Assessment of the Mechanically Ventilated Patient

Patient-Ventilator Synchrony

- Analyzed esophageal pressure waveforms of 11 patients (3 with COPD)
- 9 patients (82%) demonstrated ineffective efforts in 2-40% of all breaths
- 7 patients had substantial dysynchrony – Defined as ≥ 10% of breaths untriggered
- 10% failed efforts threshold (or index) was subsequently adopted by investigators as the indicator of substantial dysynchrony

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- Unless cited, the contents and conclusions of the following presentation are solely those of the speaker

An analysis of desynchronization between the spontaneously breathing patient and ventilator during inspiratory pressure support
24 patients with various causes of acute respiratory failure on PSV with esophageal pressure measurements
- 13 patients (54%) demonstrated ineffective efforts
  - 30% of ARDS patients
  - 40% of surgical patients
  - 60% of COPD patients
  - 100% of COPD patients with CST > 88 ml/cmH2O

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62 patients with acute respiratory failure on PSV and VC-CMV
- PSV set to yield a VT of 6-8 ml/kg and RR < 30 and cycle at 25%
- VC-CMV set at VT 6-8 ml/kg and flow of 60 L/m
- Median of 2.1 dysynchronous breaths per minute
  - 85% were ineffective efforts
  - 13% were double-triggered breaths
  - Remainder were auto-triggering and delayed cycling
- 15 patients (24%) had a dysynchrony index > 10%

20 patients with ALI who were ventilated using the ARDS network strategy
- Double-triggers occurred in 9.7% of all breaths at an average of 2.3/minute
- More than 3 double-triggered breaths/minute occurred in 33% of the study population
- More than 6 double-triggered breaths/minute for longer than 12 hours occurred in 45% of the patients

Patient-ventilator synchrony is common, and its prevalence depends on numerous factors, including patient population; type of asynchrony; ventilation mode and settings; and confounding factors (eg, state of wakefulness, sedation).

Patient-ventilator asynchrony (may possibly be) associated with adverse (outcomes), including increased/wasted WOB, discomfort, increased need for sedation, confusion during the weaning process, prolonged mechanical ventilation, longer ICU and hospital stay, and possibly higher mortality

How often does patient-ventilator asynchrony occur and what are the consequences?
Patient-Ventilator Dysynchrony

That which turns the breath on is called the **trigger**

That which occurs during the breath is called the **inspiratory flow** (or the **limit**)

That which turns the breath off, or ends inspiration, is called the **cycle**

That which occurs after inspiration has been completed is called **expiration**
Trigger Dysynchrony

- Ineffective trigger
  - Most common form of dysynchrony in which the patient’s inspiratory effort fails to trigger the ventilator and is not rewarded with a breath
  
  - Also called:
    - Ineffective efforts
    - Untriggered breaths

Trigger Dysynchrony

Recognizing ineffective efforts

- When the patient begins the inspiratory effort, the pressure decreases slightly
- The ventilator doesn’t detect the drop in pressure to initiate an assisted breath, detectable by a lack of inspiratory flow

Trigger Dysynchrony

Recognizing ineffective efforts

- When the patient finishes the inspiratory effort and effectively exhales out, the pressure begins to increase
- Flow exits the patient’s lung and travels towards the expiratory valve, observed on the expiratory arm of the flow-time scalar
-- Significant ineffective efforts can also be detected on the capnograph

- Ineffective efforts result in an increased work of breathing on the patient’s behalf
  - This is due to the patient’s employment of muscles of inspiration to expand the thoracic cage in an effort to initiate a breath
  - Ineffective efforts can also result in a phenomenon of breathlessness and agitation because of the undelivered breath

- The ventilator’s trigger mechanism is mathematically / numerically based on the actual PEEP setting and that sensitivity which is set

**Clinical implications of ineffective efforts**

- The ventilator’s trigger mechanism is mathematically / numerically based on the actual PEEP setting and that sensitivity which is set
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Ineffective efforts often come in the presence of unintentional PEEP or auto-PEEP because the ventilator “does not know about the auto-PEEP” and still requires the patient to alter the pressure to the “pre-auto-PEEP levels” to trigger a breath.

