Ventilator Dyspnea: Optimizing Ventilator/Patient Synchrony

Kenneth Miller, MEd, RRT-ACCS, NPS. AC-E
Clinical Educator
Respiratory Care
Lehigh Valley Health Network
Allentown, Penna.

Learning Objectives

- Review the basics of breathing
- Describe relationship between the control of breathing & mechanical ventilation
- Define what is ventilator asynchrony
- Describe the potential negative sequale of ventilator asynchrony
Goals of Mechanical Ventilation

- Optimize gas exchange
- Maximize ventilator-patient interfacing
- Minimize ventilator induced injury
- Facilitate ventilatory liberation
**Historical Perspective**

- **Controller**-ventilator unable to respond to patient effort
- **Assistor**-ventilator capable of “triggering”
- 1930-Barach et al. recognized the need for high flows to make patient’s comfortable on CPAP
- 1950-1960s-Avery-therapeutic hyperventilation
- 1962-Harrison first true champion of patient-triggered augmented ventilation
- 1973-Downs introduced IMV
- 1986-Marini published classic paper of WOB during mechanical ventilation

---

**Timeline of patient-ventilator interaction.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>Ventilation during surgery</td>
</tr>
<tr>
<td>1950</td>
<td>Alkalotic apnea for flail chest</td>
</tr>
<tr>
<td>2010</td>
<td>IMV SIMV Rise time, flow cycling, automated control, closed-loop control</td>
</tr>
</tbody>
</table>

Branson, R. D. Respir Care 2011;56:15-24

(c) 2012 by Daedalus Enterprises, Inc.
An early intermittent mandatory ventilation system that included an H-valve and an integral one-way valve to provide continuous flow for spontaneous breathing.

Branson, R. D. Respir Care 2011;56:15-24

Nilsestuen, Hargett RC 2005;50:202
Fernandez AJRCCM 1999;159:710
Control of Breathing Overview:

- Normal pH – maintains cellular function
  - Central Controller
    - Brain stem – medulla & pons
  - Sensors – Central & peripheral chemoreceptors
  - Effectors – Neurons in spinal cord
Control of Ventilation

Ideally, ventilator gas delivery would perfectly match patient demand. This patient-ventilator interaction depends on how the ventilator responds to patient respiratory effort and, in turn, how the patient responds to the breath delivered by the ventilator. It is now evident that the interaction between patient and ventilator is frequently suboptimal, with consequences that appear to have substantial clinical relevance. Indeed, some clinicians have referred to this state as a “tug-of-war!!”
(Williams MD, Hinojosa-Kurtzberg PhD & Parthasarathy MD, 2011)
Interactions among clinician, patient, and ventilator.

Pharmacological Intervention
(eg, bronchodilator, sedation)

Set Variables
(eg, PEEP, VT, flow, modes: PAV, NAVA)

Patient

Automation
(eg, Smartcare)

Ventilator

Control of Breathing During Mechanical Ventilation: Who Is the Boss?
Kathleen Williams MD, Marina Hinojosa-Kurtzberg PhD, and Sairam Parthasarathy MD
Patient-Ventilator Synchrony

- Adequate resting of respiratory muscles
- Improved gas exchange
- Patient comfort
What is Ventilator Asynchrony?

Defined as a “mismatch” between the patient and ventilatory inspiratory time, flow and expiratory time.

Chao et al. found that more than 10% of patients admitted to a weaning center exhibited this phenomenon.

This mismatching results in weaning failure secondary to due to diaphragmatic muscle energy waste.
Patient-Ventilator Relationship
Phases of a Single Breath

Components of a patient-triggered mechanical breath.

Sassoon, C. S. Respir Care 2011;56:39-51

(c) 2012 by Daedalus Enterprises, Inc.
Factors in Patient-Vent Synchrony

- Trigger setting/type
- Rise-time
- Flow delivery pattern
- Sedation level
- Respiratory drive
- AutoPEEP
- Airway size
- Pathology of respiratory system
- Thoracic-abdominal impedance
- Airway patency

Treat the Patient and You May Achieve Synchrony!!

Examples:
- Metabolic acidosis
- Pain/anxiety/fear
- Hypoxemia
- Airway obstruction
- Fever
Three Main Patterns of Asynchrony

**Trigger asynchrony:**
- Can manifest as a delay or absent of inspiration or unwanted breaths (auto-triggering)

**Flow asynchrony:**
- This can manifest as too slow or too fast of delivered flow to match the patient’s flow requirements

**Cycle or termination asynchrony:**
- This can manifest when the inspiratory time of the breath is longer than what the patient desires or termination inspiratory can not be reached secondary to leaks or prolonged exhalation.

