500/19 = 26.3ml/cmH2O
Raw: 24-19/1 = 5cmH2O/L/s

The patient’s compliance is very low, suggests that some condition is making the lungs stiffer.
Raw is low considering the presence of an artificial airway.
Time Constants

- Heterogeneous not homogeneous lungs
- Representation of passive filling and passive emptying
- Differences in compliance and resistance affect how rapidly the lung units fill and empty
  - Normal lung units fill within a normal length of time
  - Decreased compliance – stiff lung units fill rapidly
  - Increased airway resistance – narrow airways cause slow filling
- Time constant = compliance x resistance
- Important for setting inspiratory time and expiratory time
Types of Ventilators

- Negative Pressure
- Positive Pressure
- High Frequency
Negative Pressure Ventilators

- Attempts to mimic normal physiology
- Types:
  - Iron lung – tank ventilator
  - Chest cuirass
- Maintained without the need for ETT, tracheostomy, able to talk and eat
- Cardiovascular concerns, access to patient
High Frequency Ventilation

- Above normal ventilating rates with below normal ventilating volumes
- HFPPV
- HFJV
- HFOV
Positive Pressure Ventilators

- Requires airway interface
- Applies pressure to create gradient between mouth and lung
Pressure Measurement

- Manometer – pressure gauge
- Pressure points graphed over time during the breath cycle
- Used to:
  - Monitor patients
  - Describe modes of ventilation
  - Calculate a variety of parameters
- Baseline/End expiratory pressure
- Peak
- Plateau
Baseline pressure
End of expiration

FRC

Plateau pressure
End of inspiration
before exhalation
occurs

V_T + FRC