Asynchrony During Mechanical Ventilation
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Disclosure Statement

• I have received research funding from Covidien to support a clinical research assistant
Objectives

• To define patient-ventilator asynchrony
• To understand why it occurs
• To recognize major types of asynchrony
• To learn ways to manage asynchrony
Synchronous
Simultaneous occurrence of events

Asynchronous
Events not coordinated in time
Assisted Spontaneous Breathing

\[ P_{\text{vent}} + P_{\text{mus}} = (\text{Flow} \times \text{Resistance}) + (\text{Volume} \times \text{Elastance}) \]
Definition

- Patient-Ventilator Asynchrony occurs when the timing of the ventilator cycle is not simultaneous with the timing of the patient’s respiratory cycle
  - Neural Ti ≠ Ventilator Ti
  - Neural Te ≠ Ventilator Te
Associated with Weaning Failure

Patients with high level of asynchrony:
  – Longer duration of MV
  – Higher incidence of tracheostomy
  – Less likely to successfully wean from MV
  – Longer ICU LOS
  – Longer Hospital LOS
  – Less likely to be discharged home

De Wit, Critical Care Medicine (2009) 37: 2740-45
Assisted Spontaneous Breathing

Patient-ventilator interaction:
- Mechanical properties of lung and chest wall
- Neural function
- Clinical input
Key Phases of Each Breath

- Trigger sensitivity
- Initial flow rate
- Trigger
- Set pressure
- Control of flow
- Initial flow rate
- Set Ti
- % of peak flow
- Set pressure
- Control of flow
- (responsiveness to patient demand)
- (elastance and resistance)
Case 1
Case 1

• Mr. H., 63 year old male with emphysema admitted to ICU with COPD exacerbation

• Current active issue: Prolonged weaning from mechanical ventilation.
Case 1 continued

- Progress: Remains on PSV 16-18 cmH\textsubscript{2}O; at every attempt to reduce PSV below 15 cmH\textsubscript{2}O, RR $\uparrow$ 40, and is therefore placed on higher PSV at which RR $\downarrow$ 18-22. The airway pressure and flow tracings seen on the ventilator are shown below.
PSV 16 (Paw (cmH$_2$O) top and Flow (L/sec) bottom)

PSV 12 (Paw (cmH$_2$O) top and Flow (L/sec) bottom)
PSV 16 (Paw (cmH$_2$O) top and Flow (L/sec) bottom)

PSV 12 (Paw (cmH$_2$O) top and Flow (L/sec) bottom)
Ineffective Efforts (IE)  Patient 1  Ventilator 0
COPD (Auto-PEEP)

PEEP = 6 cm H₂O
SENSITIVITY = 2 cm H₂O

Pressure (cm H₂O)

Pt effort

Trigger threshold

Ventilator triggered

ΔP = 2 cm H₂O

ΔP = 8 cm H₂O

Ventilator triggered

Trigger threshold
Measures to Reduce PEEPi

- Reduce resistance in airways
  - Bronchodilators and steroids
  - Tube patency – remove secretions
- Prolong expiratory time
  - Reduce inspiratory time (cycle sooner)
  - Decrease respiratory rate
- Decrease Tidal Volume
  - Decrease pressure support
PSV 16 (Paw (cmH₂O) top and Flow (L/sec) bottom)

PSV 12 (Paw (cmH₂O) top and Flow (L/sec) bottom)
Delayed Cycling

Mechanical Ti > Neural Ti
Delayed Cycling

![Graph showing proximal airway pressure and flow over time, with delayed cycling cycles labeled A and B.](image)

*Respir Care 2011;56(1):52-57*
Delayed Cycling

![Graph showing inspiratory resistance vs. time](image)

- Inspiratory resistance (cmH$_2$O.L$^{-1}$.s)
- Time s
- Inspiratory flow L/s

- Rrs = 5
- Rrs = 10
- Rrs = 15
- Rrs = 20
- Rrs = 25

+ = cycling with ET = 0.25
Delayed Cycling

- Delayed cycling
  - ↓ Expiratory time → ↓ Lung emptying
    - ↑ Dynamic hyperinflation/PEEPi
      - ↑ Trigger delay
        - ↑ Trigger workload
      - ↑ Non-triggering breaths
      - ↑ Respiratory muscle workload
PSV 16 (Paw (cm$H_2$O) top and Flow (L/sec) bottom)

