Using Ventilator Waveforms to Optimize Patient – Ventilator Synchrony

Nuala Meyer, MD MS
Goals of the Talk

• Recognize the different types of ventilator asynchrony
• Anticipate clinical scenarios for which asynchrony is common
• Tools to optimize conventional modes of ventilation
  – Pressure Support
  – Volume Control
  – Pressure Control
Types of Asynchrony

1. Auto-triggering
2. Ineffective Triggering
3. Double triggering
4. Premature Cycle
5. Delayed Cycle

Types of Asynchrony

1. Auto-triggering
2. Ineffective Triggering
3. Double triggering
4. Premature Cycle
5. Delayed Cycle

- Common: 24 – 80% of ventilated patients
- Asynchronies are frequently undetected
  - Even by ICU Attendings
- Increases energy expenditure, may exacerbate weakness

Types of Asynchrony

1. Auto-triggering
2. Ineffective Triggering
3. Double triggering
4. Premature Cycle
5. Delayed Cycle

- Common: 24 – 80% of ventilated patients
- Asynchronies are frequently undetected
  - Even by ICU Attendings
- Increases energy expenditure, may exacerbate weakness

Auto-Triggering in a man with C3 spinal level

- Sawtooth, oscillating flow in expiratory waveform
- Frequent culprits: excess moisture, nebulized medication, in-line suction device, cuff leak, cardiac oscillations
Auto-Triggering in a man with C3 spinal level

- Sawtooth, oscillating flow in expiratory waveform
- Frequent culprits: excess moisture, nebulized medication, in-line suction device, cuff leak, cardiac oscillations
Ineffective Triggering

• Ventilator detects patient effort as flow or pressure at the interface
  – Flow trigger is more sensitive than pressure*
  – Increasing the flow threshold will ↑ ineffective breaths

• Common for patients with COPD, iPEEP
  – Correlates with higher levels of Pressure Support
Ineffective Triggering

Thille AW Intensive Care Med 2008
Ineffective Triggering

Flo (L/s)

Airway Pressure (cm H$_2$O)

iPEEP

Thille AW Intensive Care Med 2008
Change in slope at end-exhalation:

- Start of ventilator insufflation
- Flow increase
- Pressure drop
Change in slope at end-expiration:

- Start of ventilator insufflation
- Flow increase
- Pressure drop
- Start of patient’s effort
- Wasted Effort: Ineffective breath

- Intrinsic PEEP
Change in slope at end-exhalation:

- **Start of ventilator insufflation**
- **Flow increase**
- **Pressure drop**
- **Start of patient’s effort**
- **Wasted Effort: Ineffective breath**
- **Intrinsic PEEP**

Flow (L/s)

Airway Pressure (cmH₂O)

Esophageal Pressure (cmH₂O)

Time (s)
Change in slope at end-exhalation:

- **Flow (L/s)**
- **Airway Pressure (cmH₂O)**
- **Esophageal Pressure (cmH₂O)**

**Start of ventilator insufflation**
- Flow increase
- Pressure drop

**Start of patient’s effort**
- Wasted Effort: Ineffective breath

**Intrinsic PEEP**
Change in slope at end-exhalation:
Change in slope at end-exhalation:
Change in slope at end-exhalation:
Match ePEEP to iPEEP

- Waterfall Analogy: – Tobin MJ et al
- Applying ePEEP has little effect on upstream pressure until it equals / surpasses iPEEP
- Allows ventilator to detect “standard” trigger effort

Martin MJ; Principles and Practice of Mechanical Ventilation, 2nd Ed
Match ePEEP to iPEEP

- Waterfall Analogy: 
  – Tobin MJ et al
- Applying ePEEP has little effect on upstream pressure until it equals / surpasses iPEEP
- Allows ventilator to detect “standard” trigger effort

Martin MJ; Principles and Practice of Mechanical Ventilation, 2nd Ed
Matching ePEEP to iPEEP
Matching ePEEP to iPEEP
Matching ePEEP to iPEEP
Double Trigger (Breath Stacking)

Pohlman MC Critical Care Med 2008
Optimizing Pressure Support

FLOW

PRESSURE
PSV: How is Inspiration Ended?

• Control of Inspiration: Expiration varies by ventilator
  – Flow Cycle: cycle off at a % of Peak flow
    • E-cycle, E-sensitivity
  – 25% of Peak (Inspiratory) Flow is Default

Hess D Respir Care 2005
25% Flow Cycle: a Poor Fit
25% Flow Cycle: a Poor Fit

• Emphysema: loss of elastic recoil
  – Peak flow is low, and high compliance doesn’t limit inspiratory flow
  – Need to cycle off sooner \( \Rightarrow \) flow cycle \(~40\%\)

• Low compliance: IPF, ARDS
  – Stiff lungs achieve a high peak flow very early
  – Rapid decrement in flow results in short, small \( \text{Vt} \)
Airflow Obstruction and Flow Cycle
Airflow Obstruction and Flow Cycle
Airflow Obstruction and Flow Cycle

![Graph showing airflow obstruction and flow cycle with pressure and flow variables.](image)
Airflow Obstruction and Flow Cycle

Actively interrupt flow to trigger exhalation
Low Compliance: Turn Down Flow Cycle
Volume Control
Goal is to Match Flow: Patient

RR  32
VE 17.5 L/min
Goal is to Match Flow: Patient

RR 32
VE 17.5 L/min
Goal is to Match Flow: Patient

Options
- Tolerate it
- Find/Fix Why VE So High
- Sedate +/- Paralyze
- Set Higher flow rate
- Change to square
- Increase RR in effort to “overdrive” ventilation
- Change to PC
- Change to PRVC / VC
Goal is to Match Flow: Patient

Options
- Tolerate it
- Find/Fix Why VE So High
- Sedate +/- Paralyze
- Set Higher flow rate
- Change to square
- Increase RR in effort to “overdrive” ventilation
- Change to PC
- Change to PRVC / VC
Pressure Control: Optimize I–Time
Pressure Control: Optimize I–Time

- Difficult to predict neural I–Time
- Best done at the bedside
- Match I–time to Zero Flow
  - Unless attempting IRV
- Too Long
  - Inspiratory Pause
- Too Short
  - Risk Double Triggers
  - Inefficient pattern
Pressure Control: Optimize I–Time

- Difficult to predict neural I–Time
- Best done at the bedside
- Match I–time to Zero Flow
  - Unless attempting IRV
- Too Long
  - Inspiratory Pause
- Too Short
  - Risk Double Triggers
  - Inefficient pattern
I-time
TOO
LONG
I–time TOO SHORT (RR ↑ 32)
Thank You!