New Frontiers in Anesthesia Ventilation

Anesthesia Evolution

Mechanical Ventilation

- Ventilators deliver gas to the lungs using positive pressure at a certain rate.
- The amount of gas delivered can be limited by time, pressure or volume.
- The duration can be cycled by time, pressure or flow.
Indications for Mechanical Ventilation

- Respiratory Failure
  - Apnea / Respiratory Arrest
  - Inadequate ventilation (acute vs. chronic)
  - Inadequate oxygenation
  - Chronic respiratory insufficiency with FTT
- Cardiac Insufficiency
  - Eliminate work of breathing
  - Reduce oxygen consumption
- Neurologic dysfunction
  - Central hypoventilation / frequent apnea
  - Patient comatose, GCS ≤ 8
  - Inability to protect airway

Ventilatory Modes

- Negative Pressure Ventilation
  - “Iron Lung”
  - Allows long-term ventilation without artificial airway
  - Maintains normal intrathoracic hemodynamics
  - Uncomfortable
  - Limited access to patient

Positive Pressure Ventilators

- Volume Cycled
  - Minimizes hyperventilation / hypoventilation
  - Maintains normal respiratory rate and tidal volume
- Pressure Cycled
  - Minimizes pressure swings
  - Reduces airway trauma

Alphabet Soup of Ventilation

VCV, CPAP, BIPAP, SIMV, PCV, CPAP, SIMV-PC, PC-VG

Negative Pressure Ventilation

- “Iron Lung”
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Modes of Ventilation

Control Modes
- Every breath is fully supported by the ventilator
- In classic control modes, patients were unable to breathe except at the controlled set rate
- In newer control modes, machines may act in assist-control, with a minimum set rate and all triggered breaths above that rate also fully supported.
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Controlled Mechanical Ventilation (CMV)

- **Mandatory breaths**
  - All breaths delivered at a preset rate

- **Spontaneous breaths**
  - During mandatory breaths only, not between
  - Usually none

- **Key clinical concept**
  - Patients typically paralyzed and/or sedated (O.R., ICU)
  - Goal: rest muscles of respiration

Intermittent Mandatory Ventilation (IMV)

- **Mandatory breaths**
  - Machine triggered and/or machine cycled

- **Spontaneous breaths**
  - Between and during mandatory breaths

- **Synchronized Intermittent Mandatory Ventilation (SIMV)**
  - Breath synchronizes IMV breath with patient's effort

- **Key clinical concept**
  - Level of support is proportional to set frequency of spontaneous breaths
  - Historically used as a mode of weaning

Pressure Support

- **Concept**
  - Vent supplies pressure support in a preset ratio, pressure support can be fixed or variable

- **Spontaneous breaths**
  - Assisted by providing inspiratory arrest
  - Overcomes resistance of ETT, valves, etc.

- **Advantages**
  - Decreased work of breathing
  - Patient comfort

- **Disadvantages**
  - Need backup support (rate) if effort changes

Modes of Ventilation

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

Breath Types

![Breath Types Diagram]
Breath Trigger

• How does the vent know when to give a breath?
  • Patient effort
  • Elapsed time

• The patient’s effort can be “sensed” as a change in pressure or a change in flow (in the circuit)

Volume Controlled Ventilation (VCV)

• Set volume delivered at a constant flow
• PIP allowed to vary
  – Compliance
  – Resistance
• Volume is adjusted to avoid atelectasis
• Rate adjusted for ETCO₂

Limitations of Conventional AGM Ventilators

1. No protection against barotrauma
2. No tidal volume compensation
3. Manual pre-use checkout
4. Compressed medical gas consumption
5. Lack of pressure-control ventilation
6. Vₚ precision
7. Weaning or spontaneous ventilation modes

Advantages of New Anesthesia Ventilation Modes

1. Highly accurate Vₜ
2. Prevention of errors
   • Early apnea detection
   • Easier connections – less variation
3. Patient determines amount of ventilatory support
4. Improved weaning options
5. Ability to care for more complex patients more precisely

Brent Dunworth, MSN, CRNA
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Pressure Control Ventilation (PCV)
- Inspiratory pressure controlled
- Volume varies
  - Compliance (pulmonary)
  - Resistance (airway)

Flow is high at first to produce the set pressure early in inspiration
- Less flow later to maintain the set pressure through the inspiratory time
  - Target pressure is adjusted to produce $V_T$
  - Rate is adjusted to maintain ETCO$_2$

Advantages
- Ability to deliver increased $V_T$ at a lower pressure
- Greater gas flow in early inspiration may result in greater delivered $V_T$ at similar or less pressure

Disadvantages
- Possible hyper- or hypo-ventilation quickly
- Barotrauma possible if sudden compliance change.

Indications
- Danger of high PIP
  - COPD
  - Neonates/Infants
  - LMA
- Low compliance
  - Pregnancy
  - Major surgery
  - Laparoscopy
  - ARDS
- Compensate for leaks
  - Uncuffed ETT
  - LMA

Initial Settings
- Pressure limit: 20 cmH$_2$O
- Rate: 6-10
- PEEP: 0

Target pressure is adjusted to produce $V_T$
Pressure Control Ventilation – Volume Guarantee (PCV-VG)

- Ventilator operates as PCV, but a tidal volume target is also set.
  - Ventilator dynamically adjusts the inspiratory flow to achieve the desired V̇\textsubscript{T} breath-by-breath.

