Learning Objectives:
- Compare ventilation modes available on state-of-the-art mechanical ventilators with respect to their attributes, advantages and disadvantages.
- Identify modes available on specific brands of ventilators.
- Explain the purposes, physiological effects and adjustment of tube compensation, expiratory timer and rise time.
- Describe the evidence base for current modes of ventilation.

### Ventilation Modes

**Volume Control**

- **Advantages**
  - variable flow to meet patients' demands
  - increased mean airway pressure-improved oxygenation
  - limits excessive airway pressure
  - improves gas distribution
  - decreases WOB

- **Disadvantages**
  - preset, limited flow - may not meet patients' needs
  - possibility of volutrauma

**Pressure Control**

### Volume Control

- **Advantage**
  - constant TV, despite changes in patients' lung mechanics
## Pressure Control

- **Disadvantages**
  - TV varies with mechanics
  - TV may become excessive, causing overdistension, volutrauma
  - inconsistent changes in TV with PEEP, PIP

## Pressure Support

- **Attributes**
  - pressure-limited
  - flow-cycled- inspiration ended by reaching a percentage of the peak inspiratory flow
  - variable flow to meet patients' demands
  - decreases WOB

## Pressure Support

- Original purpose- overcome WOB imposed by ETT
- Problem- correct level of PS is hard to identify, because imposed WOB varies with flow rates, impedance
- Estimated PS level = PIP - Ppt

## Dual Control Modes

- Combine volume and pressure control to achieve advantages of each type:
  - guaranteed minimum tidal volume
  - minimized plateau pressure

## Dual Control Modes

- Breaths are pressure controlled with a guaranteed minimum volume, based on feedback on patient ventilation to ventilator logic
- Types:
  - within breath
  - breath-to-breath

## Within Breath Dual Control

- Availability:
  - volume-assured pressure support- VAPS (Bird 8400sti, TBird)
  - pressure augmentation PA (Bear 1000)

FYI - Click for picture of TBird™ ventilator
### Within Breath Dual Control
- Pressure support with volume guarantee for every breath
- Breath initiated, ventilator compares output with target, changing to volume control, if needed

### Dual Control Breath-to-Breath
- Volume guarantee over several breaths
- Ventilator delivers test breaths, then adjusts pressure and flow to deliver a minimum tidal volume

### Dual Control Breath-to-Breath
- Pressure control with volume guarantee - company names
  - Pressure-Regulated Volume Control- PRVC (Maquet)
  - Volume Targeted Pressure Control- VTPC (Newport e360)
  - Volume Control Plus (VC+) (PB 840)
  - AutoFlow (Drager Evita)
  - P-CMV (Hamilton Galileo, Raphael, G-5)
  - Pressure control volume guarantee (PCV-VG) GE Engstrom

### Dual Control Breath-to-Breath
- Volume guaranteed PSV
  - Maquet Servoi, Servo 300
  - Newport e360
  - Puritan Bennett 840
  - Drager Evita ventilators
  - Hamilton Galileo, Raphael, G-5
  - GE Engstrom

---

Maquet Servoi®

![Maquet Servoi](image_url1)

Image courtesy of Maquet Medical

FYI - Link to Maquet ventilators

Newport e360®

![Newport e360](image_url2)

Image courtesy of Newport Medical

FYI - Link to Newport products page
http://www.newportnmi.com/ProductTOC.asp
**Puritan Bennett 840**

![Image of Puritan Bennett 840]

FYI - Link to Drager Ventilators
http://www.draeger.us/sites/enus_us/Pages/Hospital/ProductSelector.aspx?navID=218

**Drager Ventilators**

**Drager Evita**

**Drager Evita XL**

Images courtesy of Drager Medical

FYI - Link to Drager Ventilators
http://www.draeger.us/sites/enus_us/Pages/Hospital/ProductSelector.aspx?navID=218

---

**Hamilton Ventilators**

**Hamilton G-5**

**Hamilton Galileo**

Images courtesy of Hamilton Medical

FYI - Link to Hamilton Ventilators
http://www.hamilton-medical.com/

---

**GE Engstrom Carestation**

- FRC measurement during ventilation - volume-oriented PEEP adjustment
- Intrathoracic pressure measurement

![Image of Intrathoracic pressure sensor]

Images courtesy of GE Healthcare

---

**GE Engstrom Carestation**

- Intrathoracic pressure measurement

![Diagram of Intrathoracic pressure measurement]

Images courtesy of GE Healthcare
GE Engstrom Carestation®

Intratracheal pressure measurement

Pressure control with volume guarantee

- Deliver minimum set TV, VE, with automatic reduction in delivery pressure

Precautions

- not for all patients
- erratic patient effort prevents ventilator logic from making appropriate adjustments and tidal volume will not be delivered.