Ineffective efforts occur when utilizing a flow trigger much the same way except.....
- If there is no drop in pressure when the patient initiates the inspiratory effort then there will not be any flow taken from the bias flow in the circuit.
1) If ineffective efforts are due to air trapping and the development of auto-PEEP, then the cause of air trapping (obstruction to expiratory flow or inappropriate ventilator settings) must be identified and corrected.

2) Correcting ineffective efforts due to inappropriate trigger setting.

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Auto-triggering

- An unscheduled or unintended machine-delivered breath that occurs in the absence of respiratory muscle contraction (by way of neural stimulation)

- Etiologies include
  - Cardiac oscillation
  - Hiccups
  - Leaks in the circuit
  - Water in the circuit

Clinical implications of auto-triggering

- Auto-triggering can result in a respiratory alkalosis due to the delivery of undesired or unnecessary ventilation
Trigger Dysynchrony

- Correcting auto-triggering

CMV Volume

- Ineffective efforts
  1) Correct air-trapping
  2) Adjust the triggering mechanism

- Auto-triggering
  1) Adjust the triggering mechanism

- Double-triggering
  Not a trigger dysynchrony, but actually a cycle dysynchrony and will be covered in that section

Inspiratory dysynchrony

Inadequate flow
There should be a linear rise in the peak pressure that nearly plateaus, forming a nearly square pressure waveform.

• The non-linear rise in pressure indicates that a higher initial peak flow is needed to keep pace with the patient’s initial flow demands.

The clinical implication of continued inadequate flow is an increased WOB (the area under the reference curve).

• In addition, there is a phenomenon of breathlessness.
• If inadequate flow is recognized while using CMV Volume, it is corrected by increasing the peak inspiratory flow rate (on a ventilator with set peak flow).

**Inspiratory Dysynchrony**

**Correcting inadequate flow**

**Patient-Ventilator Dysynchrony**

**CMV Volume**

**Inspiratory dysynchrony**

**Excessive flow**

**Inspiratory Dysynchrony**

• Excessive flow
  - The peak inspiratory flow can also be set too high with regards to a patient's demand.
  - If the peak inspiratory flow is set too high with regards to a patient's demand, there is a spike observed on the left side of an individual pressure-time scalar.

• If inadequate flow is recognized while using CMV Volume, it is corrected by decreasing the inspiratory time (on a ventilator with set inspiratory time).
Excessive flow will cause preferential distribution of volume predominantly to independent lung zones or areas of least resistance.

If excessive flow is recognized while using CMV Volume, it is corrected by decreasing the peak inspiratory flow rate (on a ventilator with set peak flow).

If excessive flow is recognized while using CMV Volume, it is corrected by increasing the inspiratory time (on a ventilator with set inspiratory time).

- Inadequate flow
- Excessive flow
Inadequate flow

1) Increase inspiratory flow
2) Decrease inspiratory time

Excessive flow

1) Decrease inspiratory flow
2) Increase inspiratory time

Premature cycling or “double-triggering”

• Caused by a dysynchrony between the patient’s neural inspiratory time and the ventilator’s inspiratory time
  1. The ventilator has cycled the inspiratory phase (delivered the set volume)
  2. However, the patient continues to inspire and expand their thoracic cage
  3. The pressure / flow in the circuit is thereby decreased and an additional breath is triggered without exhaling the previous

Recognizing premature cycling

In addition to the graphical presentation used to identify premature cycling, the exhaled Vt will read 0 ml for the breaths that were not exhaled followed by a “doubled volume”
• In addition to the graphical presentation used to identify premature cycling, the exhaled \( V_t \) will read 0 ml for the breaths that were not exhaled followed by a "doubled volume"
• The clinical implications of severe cycle dysynchrony can be profound if the intention is to volume limit a patient who has ARDS.

- Increased WOB

- Clinical implications of premature cycling

- moderate cycle dysynchrony

- mild cycle dysynchrony
Clinical implications of premature cycling

- Mild cycle dysynchrony
- Increased WOB

Correcting premature cycling

- The inherent problem in a cycle dysynchrony is that the ventilator’s inspiratory time is shorter than the patient’s inspiratory time

To correct the problem, the ventilator’s inspiratory time needs to be lengthened to match the patient’s neural inspiratory time.

In CMV Volume, the flow can be decreased OR
In CMV Volume, the volume can be increased
(on a ventilator with set peak flow)
• To correct premature cycling on a ventilator with a set inspiratory time, the volume AND the inspiratory time should be increased.