PSV 12 (Paw (cm$H_2$O) top and Flow (L/sec) bottom)
Adverse effects of both insufficient and excessive levels of pressure support

**Goal:** provide optimal unloading of the respiratory muscles
Case 2
Case 2

- A 24 year old woman is admitted with ARDS
- 10 days later the patient is improving.
- $\text{FiO}_2$ has been weaned to 0.40 and PEEP is at 10 cmH$_2$O
- CXR, although improved, still shows bilateral airspace disease
- You would like to start weaning the patient from the ventilator and order sedation to be weaned.
- However, when sedation is lightened, the patient “does not tolerate pressure support” and looks asynchronous on assist control.
Case 2 continued

• Flow (L/sec) (top) and Airway Pressure (cmH2O) (bottom) shown below:
Double Triggering

Mechanical Ti < Neural Ti

Flow

Pao

Peso

Double Triggering (DT)  Patient 1  Ventilator 2
Premature Cycling

A

Proximal Airway Pressure

Flow

Ins. 0 Exp.

25% 10%

Neural Ti

Cycle setting
Measures to Reduce Double Triggering

• Double triggering occurs in setting of high ventilatory demand and short ventilator inspiratory time (ACV more common than PSV)

• Aim for ways to reduce ventilatory demand
  – Increase Vt
  – Sedation

• Increase Ti
  – Reduce cycling criterion (Esens), or increase Ti
Case 3

Asynchrony During Mechanical Ventilation
Case 3

• An 80 year old woman, admitted to ICU with pneumonia, dehydration and weight loss.
• PMHx: congestive heart failure
• The nurse calls you to the bedside. The ventilator keeps alarming for “high respiratory rate.” The patient’s respiratory rate is 35 to 40.
• The RRT has tried assist control/ pressure control, assist control/volume control and pressure support, but “cannot get the patient to settle.”
• The nurse would like an order for more sedation and asks if you are considering paralyzing the patient.
Case 3 continued

- The patient is awake, with a high respiratory rate, but no other signs of distress.
- The airway pressure (bottom) and flow tracings (top) seen on the ventilator are shown below.
Auto-triggering

### Flow

<table>
<thead>
<tr>
<th>Ref Line</th>
<th>Curs 1</th>
<th>Curs 2</th>
<th>Min</th>
<th>Max</th>
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<tbody>
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<td>NaN</td>
<td>1.6</td>
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### Pao

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<th>Curs 2</th>
<th>Min</th>
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<td>3.09</td>
<td>20.2</td>
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</table>

### Peso

<table>
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<tr>
<th>Ref Line</th>
<th>Curs 1</th>
<th>Curs 2</th>
<th>Min</th>
<th>Max</th>
</tr>
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<tr>
<td>0.00</td>
<td>4.03</td>
<td>NaN</td>
<td>-3.19</td>
<td>NaN</td>
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</tbody>
</table>

### Delta Slope Integral

- Delta: NaN
- Slope: NaN
- Integral: 172.29

### Delta Slope Integral

- Delta: NaN
- Slope: NaN
- Integral: 175.17

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### Autotriggering (AT)

**Patient 0**

**Ventilator 1**
Auto-triggering

- The delivery of a mechanical breath in the absence of a clear contraction of the respiratory muscles.
Auto-triggering

- Circuit leak
- Water in the circuit
- Cardiac oscillations
- Nebulizer treatments
- Negative suction applied through chest tube

- Fix leak, empty water from circuit
- Increase Trigger sensitivity
- Change from flow to pressure triggering
Case 3 continued

- You increase the trigger threshold (make it less sensitive) and the RR immediately drops to 24, and the patient, appearing more comfortable, drifts off to sleep. However, soon the nurse is calls to let you know that now the ventilator is alarming for apnea. Although the patient is on fentanyl at 50 ug/hr, she arouses easily and obeys commands.

