

Ventilation Modes & Controls

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This Presentation is Approved for
1 CRCE Credit Hour

Learning Objectives

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

Ventilation Modes

Volume Control

- Advantage
 - ❖ Constant TV, despite changes in patients' lung mechanics

Volume Control

- Disadvantages
 - ❖ Preset, limited flow - may not meet patients' needs
 - ❖ Possibility of volutrauma

Pressure Control

- Advantages
 - ❖ Variable flow to meet patients' demands
 - ❖ Increased mean airway pressure - improved oxygenation
 - ❖ Limits excessive airway pressure
 - ❖ Improves gas distribution
 - ❖ Decreases WOB

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 = $PIP - P_{pt}$

Dual Control Modes

- > Combine volume & 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 see links below 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 & 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 - VTFC (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®



FYI see links below for Maquet ventilators

Newport e360®




FYI see links below for Newport products page

Puritan Bennett 840®

A photograph of a Puritan Bennett 840 ventilator. It features a large, multi-panel LCD screen displaying various respiratory parameters and waveforms. The device is white and blue, with a control panel on the right side of the screen.

Drager Ventilators®

Two photographs of Drager ventilators. The one on the left is a smaller, desktop-style unit with a single screen. The one on the right is a larger, floor-standing unit with a larger screen and more complex controls.

FYI see links below for Drager ventilators

Hamilton Ventilators®

A photograph of a Hamilton ventilator. The screen shows a large tidal volume waveform and various numerical data points. The device is white and blue.

FYI see links below for Hamilton ventilators

GE Engstrom Carestation®

A photograph of a GE Engstrom Carestation ventilator. It is a tall, white floor-standing unit with a large screen and multiple control panels. It has a sleek, modern design.

FYI see links below for GE Engstrom Carestation

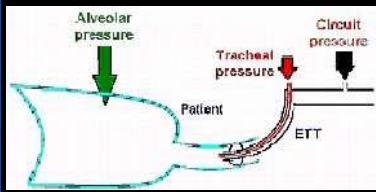
GE Engstrom Carestation®

- > FRC measurement during ventilation - volume-oriented PEEP adjustment
- > Intratracheal pressure measurement

A photograph of a clear plastic device used for intratracheal pressure measurement. It has a circular opening and two green ports on top.

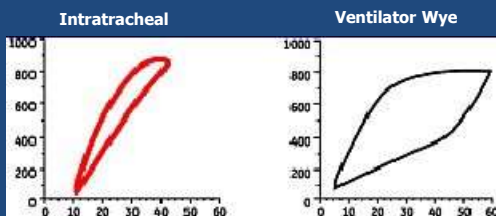
GE Engstrom Carestation®

- > Intratracheal pressure measurement

A schematic diagram showing a patient's airway. A green arrow points to the alveolar space, labeled 'Alveolar pressure'. A red arrow points to the trachea, labeled 'Tracheal pressure'. A black arrow points to the circuit, labeled 'Circuit pressure'. The patient's airway is labeled 'Patient' and the endotracheal tube is labeled 'ETT'.

GE Engstrom Carestation®

- > Intratracheal pressure measurement



Pressure Control with Volume Guarantee

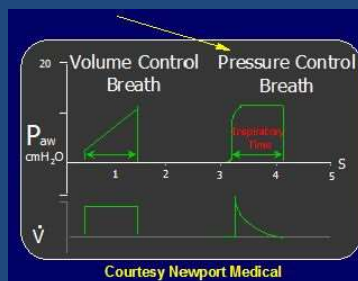
- > Deliver minimum set TV, VE, with automatic reduction in delivery pressure

Pressure Control with Volume Guarantee

- > Breath attributes
 - ❖ Patient or time-triggered
 - ❖ Pressure limited
 - ❖ Flow variable - meets patient demands
 - ❖ Time-cycled - proper adjustment of inspiratory time is critical

Pressure Control with Volume Guarantee

- > Wave form



Pressure Control with Volume Guarantee

- > Precautions
 - ❖ Not for all patients
 - ❖ Erratic patient effort prevents ventilator logic from making appropriate adjustments & tidal volume will not be delivered