**Advantages**

1. Control of PIP (through pressure control mode)
2. Control of arterial CO\textsubscript{2} (through guarantee of V̇\textsubscript{T} and minute ventilation)

Clinical Uses of PCV

Synchronized Intermittent Mandatory Ventilation (SIMV)

- VCV with intelligence
  - Senses patient respiratory effort and delivers a "synchronized" breath
- Advantages
  - No breath stacking
  - May breathe spontaneously between ventilator breaths

**Additional options**

- SIMV-PC

SIMV
**New Frontiers in Anesthesia Ventilation**

**Pressure Support Ventilation (PSV)**

- "Triggering" vent requires certain amount of work by patient
- Can decrease work of breathing by providing flow during inspiration for patient triggered breaths
- Can be given with spontaneous breaths in IMV modes or as stand alone mode without set rate
- Flow-cycled

**INDICATIONS for PSV:**

- Spontaneous breathing patient under general anesthesia
- LMA or ETT
- Provision of normocapnia without bucking
- Too deep \( \rightarrow \) hypoxemia
- Too light \( \rightarrow \) bucking and awareness

**Clinical use of PSV**

- Spontaneous breathing under general anesthesia
  - Unassisted is contraindicated
    - Airway resistance and the circle system
  - \( {\text{ETCO}}_2 \) rises
- Normalize \( {\text{ETCO}}_2 \)
- Spontaneous breathing for extended time periods during surgery
- Weaning from mechanical ventilation

**Noninvasive Positive Pressure Ventilation (NIPPV)**

- Deliver PS and CPAP via tight fitting mask (BiPAP: bi-level positive airway pressure)
- Can set "back up" rate
- May still need sedation
Noninvasive Positive Pressure Ventilation (NIPPV)

- Selection Criteria (at least 2 should be present)
  - Moderate to severe dyspnea with use of accessory muscles and paradoxical abdominal motion
  - Moderate to severe acidosis (pH 7.30-7.35) and hypercapnia (PaCO2 >45-60 mmHg)
  - Respiratory frequency 25 breaths per minute
- Exclusion Criteria (any may be present)
  - Respiratory arrest
  - Cardiovascular instability (hypotension, arrhythmias, MI)
  - Somnolence, impaired mental status, uncooperative patient
  - High aspiration risk, viscous or copious secretions
  - Recent facial or gastrointestinal surgery
  - Craniofacial trauma, faxed nasopharyngeal abnormalities
  - Burns
  - Extreme obesity

Clinical Utility (Scenario 1)

- 100 kg patient for robotic-assisted radical prostatectomy
- PMH: CAD, 2 stents; NIDDM
- Considerations: abdominal insufflation + long periods of steep Trendelenburg position.

- Ventilation strategy?
  - PCV
  - PCV-VG

Clinical Utility (Scenario 2)

- 7 hour “big belly” case for pelvic tumor
- PMH: 40 year-old female, otherwise healthy
- Considerations:
  - 6000 mL IVF in;
  - 500 mcg fentanyl;
  - 2 mg hydromorphone + more titrating
- Utilized PCV-VG during entire case

- Ventilation strategy during closing and emergence?
  - SIMV
  - SIMV + PS
  - PS if ETT to PACU necessary

Clinical Utility (Scenario 3)

- 3 kg neonate for omphalocele repair

- Ventilation strategy:
  - PCV
  - PCV-VG

Clinical Utility (Scenario 4)

- 65 year old male status post right radical nephrectomy (3 hours)
- After extubation, appears still a bit “weak” with shallow tidal volumes

- Ventilation strategies:
  - NIPPV
  - Reintubation (PSV, CPAP, SIMV)

GE Aisys

- Modes
  - Volume & pressure control
  - SIMV (volume or pressure)
  - PCV-VG
  - PSV-Pro
- Features
  - Electronic gas and vapor control
  - Automated FDA machine checkout
GE Avance
- Modes
  - Volume & pressure control
  - SIMV (volume or pressure)
  - PCV-VG
  - PSV-Pro
- Features
  - Electronic flowmeters
  - Conventional vaporizers

Drager Apollo
- Modes
  - Volume & Pressure Control
  - SIMV
  - PSV
- Features
  - Hybrid flowmeters
  - Conventional vaporizers
  - Electronic + manual checkout

Anestar
- Modes
  - Volume & Pressure Control
  - PSV
- Features
  - Hanging bellows
  - Traditional flowmeters and vaporizers

Drager Fabius GS
- Modes
  - Volume & Pressure Control
  - SIMV
  - PSV
- Features
  - Piston ventilator
  - Hybrid flowmeters
  - Electronic + manual checkout

Paragon
- Modes
  - Volume & Pressure Control
  - PSV
- Features
  - Traditional flowmeters and vaporizers

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