\[
\text{ABG: } pO_2 \ 89, \ pCO_2 \ 30, \ pH \ 7.50, \ HCO_3^- \ 24
\]
Periodic Breathing

10 seconds
Central apnea
Summary
# Types of Gross Asynchrony

<table>
<thead>
<tr>
<th></th>
<th>Patient Breath</th>
<th>Ventilator Breath</th>
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</thead>
<tbody>
<tr>
<td><strong>Triggering Problem</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ineffective Efforts (IE)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Autotriggering (AT)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cycling off Problem</strong></td>
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<tr>
<td>Double Triggering (DT)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Delayed Cycling (DC)</td>
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# Bedside Management

<table>
<thead>
<tr>
<th>Type</th>
<th>Correction</th>
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<tr>
<td><strong>Ineffective triggering</strong></td>
<td>Decrease trigger threshold&lt;br&gt;Reduce sedation&lt;br&gt;Reduce the potential for intrinsic PEEP (decrease $V_T$, $V_E$, increase $T_E$)</td>
</tr>
<tr>
<td>- weak inspiratory effort</td>
<td></td>
</tr>
<tr>
<td>- High PEEPi (COPD)</td>
<td></td>
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<tr>
<td><strong>Delayed Cycling</strong></td>
<td>Increase cycling criterion ($Esens$)&lt;br&gt;Decrease $Ti$</td>
</tr>
<tr>
<td>- Low elastic recoil (emphysema)</td>
<td></td>
</tr>
<tr>
<td>- High resistance (COPD)</td>
<td></td>
</tr>
<tr>
<td><strong>Auto-triggering</strong></td>
<td>Increase trigger threshold&lt;br&gt;Switch from flow to pressure triggering&lt;br&gt;Avoid hyperventilation</td>
</tr>
<tr>
<td>- cardiogenic oscillations or circuit leaks</td>
<td></td>
</tr>
<tr>
<td>- absence of patient effort</td>
<td></td>
</tr>
<tr>
<td><strong>Double-triggering</strong></td>
<td>Aim for ways to reduce ventilatory demand.&lt;br&gt;Is $V_T$ too small? $Ti$ too short?&lt;br&gt;Decrease cycling criterion ($E_{sensitivity}$)</td>
</tr>
<tr>
<td>- high ventilatory demand, and</td>
<td></td>
</tr>
<tr>
<td>- short ventilator inspiratory time (ACV more common than PSV)</td>
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</tbody>
</table>
Assisted Spontaneous Breathing

Patient-ventilator interaction:
- Mechanical properties of lung and chest wall
- Neural function
- Diaphragm contraction
- Clinical input
PAV

\[ P_{\text{mus}} = \text{Flow} \times R_{\text{tot}} + V_{t} \times E_{\text{st}} \]

PAV instantaneously measures the flow and volume being pulled in by the patient, and, knowing the elastance and resistance of the respiratory system, determines how much pressure to provide for each breath.
NAVA senses activity in the diaphragm and responds by providing the requested level of ventilatory assist. The Edi signal is obtained by an electrode array mounted close to the distal tip of the Edi catheter. This catheter can also serve as a conventional nasogastric feeding tube.
Future Research
Asynchrony may be costly
Reducing patient-ventilator asynchrony may improve outcome

**IF**
- Sleep Quality increases
- Sedation decreases?
- VIDD decreases?

**THEN**
- Delirium decreases
- Duration of Mechanical Ventilation decreases
- ICU LOS decreases
- Hospital LOS decreases
- Mortality decreases

Reducing patient-ventilator asynchrony may improve outcome
Key issues of patient-ventilator interaction during Variable Gas Flow Delivery (PSV)
Delays in Flow Delivery
Active Exhalation Initiating Cycling
Neuro-Ventilatory Coupling: NAVA senses the electrical activity of the diaphragm (Edi), the earliest respiratory signal that can be detected. Conventional technology is limited to sensing patient effort at the final stage of the respiratory process.