Factors to Consider in Determining How Often Patient-Ventilator Asynchrony Occurs:

- Timing of observations
- Duration of observations
- Method of detection
- Esophageal pressure
- Electrical activity of the diaphragm
- Waveform analysis
- Type of asynchrony
- Patient population
- Type of mechanical ventilation
- Pressure or volume targeted
- Ventilation mode (conventional vs newer modes)
- Triggering method
- Cycling method
- Degree of ventilatory support
- Sedation
Effect of Patient-Ventilator Asynchrony* on Outcomes in an Observational Study.

<table>
<thead>
<tr>
<th>Ineffective-Effort Index</th>
<th>Ineffective-Effort Index</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10%</td>
<td>&lt; 10%</td>
<td></td>
</tr>
<tr>
<td>Number of patients</td>
<td>16</td>
<td>44</td>
</tr>
<tr>
<td>Duration of mechanical ventilation (median d)</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>28-d ventilator-free survival (median d)</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>ICU stay (median d)</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Hospital stay (median d)</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>ICU mortality (%)</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>Hospital mortality (%)</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

* Patient-ventilator asynchrony was defined as an ineffective-effort index > 10%.
NS = difference not significant

Proportions of Asynchronous Breath Types Asynchrony-Trauma pts

<table>
<thead>
<tr>
<th>Asyn Index&gt;10%</th>
<th>Asyn Index&lt;10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of breaths</td>
<td>4,549</td>
</tr>
<tr>
<td>Total number of asynchronous breaths</td>
<td>235</td>
</tr>
<tr>
<td>Missed/ineffective trigger</td>
<td>32 (13.6)</td>
</tr>
<tr>
<td>Double-trigger</td>
<td>41 (17.4)</td>
</tr>
<tr>
<td>Short-cycle</td>
<td>6 (2.6)</td>
</tr>
<tr>
<td>Long-cycle</td>
<td>27 (11.5)</td>
</tr>
<tr>
<td>Ventilator breath stacking</td>
<td>120 (54.9)</td>
</tr>
</tbody>
</table>

Patient-Ventilator Asynchrony in a Traumatically Injured Population
Bryce RH Robinson MD, Thomas C Blakeman MSc RRT, Peter Toth MD, Dennis J Hanseman PhD, Eric Mueller PharmD, and Richard D Branson MSc RRT FAARC
RESPIRATORY CARE • NOVEMBER 2013 VOL 58 NO 11
During this tracing of 30 seconds, the ventilator displays that the patient rate is 16 breaths/min.

de Wit, M. Respir Care 2011;56:61-72

(c) 2012 by Daedalus Enterprises, Inc.
Severe WOB noted by Pressure time curve dipping

Air trapping
Excessive P01

Secretions, bronchospasm, air-trapping
Effects of Asynchrony

- Increased work of breathing
- Muscle damage/stress
- Patient anxiety
- Dynamic hyperinflation
- Prolonged weaning time
- Increased length of hospital stay
- Increased cost of health care

Adverse Effects of Patient-Ventilator Asynchrony on Outcomes:
- Ultrastructure injury to respiratory muscles
- Eccentric or plyometric contraction
- Worsens mechanics (intrinsic PEEP)
- Alters gas exchange (auto-triggering, increased PaCO2).
- Wastes respiratory work (unnecessary load).
- Confounds lung-protective strategy (breath-stacking leads to increased tidal volume).
- May cause periodic breathing, sleep fragmentation.
How Do We Optimize Ventilator-Patient Interfacing?

- Clinical management interventions
- Adjust the ventilator
- Utilize advance modes of ventilation
Clinical Management

- Maintain a patent airway
  - Secretion removal, aerosolized medications, correct endotracheal size, minimize auto-PEEP, remove soiled HMEFs, no H2O in the circuit!
- Provide adequate sedation
  - Reduce anxiety and pain, minimize respiratory depression, correct underlying factors
- Facilitate extubation
  - Daily SBTs, extubate to BIPAP, High Flow Oxygen
Awake & Breath

- Use of a protocol incorporating daily awakening has been shown to ↓ the amount of opioid administered and to ↓ both duration of MV & ICU LOS
- Proven NNT = 7 for the endpoint of mortality

Controlling Ventilation With Sedation

- Bolus vs. continuous infusion
- Narcotics vs. hypnotics
- Neuromuscular paralyzation

APRV a muck!!
Ventilator Adjustments

- Meet the patients ventilatory demands
  - Increasing inspiratory flow
  - Increasing set rate
- Change triggering threshold
  - Decreasing triggering sensitivity
  - Changing from pressure to flow triggering
  - Minimize auto-PEEP
- Adjust expiratory termination criteria
  - Adjust ETS% during pressure support
  - Shorten set inspiratory time
- Optimize ABGs
Self triggering with leak
Help I need suctioning
Pinched flow sensor

Leak causes auto-trigging
Advanced Modes

- Proportional Assist Ventilation (PAV)
- Neural Assisted Ventilation (NAVA)
- Adaptive Support Ventilation (ASV)
- Smart Care

May optimize patient-ventilator interfacing!!!

