Modes of Ventilation

Janeen Jordan, MD
TACS Fellow
“...an opening must be attempted in the trunk of the trachea, into which a tube of reed or cone should be put; you will then blow into this, so that the lung may rise again...and the heart becomes strong...”

Vesalius 1555
Fun Facts

- Vesalius credited with the first positive pressure ventilation 1555

- Iron Lung
  - invented by Phillip Drinker and Louis Agassiz Shaw
  - Pumps that increase/decrease air pressure
  - Negative pressure ventilation
  - Treatment of coal gas poisoning
  - First used in 1928 at Children’s Hospital, Boston

- Emerson company prototype in late 1950s
  - Positive-pressure ventilation
  - Became famous in mid-1900s during polio outbreak
After bronchodilator
(peak expiratory flow = 59 L/min)

Before bronchodilator
(peak expiratory flow = 45 L/min)
Ventilation or blood flow / unit of lung volume

Blood flow

Ventilation

\( \dot{V}_A/\dot{Q} \)

Ratio

Bottom of Lungs

Top of Lungs
## Oxygen Inhaled Therapy

<table>
<thead>
<tr>
<th>Device</th>
<th>Reservoir Capacity</th>
<th>Oxygen Flow (L/min)</th>
<th>Approximate (FiO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Cannula</td>
<td>50mL</td>
<td>1</td>
<td>0.21–0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>0.24–0.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.28–0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.34–0.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>0.38–0.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.42–0.46</td>
</tr>
<tr>
<td>Face Mask</td>
<td>150–250mL</td>
<td>5–10</td>
<td>0.40–0.60</td>
</tr>
<tr>
<td>Mask–Reservoir bag</td>
<td>750–1250mL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial Rebreather</td>
<td></td>
<td>5–7</td>
<td>0.35–0.75</td>
</tr>
<tr>
<td>NonRebreather</td>
<td></td>
<td>5–10</td>
<td>0.40–1.00</td>
</tr>
</tbody>
</table>
Indications for Mechanical Ventilation

- Respiratory failure due primary lung disease
  - COPD, CF, Asthma, pneumonia
- Acute respiratory acidosis (PaCO$_2$ > 50mmHg, pH < 7.25)
  - Myasthenia Gravis, Guillain–Barre, spinal cord injury, ALS, Muscular Dystrophy
- Increase work of breathing
- Hypoxemia (PaO$_2$ < 55mmHg)
- Acute lung injury
- Apnea with respiratory arrest
- Hypotension
Overview

- Non-invasive vs Invasive
- Controlled vs Assisted
- Pressure controlled vs Volume controlled vs both
Non-invasive Ventilatory Support

- **CPAP**
  - Continuous pressure throughout spontaneous inspiration and exhalation
  - Requires intact respiratory drive and adequate tidal volume
  - Increases FRC by opening unventilated alveoli
  - Decreases right-to-left V/Q shunting
  - OSA, obesity
Non-invasive Ventilatory Support

- BiPAP
- A valve sets 2 pressure levels
  - An inspiratory positive airway pressure
  - An expiratory positive airway pressure
  - Neuromuscular disorders, CHF, COPD, asthma
Non-invasive Ventilatory Support

- Avoided in patient with hemodynamic instability
- Those unable to protect their airway
- Severe hypoxia or morbid obesity should be observed
- Acidemia predicts failure (pH 7.22)
Non-invasive Ventilatory Support

- **Bedside Observation**
  - Conscious level
  - Chest wall motion
  - Accessory muscle recruitment
  - Patient-ventilator synchrony

- **Vital Signs**
  - Respiratory Rate
  - Exhaled $V_T$ (flow, volume, pressure waveform for poor synchrony)
  - Heart Rate
  - Blood Pressure
  - Telemetry

- **Gas Exchange**
  - Pulse oximetry
  - Arterial blood gas at baseline, after 1–2hrs, then as clinically indicated
Invasive Ventilatory Support

- Pressure Support Ventilation
  - Pressure–triggered, pressure–targeted, flow–cycled mode of ventilation
  - Delivers a preset inspiratory pressure to assist spontaneous breathing
  - Pressure is maintained throughout inspiration
  - Reduction in inspiratory flow triggers the ventilator to cycle into expiration
  - Patient must have intact respiratory drive and adequate $V_T$
Invasive Ventilatory Support

- Continuous Mandatory Ventilation (CMV)
  - Supplies full support to respiratory muscles
  - Hyperventilation
  - Dyssynchrony

- Assist–control ventilation (AC)
  - Set rate and volume
  - Spontaneous breaths are augmented to receive full $V_T$
Volume-controlled ventilation (VCV)

- Vent controls flow and inspiratory time to achieve desired volume
- The dependent variable becomes pressure which is determined by lung mechanics, vent setting and inspiratory effort (higher volume, higher flow, lower compliance, higher resistance = higher pressure)
- Used when PaCO$_2$ control needed
Invasive Ventilatory Support

- Pressure-controlled ventilation (PSV)
  - Airway pressure and inspiratory time are controlled
  - Dependent variable are flow and volume
  - Decreases volu-trauma
  - Better alveolar recruitment
  - Can result in hypoventilation in the presence of auto-PEEP
Synchronized Intermittent Mandatory Ventilation (SIMV)

- Vent provides a mandatory respiratory rate
- Pressure, volume controlled or both
- Mandatory Minute Ventilation
Invasive ventilatory Support