Pressure support with volume guarantee

- Pressure support breaths with minimum tidal volume
- Breath attributes
  - patient-triggered
  - pressure-limited
  - flow-cycled
  - flow variable
  - volume guarantee (minimum)
**Pressure support with volume guarantee**

- **Precautions**
  - Pressure level increases to maintain TV for a patient with obstruction
  - auto-PEEP may result from patient actively attempting to exhale

---

**Precautions**

- During hyperpnea, as due to increased demand, the ventilator will reduce its support when it is most needed

---

**Precautions**

- Inappropriate expiratory trigger prolongs inspiration & may cause:
  - auto-PEEP
  - patient discomfort
  - inability to trigger breaths

---

**Commonalities**

- IBW entered
- respond to changes in mechanics
- % support adjusted
- TV determined by ventilator

---

**Proportional assist ventilation (PAV)** (TM) Puritan Bennett 840

**Adaptive support ventilation (ASV)** (TM) Hamilton ventilators

---

**Weaning mode**

- Support level is based on patient demand
- Ventilator adapts to changes in resistance and compliance
- Weaning proceeds by decreasing % support by ventilator
- Graphics display of WOB

---

FYI - Click to download article on dead space and body weight

www.rcjournal.com/contents/07.08/07.08.0885.pdf
Volume-pressure loop

- spontaneous WOB

\[ \text{spontaneous breaths} \]

\[ \text{WOB} \]

\[ \text{Inspiration} \]

\[ \text{Expiration} \]

\[ \text{P}_{aw} \] cm H₂O/mbar

\[ \text{VT} \] LITERS

\[ \text{VT} \] LITERS

Adaptive Support Ventilation

- Not just a weaning mode
- ASV algorithm determines optimal breathing pattern (TV, f) for patient, based on:
  - estimated anatomic deadspace
  - expiratory time constant (R*C)

Adaptive Support Ventilation

- Ventilator maintains minimum minute ventilation
- Absence of patient effort- pressure control with volume guarantee
- Presence of patient effort
  - automatic reduction of mandatory breaths
  - automatic reduction of pressure support

Adaptive Support Ventilation

- Weaning proceeds by decreasing % minute volume support by ventilator

Neurally adjusted ventilatory assist (NAVA)™

- Modality developed by Maquet™
- a gastric catheter detects and transmits diaphragmatic electrical activity to the ventilator.
- ventilator uses the strength of the signal to adjust the level of support for the patient.

Tube compensation

- Provides PSV level based on tube size and inspiratory flow
  - availability
    - Drager ventilators
    - Hamilton ventilators
    - Puritan-Bennett 840
    - Engstrom Carestation

FYI - Click for article on ASV
http://www.ijccm.org/article.asp?issn=0972-5229;year=2013;volume=17;issue=1;spage=16;epage=22;aulast=Fernandez

FYI - Click to view or bookmark video about NAVA (28 min.)
http://vimeo.com/44685561

Copyright 2008 AP Jones
Tube compensation
- Provides PSV level based on tube size
  - theoretically, WOB same as if patient is extubated; but.....??
  - "electronic extubation"
  - measurement of rapid shallow breathing index on tube compensation mode

FYI - Click for article on tube compensation
http://services.aarc.org/source/DownloadDocument/DownloadDocs/05.10.0640.pdf

Adjustable Expiratory Trigger
- Purposes
  - increase synchrony for expiration
  - increase patient comfort
  - prevent auto-PEEP
  - leak compensation - especially important for uncuffed tubes (pediatrics)

Adjustable Expiratory Trigger
- Adjusted by observing:
  - patient effort- working to exhale
  - I:E ratio
  - ventilator graphics
  - Patient expiratory effort
  - Late termination
  - Inability to trigger

Adjustable Expiratory Trigger
- Ventilators with adjustable expiratory triggers:
  - Hamilton ventilators
  - Puritan Bennett 840
  - Newport e360
  - Maquet Servoi
  - Drager ventilators
  - Engstrom Carestation

Adjustable rise time
- Rise time- time required to reach PIP
- Purposes:
  - improve patient comfort
  - decrease inspiratory WOB
- Adjusted by observing:
  - patient inspiratory effort
  - ventilator graphics

Adjustable rise time
- Rise time adjustment- observe pressure waveform
- Linear or bowed upward rise in pressure after trigger on the pressure wave
- Slow rise in pressure, concave shape of the pressure wave

Copyright 2008 AP Jones
Evidence for Ventilation Modes
- Pressure control with volume guarantee - decreased PIP
- Pressure support with volume guarantee - no evidence
- Automatic tube compensation - increased tolerance of SBT

FYI - Link to article on evidence for new modes
http://www.advanceformrc.com/SharedResources/advanceforMRC/Resources/DownloadableResources/NewModes.pdf

Evidence for Ventilation Modes
- Proportional assist ventilation - better sleep; no improvement over PSV in duration of ventilation, mortality
- NAVA - no RCTs, no evidence
- APRV - improved hemodynamics; shorter duration of ventilation, ICU stay
- HFOV - no differences in duration of ventilation or mortality

Developments In Mechanical Ventilation That Will Outlast The Next Decade (Kacmarek)
- Noninvasive PPV
- Lung protective strategies
- Combined pressure-volume

Developments In Mechanical Ventilation That Will Outlast The Next Decade (Kacmarek)
- Noninvasive PPV
- Lung protective strategies
- Combined pressure-volume targeted modes
- Prone positioning
- Tracheal gas insufflation

Summary & Review
- Volume and pressure-targeted ventilation each have advantages and disadvantages
- Dual control modes developed to combine volume and pressure modes

Summary & Review
- Dual control - within breath, or breath-to-breath
- Pressure control with volume guarantee
- Pressure support with volume guarantee
Summary & Review

- Modes tailored to patient
  - Adaptive support ventilation
  - Proportional assist ventilation
  - Maquet NAVA

- Additional ventilator adjustments
  - Expiratory trigger
  - Inspiratory rise time
  - Compensation for tube resistance

- Evidence for newer modes
  - Kacmarek's ventilation strategies through the next decade

References

- Branson RD. Techniques for automated feedback control of mechanical ventilation. The clinical and management quarterly newsletter NAMDRG 2001;25(3).
- Kacmarek RM. Which developments in mechanical ventilation will outlast the next decade? http://www.chestnet.org/education/pccu/vol14/lesson1.html

END