PAV

- PAV is a form of synchronised partial ventilatory assistance with the peculiar characteristic that the ventilator generates pressure in proportion to the patient's instantaneous effort — that is, the more the patient pulls, the more pressure the machine generates. Thus, with PAV the ventilator amplifies the patient's inspiratory effort without any preselected target volume or pressure.
- The aim of PAV is to allow the patient to attain whatever ventilation and breathing pattern seems to fit the ventilatory control system. PAV therefore assumes control of the breathing system and a condition in which the neuroventilatory uncoupling is determined by the discrepancy between the high ventilatory demand and the insufficient capability of the ventilatory pump to cope with the workload.
- PAV provides a sort of “additional muscle” under the complete control of the patient's ventilatory drive for determining the depth and frequency of the breaths.
Neurally Adjusted Ventilatory Assist (NAVA) - is a mode of ventilation ventilation. NAVA delivers assistance in proportion to and in synchrony with the patient's respiratory efforts, as reflected by the Edi signal. This signal represents the electrical activity of the diaphragm, the body's principal breathing muscle.

The act of taking a breath is controlled by the respiratory center of the brain, which decides the characteristics of each breath, timing and size. The respiratory center sends a signal along the phrenic nerve, excites the diaphragm muscle cells, leading to muscle contraction and descent of the diaphragm dome. As a result, the pressure in the airway drops, causing an inflow of air into the lungs.

With NAVA, the electrical activity of the diaphragm (Edi) is captured, fed to the ventilator and used to assist the patient's breathing in synchrony with and in proportion to the patient's own efforts, regardless of patient category or size. As the work of the ventilator and the diaphragm is controlled by the same signal, coupling between the diaphragm and the SERVO-i ventilator is synchronized simultaneously.
ASV is a closed loop mode of ventilation designed to maintain goal-directed mechanical ventilation using a Lung Protective Strategy. Will deliver time-cycled ventilations when indicated and will switch to PSV when the patient starts spontaneous breathing. In PSV will continue target a desired tidal volume.

ASV streamlines the set-up and weaning of the mechanical ventilation patient.

Ventilation targets are derived from analysis of the patients pulmonary mechanics and are automatically implemented.

All time-cycled delivered breaths are Pressure regulated volume targeted breaths. (PRVC) Spontaneous breaths are delivered with pressure support targeted at a desired tidal volume.

Ventilator parameters: Tidal volume/respiratory rate are set based on Otis’ least work physiology.
SmartCare/PS is based on a clinical protocol for weaning. The system "divides the control process into three steps:"

"Step 1: Stabilizing the patient within a respiratory comfort zone by regulating the level of pressure support based on three parameters: breathing rate, tidal volume and end tidal CO2."

"Step 2: Reducing invasiveness by testing whether the patient can tolerate a lower pressure support level without leaving the comfort zone."

"Step 3: Testing readiness for extubation by maintaining the patient at the lowest limit of support".
Clinical Example #1

- 24-year old female with status asthmaticus
- Acute hypercapnic respiratory failure
- 7.24/69/58 on room air
- Post-intubation pH 7.14, PaCO2 98 at 6ml/kg to prevent barotrauma
Clinical Example #1 (cont.)

- Tachypnea  
  - breath stacking,  
  - autoPEEP
- Heavy sedation
- Continued tachypnea  
  - double-triggering ventilator, plateau pressures > 35 cm H₂O
- Nimbex & continued heavy sedation – to prevent barotrauma
- pH 7.25/108/102 with bicarb drip

Ventilator Adjustments

- Long expiratory time/low set rate
- Relieve auto-PEEP
  - Increase set PEEP?
  - Continuous Nebulization
  - Consider Heliox
- Place on PSV and extend ETS%
Secretions, bronchospasm, air-trapping

Pre Heliox Raw
Post heliox administration 70/30

Auto PEEP via the Pressure/time curve
Outcome

- Normalize pH
- Control tachypnea
- Use of bicarb, paralytic, sedation
- Altered normal process for control of breathing
- Wean when stabilized

Clinical Example #2

- 64-year old male admitted with Sepsis
- Developed metabolic acidosis: 7.11/31/78 on Ventilator.
- Ventilator Settings:
Evidence of severe increased work of breathing

IntelliCuff
Clinical Example #2

Outcome

- Set rate increased to match patient’s ventilatory demands
- Acidosis corrected with NaHCO3 and fluid
- Appropriate sedation administered.
- Clinical management of Sepsis

Summary

- Mechanical Ventilation not a normal breathing process.
- Clinical issues must be addressed.
- Lots of factors to consider in patient-ventilatory synchrony
- Newer modes of ventilation may promote better patient-ventilator inter-facing.
- The importance of minimizing ventilator asynchrony can not be minimized!!
Questions?