- Dual-controlled Ventilation (PRVC)
  - Pressure is adjusted breath to breath to give a desired $V_T$
  - Advantage ability of the ventilator to meet patient demand while maintaining minute ventilation
  - As patient effort increases, support decreases and can lead to dyssynchrony
Invasive Ventilatory Support

- Pressure-controlled inverse ratio ventilation (PCIRV)
  - Inspiratory time is set longer than expiration
  - Results in higher mean airway pressure and enhanced recruitment
  - Can result in higher auto-PEEP and hemodynamic compromise
Airway Pressure Release Ventilation (APRV)

- Vent controls the inspiratory pressure by allowing the exhalation valve to open if pressure increases and by adding additional flow if the pressure decreases
- Used for recruitment at lower airway pressures
- Increases $\text{PaO}_2$ with minimal barotrauma, HD instability and lower sedation
DHMC SICU MECHANICAL VENTILATION PROTOCOL

**Mechanical Ventilation**
- E.V.S.
  - A/C → Sedation/Analgesia
  - VT → 10 ml/Kg/IBW
  - RR → pH 7.40 ± .05
  - Flow → Pco2 35-40
  - PEEP → 1:1:3 - 1:4
  - +5 if tolerated

**Recruitment Maneuver**
- Press Control Vent
- PIP 20 cm H2O
- I:E ratio 1:1 (3 sec I.T.)
- R.R. 10/Min
- PEEP 25 cm H2O
- 2 minute Duration
- Monitor vital signs

**B.P.F.**
- Wean if possible
- FVS – SIMV/PS
- Limit Vt to <10ml/Kg
- RR (Accept higher Pco2)
- Minimize inap. Time
- Paw/Use square Flow wave
- D/C PEEP
- Tx Airflow obstruction
- Consider unconventional therapies-ILV,PL PEEP
- Fibrin Glue
- Consider HcO3Drip for Ph ≤ 7.20

**Auto-PEEP**
- Treat Cause:
  - Excessive Secretions
  - Bronchospasm
  - Pulmonary Contusion
  - ARDS
  - COPD/Asthma
  - EXTRINSIC
  - Intrinsic
  - Localized Dz
  - High VE
  - Small E.T.T.
  - Low Flows
  - Mode of Ventilation

**A.L.I.**
- 250-300
- 300>
- <200

**PaO2/FiO2**
- Cardiopulmonary Stable
- Yes
- No
- If OK
- Yes
- No
- Reassess q Day

** Continue F.V.S.**
- T-Piece Or Extubate
- P.V.S.
- SIMV/PS
- PEEP to Maintain Lung Volume

**ARDS**
- Lung Protective
- A/C (Pressure Control)
- VT → plat p≤ 30cm H2O
- VT = 6ml/Kg/IBW
- PIP>7.25
- I:E ratio to 1:1
- Decelerating flow wave form
- PEEP 12.5 cm H2O + 2.5
- Consider
  - Tracheal gas insufflation
  - Prone Ventilation
  - Steroid "rescue" therapy
  - Recruitment maneuver for hypoxemia/Best PEEP

**ARDS**
- Pt at Risk MOF
- ISS >25 OR ISS >15 + 6 units PRBC/12 Hr
- Significant Pulm contusion
- Sepsis

* Acute Onset
* Bilat Infiltrates on CXR
* PCWP ≤ 18 MMHg
ACUTE HYPOXIC EVENTS DURING MECHANICAL VENTILATION

Acute Hypoxic Event → Hand Ventilate ↑FIO₂ → ET Tube Cuff Leak → Repair/Replace ET Tube → Difficult Bagging → Obstruction → √ Tube Position Deflate Cuff R/O Plug → Obstruction Persists → Replace ET Tube

Physical Exam → Check: O₂ Source Ventilator Circuit → Correct Mechanical Problems → Tension Pneumothorax → Chest Tube → ABG CXR Recent Events (EKG) → Intervention or Procedure → New Complications → Progression Underlying Disease
AC $V_T$ 550 (8cc/kg), RR 20, $FiO_2$ 50%, PEEP 5

ABG 7.50/32/80/2.5  PulseOx 99%

- Problem: Respiratory alkalosis
- A) Increase or Decrease the Respiratory rate
  - Answer: Decrease
- B) Increase or Decrease the Tidal Volume
  - Answer: Decrease
Patient #2

- AC $V_T$ 550 (8cc/kg) RR 20, $FiO_2$ 50%, PEEP 5
- ABG 7.38/42/50/−0.7 PulseOx 82%
  - Problem: hypoxemia
  - Increase or decrease $FiO_2$
    - Increase $FiO2$
  - Increase or Decrease PEEP
    - Increase PEEP
Patient #3

- AC $V_T$ 450 (6cc/kg) RR 20, $FiO_2$ 50%, PEEP 10
- ABG 7.38/42/70/−0.7  PulseOx 92%
- PP 40, Compliance 22
  - Problem: Stiff lungs, barotrauma
  - Increase or decrease $FiO_2$
  - Increase or Decrease PEEP
    - Decrease PEEP
Patient #4

- AC $V_T$ 550 (8cc/kg), RR 20, FiO$_2$ 50%, PEEP 5
- Sat 83%, HR 120 ST
- 7.48/32/45/2.0
References

- DHMC SICU Mechanical Ventilator protocol.