Basic Principle of Mechanical Ventilation in Pediatric

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Objectives

- **Definition:** normal and artificial ventilation
- Indication
- Classification of different modes of ventilation
- Troubleshooting and complication
- High frequency ventilation
Respiration

- Exchange of oxygen (O₂) and carbon dioxide (CO₂) between the organism and the external environment.
Respiratory Failure

- Inability of the pulmonary system to meet the metabolic demands of the body through adequate gas exchange.
- Two types of respiratory failure:
  - Hypoxemic
  - Hypercarbic
- Each can be acute and chronic.
- Both can be present in the same patient.
- Management of this condition required assisted mechanical ventilation
What does Mechanical ventilation mean?

• “Assisted Ventilation involves the Delivery of *Flow* and *Pressure* to the Patient’s Airway in Order to Effect Change in Lung *Volume*”

• A *mechanical ventilator* is a machine that generates controlled flow of gas into a patient’s airway
Mechanical Ventilation / Normal ventilation

Positive pressure ventilation

Normal ventilation
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- Examples and Scenarios
Goals of Mechanical Ventilation
(End-result)

- Achieve and maintain adequate pulmonary gas exchange
- Minimize the risk of lung injury
- Reduce patient work of breathing
- Optimize patient comfort
- To normalize blood gases and provide comfortable breathing
What is the work of Breathing?
(Compliance & Resistance)

**Resistance**
- Resistance is determined by the
- Properties of the airway
- Length
- Diameter
- Branching and Surface Characteristics
- Type of Flow (Laminar or Turbulent)

**Compliance**: measurement of the elasticity of the lung and chest wall
work of Breathing
(resistance + compliance)

Airway Resistance

"The Feature of the Tube"

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

Pressure Difference = Flow Rate \times Resistance of the Tube

Compliance

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

Volume Change = Pressure Difference \times Compliance of the Balloon

The ventilator decrease the work of breathing
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Ventilator Classification

(the Basic Questions: **mode** of ventilation and **type** of breath)

A. **Trigger mechanism**
   - What causes the breath to begin?

B. **Limit variable**
   - What limits the delivery of gas to the patient during the inspiratory phase {pressure or volume}.

C. **Cycle mechanism**
   - What causes the breath to end?
     - What cycles, or changes, the ventilator from one phase of the respiratory cycle to the other.
Ventilation Modes
(Attitude)

- How mechanical ventilation are delivered to the patient?
- What are the relationship between spontaneous breath and the mechanical breath?
Modes of Ventilation
the manner or method of support provided by the ventilator

- Controlled mechanical ventilation (CMV) (full control)
- Assist/Control Ventilation (A/C) (full support). Mainly used in adult
- Synchronized Intermittent Mandatory Ventilation (SIMV) and (IMV) (partial support). Commonly used in pediatrics
- Spontaneous Modes
  - Pressure Support Ventilation (PSV)
  - Continuous Positive Airway Pressure (CPAP)
Modes of Ventilation

- **Controlled Breath**
- **Assisted Breath**
- **Spontaneous Breath**
- **Assisted Breath**
- **Pressure Supported Breaths**

**Flow Diagrams**:
- **Assist/Control**
- **SIMV**
- **PSV**
## Mode of ventilation
### Control vs. SIMV

#### Control Modes
- Every breath is supported regardless of “trigger”
- Can’t wean by decreasing rate
- Patient may hyperventilate if agitated
- Patient / vent asynchrony possible and may need sedation +/- paralysis

#### SIMV Modes
- Vent tries to synchronize with pt’s effort
- Patient takes “own” breaths in between (+/- PS)
- Potential increased work of breathing
- Can have patient / vent asynchrony
Type of Ventilation during breathing

(limitation of the breath during inspiration in SIMV, CMV or A/C)

Whenever a breath is supported by the ventilator, regardless of the mode, the limit of the support is determined by a preset pressure OR volume.

- **Volume Limited**: preset tidal volume
- **Pressure Limited**: preset PIP or PAP
Mechanical Ventilation

If volume is set, pressure varies…..
if pressure is set, volume varies….. according to the compliance……

\[
\text{COMPLIANCE} = \frac{\Delta \text{Volume}}{\Delta \text{Pressure}}
\]
Volume vs. Pressure Control Ventilation

- **Volume Ventilation**
  - Volume delivery constant
  - Inspiratory pressure varies
  - Inspiratory flow constant

- **Pressure Ventilation**
  - Volume delivery varies
  - Inspiratory pressure constant
  - Inspiratory flow varies

When do you use pressure or volume control ventilation?

In general pressure control in babies and small infant < 6-8 kg

In general volume control in children and adolescence > 8-10 kg
What is pressure support ventilation

Need a hand??

