Fundamentals of Mechanical Ventilation

Junior Resident Conference
December 22, 2016
Objectives

- Learner will be able to describe normal respiration.
- LWBAT describe the differences between the different modes of non-invasive respiratory support
- LWBAT describe the differences between the different modes of mechanical ventilation
- LWBAT choose the appropriate changes in ventilator support
Minute ventilation ($V_E$) = Tidal volume ($V_T$) x respiratory rate (f) 
- Normal $V_E$ = 5-8L/min 
- Controlled by PaCO2 and medullary pH

$V_T = \text{dead-space (} V_D \text{) + alveolar ventilation (} V_A \text{)}$
Normal Inspiration
Acute Respiratory Failure

Hypoxemia:
1) **Shunt (V/Q<1)**
2) Ventilation-Perfusion Mismatch
3) Diffusion limitation
4) Dead space
5) Low FiO2
6) Low barometric pressure
7) Alveolar hypoventilation

Hypercarbic
Acute Respiratory Failure

Hypoxemia:
1) Shunt (V/Q<1)
2) Ventilation-Perfusion Mismatch
3) Diffusion limitation
4) **Dead space (V/Q>1)**
5) Low FiO2
6) Low barometric pressure
7) Alveolar hypoventilation

Hypercarbic
Non-invasive techniques: Low Flow

**Nasal Cannula:**
- FiO2 range: 24-44%
- FiO2 = 20% + (4% x LO2/min)
  - Ex: 2L NC = 28% FiO2

* FiO2 influenced by inspiratory flow rate —> if patient is tachypneic they recieve less FiO2
Non-invasive techniques: Low Flow

Non-rebreathing facemask—“non-rebreather”:
- FiO2 range: >40% (can deliver up to 90% FiO2)
- Can set O2 at 8-15L/min

* Good for an acute desaturation
* Risk of CO2 retention if bag collapses on inspiration
* Drying!
* Should not be used more than 4 hours
Non-invasive techniques: High Flow

Venturi mask:
• FiO2 range: 24-44%

* Provides consistent FiO2 regardless of rate or tidal volumes
* Useful in COPD (concern re: suppression of respiratory drive)
Non-invasive techniques: High Flow

High Flow Nasal Cannula:
- 10-60 LPM
- Humidified air
- Each 10L O2 adds 1cm/H2O positive pressure
Non-invasive techniques: Positive Pressure

Continuous positive airway pressure (CPAP): increases alveolar recruitment

BiPAP: inspiratory PS + PEEP
Mechanical Ventilation: The Basics

Goals of mechanical ventilation:
• Provide adequate oxygenation
• Provide CO2 clearance
• Decrease work of breathing

Variables:
1) **Breath trigger**: what initiates the vent?
   • Change in pressure or flow (patient-initiated)
   • Set time (ie. rate) (ventilator-initated)
2) **Target**: what controls gas delivery during the breath?
   • Set flow
   • Set inspiratory pressure
3) **Cycle termination**: what terminates the breath?
   • Set volume
   • Set flow
   • Set time (I:E ratio)
4) End-expiratory pressure (PEEP)
### 5 Basic Types of Breaths

<table>
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<tr>
<th>Breath Type</th>
<th>Trigger</th>
<th>Target</th>
<th>Cycle Termination</th>
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<tbody>
<tr>
<td>Volume Assist</td>
<td>Patient</td>
<td>Inspiratory flow</td>
<td>Set Volume</td>
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<tr>
<td>Volume Control</td>
<td>Vent</td>
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<td>Pressure Assist</td>
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<td>Inspiratory time</td>
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<tr>
<td>Pressure Support</td>
<td>Patient</td>
<td>Inspiratory pressure</td>
<td>% decrease in inspiratory flow</td>
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</tbody>
</table>
5 Basic Types of Breaths

1. **Volume Control**
   - Circuit pressure: Set flow
   - Flow: In, Out
   - Volume increasing: Set volume
   - Machine triggered

2. **Volume Assist**
   - Circuit pressure: Set pressure
   - Flow: In, Out
   - Volume increasing: Set volume
   - Patient triggered

3. **Pressure Control**
   - Circuit pressure: Set pressure
   - Flow: In, Out
   - Volume increasing: Set volume
   - Machine triggered

4. **Pressure Assist**
   - Circuit pressure: Set pressure
   - Flow: In, Out
   - Volume increasing: Set volume
   - Patient triggered

5. **Pressure Support**
   - Circuit pressure: Set pressure
   - Flow: In, Out
   - Volume increasing: Set minimal flow
   - Patient triggered
Ventilator Modes
Volume-limited v. Pressure-limited

**Volume-limited**
Clinician sets:
- peak flow rate
- flow pattern
- respiratory rate
- PEEP
- FiO2

Inspiration ends after set tidal volume

I:E ratio set by flow rate (increase flow rate—>decrease I time, decrease I:E ratio)

Airway pressures determined by set volume, lung compliance, airway resistance
Volume-limited v. Pressure-limited

**Pressure-limited**
Clinician sets:
- inspiratory pressure
- I:E ratio
- respiratory rate
- PEEP
- FiO2

Inspiration ends after delivery of set inspiratory pressure

Tidal volume is determined by inspiratory pressure, lung compliance, airway/tubing resistance