If the inspiratory time alone is increased and volume left constant, the inspiratory flow would decrease (and possibly result in inspiratory dysynchrony).

• The cycling criteria (delivered volume) produces an inspiratory time that is longer than the patient's neural inspiratory time:
  – The patient begins to exhale against an incoming volume delivery and a pressure spike is created at the end of inspiration.

• A patient exhaling against a significant positive pressure, in this case the peak inspiratory pressure, will incur a work of breathing.

**Cycle Dysynchrony**

**Correcting premature cycling**

**Recognizing delayed cycling**

**Patient-Ventilator Dysynchrony**

**CMV Volume**

**Cycle dysynchrony**

**Clinical implications of delayed cycling**

**Delayed cycling**
To correct delayed cycling, the ventilator’s inspiratory time must be shortened to match the patient’s inspiratory time.

In CMV Volume, the inspiratory flow can be increased.

To correct delayed cycling, the ventilator’s inspiratory time must be shortened to match the patient’s inspiratory time.

In CMV Volume, the inspiratory time can be decreased (on a ventilator with set inspiratory time).

In CMV Volume, the inspiratory flow can be increased.

In CMV Volume, the tidal volume may be decreased (on a ventilator with set peak flow).
Premature cycling
- CMV Volume
- Cycle dysynchrony
- Decrease inspiratory flow
- Increase inspiratory time

Delayed cycling
- CMV Volume
- Cycle dysynchrony
- Increase volume
- Decrease inspiratory flow

Cycle dysynchrony
Expiratory dysynchrony

- An expiratory hold can be performed to measure auto-PEEP
- Air-trapping or auto-PEEP can be difficult to measure quantitatively in the clinical setting

Recognizing air-trapping/auto-PEEP

- If expiratory flow does not return to baseline, air-trapping is present

Area = \text{L/min} \times \text{sec}
Area = \text{L/sec} \times \text{sec}
Area = \text{Liters}
• If the area under the expiratory flow curve is less than that of the inspiratory flow, then a degree of air trapping is present.

Expiratory Dysynchrony

Recognizing air-trapping/auto-PEEP

Expiratory Dysynchrony

Correcting air-trapping/auto-PEEP

- To correct auto-PEEP the expiratory time must be lengthened
  1. Expiratory time can be increased indirectly by decreasing the TI in the appropriate manner dependent on the mode of ventilation
  2. Expiratory time can be increased directly by decreasing the respiratory rate
     - If the patient is assisting above the set respiratory rate then pharmacological means may be necessary
  3. If excessive expiratory time is required due to obstructed expiratory flow, then bronchodilator therapy should also be instituted.

Expiratory Dysynchrony

Clinical implications of air-trapping/auto-PEEP

- Air-trapping / auto-PEEP can cause an
  1) Increased work of breathing due to ineffective triggering
  2) Decreased cardiac output and blood pressure

Expiratory Dysynchrony

Correcting air-trapping/auto-PEEP

1) Decrease the inspiratory time
   • Increase the inspiratory flow
   • Decrease the tidal volume
1) Decrease the inspiratory time
   • Increase the inspiratory flow
   • Decrease the tidal volume

2) Increase the expiratory time
   • Decrease the respiratory rate

**Correcting air-trapping/auto-PEEP**

**CMV Volume**

- Air-trapping / auto PEEP
CMV Volume

Expiratory dysynchrony

- Air-trapping / auto PEEP

1) Decrease respiratory rate
2) Increase inspiratory flow / decrease inspiratory time
3) Decrease tidal volume

Patient-Ventilator Dysynchrony

TRIGGER DYSYNCHRONY
- All modes
  - Ineffective efforts
  - Auto-triggering

INSPIRATORY FLOW DYSYNCHRONY
- VC mode
  - Inadequate flow
  - Excessive flow
- PC or PS mode
  - Inadequate flow / pressure
  - Excessive flow / pressure
- V-T PC mode
  - Inadequate flow / pressure

CYCLE DYSYNCHRONY
- VC mode
  - Premature cycling
  - Delayed cycling
- PC or V-T PC mode
  - Premature cycling
  - Delayed cycling
- PS mode
  - Premature cycling
  - Delayed cycling

EXPIRATORY DYSYNCHRONY
- All modes
  - Auto-PEEP