Pressure Support with Volume Guarantee

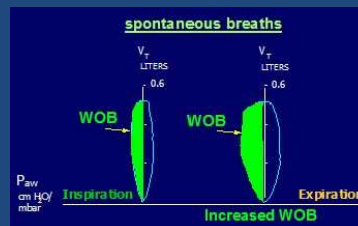
- > Pressure support breaths with minimum tidal volume
- > Breath attributes
 - ❖ Patient-triggered
 - ❖ Pressure-limited
 - ❖ Flow-cycled
 - ❖ Flow variable
 - ❖ Volume guarantee (minimum)

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

Pressure Support with Volume Guarantee

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



Pressure Support with Volume Guarantee

- > Precautions
 - ❖ Inappropriate expiratory trigger prolongs inspiration & may cause
 - Auto-PEEP
 - Patient discomfort
 - Inability to trigger breaths

Patient-Tailored Modes

- > Proportional assist ventilation (PAV™) Puritan Bennett 840
- > Adaptive support ventilation (ASV™) Hamilton ventilators

Patient-Tailored Modes

- > Commonalties
 - ❖ IBW entered
 - ❖ Respond to changes in mechanics
 - ❖ % support adjusted
 - ❖ TV determined by ventilator

FYI see links below for article on dead space & body weight

PAV

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

Volume-Pressure Loop

- > Spontaneous WOB

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

FYI see links below for article on ASV

Neurally Adjusted Ventilatory Assist (NAVA™)

- > Modality developed by Maquet™
- > A gastric catheter detects & transmits diaphragmatic electrical activity to the ventilator
- > Ventilator uses the strength of the signal to adjust the level of support for the patient

FYI see links below for video about NAVA

Tube Compensation

- > Provides PSV level based on tube size & inspiratory flow
 - ❖ Availability
 - Drager ventilators
 - Hamilton ventilators
 - Puritan-Bennett 840
 - Engstrom Carestation

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

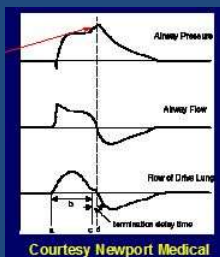
FYI see links below for article on tube compensation

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



Courtesy Newport Medical

Adjustable Expiratory Trigger

- > Ventilators with adjustable expiratory triggers
 - ❖ Hamilton ventilators
 - ❖ Puritan Bennett 840
 - ❖ Newport e360
 - ❖ Maquet Servo
 - ❖ Dräger ventilators
 - ❖ Engstrom Carestation

Adjustable Rise Time

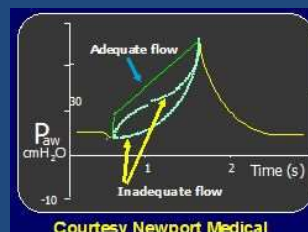
- > Rise time: time required to reach PIP
- > Purposes
 - ❖ Improve patient comfort
 - ❖ Decrease inspiratory WOB
- > Adjusted by observing
 - ❖ Patient inspiratory effort
 - ❖ Ventilator graphics

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



Courtesy Newport Medical

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 see links below for article on emerging ventilator modes & evidence for new modes

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

Summary & Review

- 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

- Frawly PM. Airway pressure release ventilation: theory and practice. AACN clinical issues 2001;12:234.
- Iotti G (Ed). Closed-loop control mechanical ventilation. Respiratory Clinics of North America 2001;7(3).
- Branson RD. Techniques for automated feedback control of mechanical ventilation. The clinical and management quarterly newsletter NAMDRC 2001;25(3).
- Woodgate PG, Davies MW. Permissive hypercapnia for the prevention of morbidity and mortality in mechanically ventilated newborn infants (Cochrane Review). In: The Cochrane Library, 4, 2001. Oxford: Update Software.

References

- Kacmarek RM. Which developments in mechanical ventilation will outlast the next decade? <http://www.chestnet.org/education/pccu/vol14/lesson1.html>