Pressure Support

• “Triggering” vent requires certain amount of work by patient

• Can decrease work of breathing by providing flow during inspiration for patient triggered breaths → increase pressure

• The amount of flow increase is limited by set pressure. (5-10)

• Can be given with spontaneous breaths, in IMV modes or as stand alone mode without set rate

• Flow-cycled
How can we set the ventilator?
(Ventilator Basics parameters)

- **FIO\textsubscript{2}** - fraction of inspired oxygen
- **Rate** - number of breaths per minute
- **Tidal Volume** - volume of each breath
- **Sensitivity** - how responsive the ventilator is to the patient’s efforts
- **PIP** - maximum amount of pressured delivered during each breath
- **Inspiratory Time (I time)** - the time spent in the inspiratory phase of the ventilatory cycle
- **I:E Ratio** - the inspiratory time compared to the expiratory time; \( I + E = \text{total cycle time} \)
- **PEEP** - positive end expiratory pressure
Initial Settings

• **Settings**
  – Rate: start with a rate that is somewhat normal; i.e., 15 for adolescent/child, 20-30 for infant/small child
  – FiO₂: 100% and wean down
  – PEEP: 3-5
  – TV 8-10 ml/kg, or PIP 14- 20
  – Pressure support 5-10
  – Determine the mode: control every breath (A/C) or some (SIMV)
Basic parameters to be set in volume and pressure control ventilation

- **Pressure Limited**
  - FiO2
  - Rate
  - I-time
  - PEEP
  - PIP

- **Volume Limited**
  - FiO2
  - Rate
  - Tidal Volume
  - PEEP
  - I time

Tidal Volume & (MV) Varies

PIP & (MAP) Varies
Adjustments

- To affect oxygenation, adjust:
  - FiO₂
  - PEEP
  - I time
  - PIP

- To affect ventilation, adjust:
  - Respiratory Rate
  - Tidal Volume
**Advanced Modes of ventilation**

- Pressure-regulated volume control (PRVC)
- Volume support
- Inverse ratio (IRV) or
- Airway-pressure release ventilation (APRV)
- Bilevel CPAP
- High-frequency
Advanced Modes

PRVC

• A control mode, which delivers a set tidal volume with each breath at the lowest possible peak pressure.

• Delivers the breath with a decelerating flow pattern that is thought to be less injurious to the lung...... “the guided hand”.
FIGURE 21-38. Pressure and flow waveforms during pressure-regulated volume control ventilation.
(1) 5 cmH₂O test breath. (2 and 3) Adjustment of pressure target to ensure delivered tidal volume. (4 and 5) Pressure target constant. (6) Pressure target decreased because tidal volume is over target (see text for details) (Courtesy of Siemens Life Support Systems, Schaumburg, IL)

PRVC: pressure regulated volume control
**Advanced Modes**

**Inverse Ratio Ventilation**
- Pressure Control Mode
- I:E > 1
- Can increase MAP without increasing PIP: improve oxygenation but limit barotrauma
- Significant risk for air trapping
- Patient will need to be deeply sedated and perhaps paralyzed as well
Advanced mode of ventilation
High frequency ventilation

- Definition: Ventilator rate > 150 per minute
- TV is < dead space
  - High frequency positive pressure ventilation: Rate 60-100 per minute
  - High frequency jet ventilation: 60-600 per minute
  - High frequency oscillatory ventilation 180-1800 per minute (Ventilation rate is given by Hertz {1 HZ = 60 cycle})
Advanced Modes:
High Frequency Oscillatory Ventilation

3100A HFOV:
SensorMedics (3100B settings)
HFOV Principle:

Decrease TV’s to physiological dead space and increase frequency
SensorMedics 3100B

- Electrically powered, electronically controlled piston-diaphragm oscillator
- Paw of 5 - 55 cmH2O
- Pressure Amplitude from 8 - 130 cmH2O
- Frequency of 3 - 15 Hz
- % Inspiratory Time 30% - 50%
- Flow rates from 0 - 60 LPM
Pressure transmission in HFOV:

Pressure damping effect

Proximal
Trachea
Alveoli
HFOV Principle:

Amplitude
Delta P =
Tv =
Ventilation

HFOV = CPAP with a wiggle!
What parameters need to be set during HFOV

- **FIO2**
  {affect oxygenation}
- **MAP** (start with 1-2 cm above what used in CV)
  {affect oxygenation}
  can be increased by 1 cm increment until satisfactory O2 saturation is achieved 80-90%
- **Oscillation Amplitude** : Amplitude of the oscillatory waves generated by ventilator (\( P \))
  Usually 20-40 cm water {affect TV}
- **Ventilation frequency** { number of cycle per second}
  start with 10-20 HZ
- **I/E ratio** 1: 2
Some indications of HFOV

- Indications:
  - RDS in newborns
  - PPHN
  - PIE
  - Air leak syndrome
  - Meconium aspiration
  - Acute hypoxic respiratory failure
Troubleshooting during ventilation

• Is the ventilator working?
  – **Look at the patient !!**
  – **Listen to the patient !!**

• When in doubt, **DISCONNECT THE PATIENT FROM THE VENT**, and begin bag ventilation.
• Ensure you are bagging with 100% O2.
• This eliminates the vent circuit as the source of the problem.
• Bagging by hand can also help you gauge patient’s compliance
**Extubation**

- **Weaning**
  - Is the cause of respiratory failure gone or getting better?
  - Is the patient well oxygenated and ventilated?
  - Can the heart tolerate the increased work of breathing?

- **Extubation**
  - Control of airway reflexes
  - Patent upper airway (air leak around tube?)
  - Minimal oxygen requirement
  - Minimal rate
  - Minimize pressure support (0-10)
  - “Awake” patient
The science of mechanical ventilation is to optimize gas exchange. The art is to achieve that without damaging the lung.