Peak airway pressure is constant (inspiratory pressure + PEEP)
Volume Assist Control Ventilation (ACV)

* Requires the least effort from the patient

Volume Assist-control Ventilation
Settings: Rate, Inspiratory volume
* Patient may initiate spontaneous breaths, given same volume as mandatory breaths

Minute ventilation = (mandatory + spontaneous breaths) x volume

Limitations:
Risk of volutrauma (safe plateau P=30-35 cmH2O)
Increasing rate —> decreased expiratory time —> may result in incomplete exhalation (AutoPEEP)
Assist Control Ventilation (ACV)
Pressure Assist-controlled Ventilation (PCV)

Volume Assist-control Ventilation
Settings: Rate, Inspiratory pressure, I:E ratio (ie: 1:3)
* Patient may initiate spontaneous breaths, given same pressure as mandatory breaths

Tidal volume limited by compliance

Limitations:
Lack of guaranteed tidal volume
Synchronized Intermittent Mandatory Ventilation (SIMV)

Settings: Rate, Inspiratory volume (volume SIMV) +/- PS
* Ventilator breaths synchronized with patient breaths
* Patient may initiate spontaneous breaths—> not supported, may have variable gas flow

Limitations: increases WOB, may fatigue weak respiratory muscles
* May augment spontaneous breaths with pressure support
Pressure Support Ventilation (PSV)

Settings: Inspiratory pressure (PS), PEEP
* Tidal volume dependent on compliance and respiratory muscle strength
* PS may be weaned as compliance increases
* No set inspiratory time (time depends on flow-cycle-usually 25%)

Limitations:
Cannot be used in patients without spontaneous respirations
Unreliable tidal volumes
Comparisons of waveforms
Advanced Modes
Airway Pressure Release Ventilation (APRV)

High continuous pressure (CPAP) with intermittent release. Allows for spontaneous breathing (+/- PS).

Advantage: maximizes alveolar recruitment while allowing CO2 exchange during release.

*Tidal volume related to driving pressure and compliance.

Limitations: hyperinflation/barotrauma in COPD.

Data from: Seymour, CW, Frazer M, Reilly, PM, Fuchs, BD. Airway pressure release and biphasic intermittent positive airway pressure ventilation: are they ready for prime time? ] Trauma 2007; 62:1298.
Biphasic Ventilation (Bilevel)

Similar to APRV except has longer lower P phase — allows for more spontaneous breaths during release phase.
High Frequency Oscillatory Ventilation (HFOV)

Ultra-fast (120-900 breaths/min) with low tidal volumes
* Rescue mode for severe ARDS—keeps alveoli open while reducing barotrauma
* Improves hypoxemia

Limitations: very uncomfortable (requires sedation/neuromuscular blockade), can’t clear secretions

Figure 8  Schematic representation of a high-frequency oscillator.
Adjuncts

- Prone positioning: may improve V/Q mismatch in severe hypoxemia
Liberation

1. Reason for intubation needs to be corrected (ie. MS, etc)
2. Maintain gas exchange without support
   - FiO2<=50%
   - PEEP<=8
   - Able to maintain normocapnia
3. CV reserve

*Initiate a spontaneous breathing trial (T-piece or CPAP)
   - Rapid shallow breathing index—RR/tidal volume(L) (<105 predictive of successful extubation)
Review Questions
An artificial airway like an endotracheal tube is used in the following type of ventilation

• Positive Pressure
• Negative pressure
One of the following modes of ventilation has the risk of patient getting respiratory alkalosis

- High Frequency Oscillatory Ventilation
- Synchronous Intermittent Mandatory Ventilation
- Assist Control Mode
- Pressure Control Mode
The mode of ventilation which allows the patient to breathe spontaneously at his or her own respiratory rate and depth between the ventilator breaths is

- High Frequency Oscillatory Ventilation
- Synchronous Intermittent Mandatory Ventilation
- Assist Control Mode
- Pressure Control Mode
Which one of the following modes of ventilation is triggered by time, limited by pressure and affects inspiration only?

• High Frequency Oscillatory Ventilation
• Synchronous Intermittent Mandatory Ventilation
• Assist Control Mode
• Pressure Assist Control Mode
There can be variations in the minute ventilation in one of the following modes of ventilation as the respiratory rate and tidal volume is determined by patient:

• High Frequency Oscillatory Ventilation
• Synchronous Intermittent Mandatory Ventilation
• Pressure Support Mode
• Pressure Assist Control Mode
Mrs. L is ventilated on pressure support with the following settings:
Pressure support: 8
PEEP: 5
FiO2: 40%
Her respiratory rate is 14 breaths/min.
Her most recent blood gas is 7.42/40/52/26

What is the problem?
What should you do next?
Mr. R is ventilated on pressure support with the following settings:
Pressure support: 8
PEEP: 5
FiO2: 40%
His respiratory rate is 11 breaths/min.
His most recent blood gas is 7.28/62/72/27

What is the problem?
What should you do next?
Thank you!

YOU FORGOT TO BREATHE!
I told you! Don't forget to breathe!

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