Basic Concepts in Adult Mechanical Ventilation
Points of Discussion

1. Basic respiratory dynamics
2. Basic ventilator parameters
3. Control variables: pressure, volume
4. Phase variables: trigger, limit and cycle
5. Conditional variables
6. Breath types
Spontaneous Breathing

Exhalation

Inspiration
Precondition of Inspiration

$\text{Pa} < \text{Pb}$

- $\text{Pa} < \text{Pb}$
  - Spontaneous breath
- $\text{Pb} > \text{Pa}$
  - Mechanical ventilation
Three - Dimensional Spring

Pleural Pressure
Alveolar Pressure Changes

- **Inspiration**
- **Mechanical Breath**
- **Spontaneous Breath**
Spontaneous Inspiration

Volume Change

Pressure Difference

Gas Flow
Mechanical Ventilation

Pressure Difference

Gas Flow

Volume Change
Airway Resistance

“The Feature of the Tube”

\[ R = \frac{\Delta P}{\Delta F} \]

Pressure Difference = Flow Rate \times Resistance of the Tube
Compliance

Volume Change = Pressure Difference × Compliance of the Balloon

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

- Measures compliance of the lung and thorax
- Tidal volume / Plateau-PEEP
- Units = ml/cmH20
Compliance and Resistance

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

\[ R = \frac{\Delta P}{\Delta F} \]
Resistance

- Measures airway resistance
  - Length
  - Viscosity
  - Flow
  - Radius$^4$
- Peak-plateau / Flowrate
- Units = cmH$_2$O/Lps
Peak and Plateau Pressures

- **Peak airway pressure reflects**
  - Baseline (PEEP)
  - Pressure due to compliance (L+T)
  - Pressure due to resistance

- **Plateau pressure (breath hold) reflects**
  - Baseline (PEEP)
  - Pressure due to compliance (L+T)
  - (alveolar distending pressure)
Peak Alveolar and Transpulmonary Pressures

\[ P(t) = \frac{VT}{CR} + \text{Flow} \times RR + \text{PEEP tot} \]

Transpulmonary pressure is a key determinant of alveolar distension.
Basic Ventilator Parameters

- **FiO2**
  - Fractional concentration of inspired oxygen delivered expressed as a % (21-100)

- **Breath Rate (f)**
  - The number of times over a one minute period inspiration is initiated (bpm)

- **Tidal volume (VT)**
  - The amount of gas that is delivered during inspiration expressed in mls or Liters. Inspired or exhaled.

- **Flow**
  - The velocity of gas flow or volume of gas per minute
Terminology
Terminology: PIP & MAP

\[ \Sigma A = A_1 + A_2 + \ldots + A_n \]

- **Peak Inspiratory Pressure**
- **Mean Airway Pressure**
- **Inspiration + Exhalation**

Pressure vs. Time graph

\[ \Sigma A = A_1 + A_2 + \ldots + A_n \]
Terminology: PEEP, I:E Ratio

- **PEEP**: Positive End Expiratory Pressure
- **I**: Inspiration
- **E**: Expiration
- **I:E Ratio**
  - **I:E = 1:2**
  - **I:E = 4:1**

**Diagram**:
- **Pressure** axis with **PIP** and **PEEP**
- **Time** axis with **T_{insp.}** and **T_{exp.}**
-标注间阳性终期压力
Terminology: Flow and Volume

Minute Ventilation = Tidal Volume \times Breath Rate
Volume = Flow X Time
PEEP

- Definition
  - Positive end expiratory pressure
  - Application of a constant, positive pressure such that at end exhalation, airway pressure does not return to a 0 baseline

- Used with other mechanical ventilation modes such as A/C, SIMV, or PCV

- Referred to as CPAP when applied to spontaneous breaths
PEEP

- Increases functional residual capacity (FRC) and improves oxygenation
  - Recruits collapsed alveoli
  - Splints and distends patent alveoli
  - Redistributes lung fluid from alveoli to perivascular space

5 cm H$_2$O PEEP
Classification

- Control variable
  - Flow (volume)
  - Pressure
- Phase variable
  - Trigger, limit, cycle, baseline
- Conditional variable
  - Patient effort and time
“Control Variable”

Which parameter remains constant despite changes in pulmonary mechanics?

*Pressure Generated Breath*

![Diagram showing pressure and flow over time](image)
Control variables

- Volume Ventilation

- Pressure Ventilation

![Graphs showing pressure and flow over time for Volume and Pressure Ventilation.](image-url)
If compliance decreases the pressure increases to maintain the same Vt
As compliance changes - flow and volumes change
New Volume Targeted Breath
Pressure Variability is Controlled

Pressure then raises to assure that the set tidal volume is delivered
Phase Variables

• A. Trigger mechanism
  • What causes the breath to begin?
    Patient (assisted)
    Machine (controlled)

• B. Limit variable
  • Which parameter is sustained at a preset level during the breath?
    Flow
    Pressure

• C. Cycle mechanism
  • What causes the breath to end?
    Volume
    Time
Trigger Variable- Start of a Breath

- Time - control ventilation
- Pressure - patient assisted
- Flow - patient assisted
- Volume - patient assisted
- Manual - operator control
Inspiratory Trigger Mechanism

- Time
  - Controlled Mechanical Ventilation
- Pressure
- Flow
- Chest impedance
- Abdominal movement
Inspiratory - delivery limits

- Maximum value that can be reached but will not end the breath-
  - Volume
  - Flow
  - Pressure
Breath Types

- Mandatory
  - Ventilator does the work
  - Ventilator controls start and stop

- Spontaneous
  - Patient takes on work
  - Patient controls start and stop

- Assisted
  - Patients triggers the breath
  - The ventilator delivers the breath as per control variable

- Supported
  - Patients triggers the breath
  - Ventilator delivers pressure support
  - Breath cycles at set flow
Thank You