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Recognizing and Managing Patient-Ventilator Asynchrony

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Learning Objectives

Following the presentation, learners will

1. Recognize the role of volume-targeted ventilation in many critically ill patients
2. Recognize ventilator waveform patterns of asynchrony
3. Identify ventilator overdrive as a means to manage many types of asynchrony
Compliance

• $P_{\text{plat}}$ and tidal volume intrinsically linked

• Compliance changes frequently because
  • Fluids
  • Inflammation
  • Position (incl CLRT)

• Changes in compliance cause
  • Change in TIDAL VOLUME in Pressure modes
  • Change in PRESSURE in volume modes
Volume Matters

- 861 patients
- Vt 6 cc/kg IBW vs 12 cc/kg IBW
- Mortality
  - 40%
  - 31%

ARDSNetwork. NEJM 342:1301, 2000
Which Pressures Matter?

- Components of $P_{\text{Peak}}$
  - PEEP
  - $P_{\text{elast}}$
  - $P_{\text{resistance}}$

- $P_{\text{plat}}$
  - $=PEEP + P_{\text{elast}}$ (i.e absence of flow)
  - Alveolar pressure
  - Lung stretch (injury)
  - Elevated in stiff lungs (ARDS, pneumonia, fibrosis)

- $P_{\text{res}}$
  - Related to flow NOT STRETCH
  - $=P_{\text{peak}} - P_{\text{plat}}$
  - Unrelated to alveolar pressure
  - Elevated obstructive lung disease, small ETTs, high flow

- $P_{\text{peak}} = 34$
- $PEEP = 8$
- $P_{\text{plat}} = 23$
- $P_{\text{res}} = 34 - 23 = 11$
- $P_{\text{elast}} = 23 - 8 = 15$
Low $V_T$ is Beneficial even at Low $P_{plat}$

Data from ARDSnet Low Vt

Hagar DN, et.al: Am J Respir Crit Care Med 172:1241, 2005
Low $V_t$ important in non ARDS

Neto, JAMA 2012;308(16):1651-59
Tidal Volume Matters

- Lower Tidal Volumes cause:
  - Less lung stretch
  - Less inflammation
  - Less lung injury in patients with shock, sepsis, post surgery...
  - Marked mortality benefit

- Is 6cc/kg IBW the best?
  - 5cc/kg or 7cc/kg? — who knows?
  - 6-8cc/kg if $P_{plat}$ is low? — don’t think so

- Volume Control Controls Volumes

Hagar DN, et.al: Am J Respir Crit Care Med 172:1241, 2005
ARDS: Starting Ventilation

- Tidal Volume
  - 6cc/kg IBW
  - IBW = 2.3kg * (height - 60) plus:
    - 50 for men
    - 45.5 for women

- PEEP

- Respiratory Rate
  - 29 +/- 7

- FiO2

- Insp Time
  - Flow 60 L/min
  - Why?
Is this Waveform Optimized?
Assume correct Vt, PEEP, FiO2
Passive or active?
Passive or active?
Passive or active?
Active

What is the flow?

"Normal Contour"
“Normal Contour”
Ventilator Synchrony

• Asynchrony
  • Absence or lack of concurrence in time—Merriam-Webster Dictionary
  • Often a miss-match between drive and delivery
  • Increases Work of Breathing

• 3 types of asynchrony
  • Trigger
  • Flow
  • Cycle
Excessive Work of Breathing

• Results in:
  • Discomfort
  • Lactic acidosis (increased drive)
  • Increased bloodflow to diaphragm
  • Diaphragm dysfunction
  • Injurious inflation
Work of Breathing Matters

- Diaphragm dysfunction
  - Electrical activity: diaphragm thickness ($T_{di}$)
  - Delta $T_{di}$ associated with outcomes
    - No change good
    - Decreased $T_{di}$ bad
    - INCREASED $T_{di}$ also bad
- Excessive respiratory effort causes diaphragm dysfunction that is associated with outcome

Goligher, Am J Resp Crit Care Med 2018;197(2);204-13
Work of Breathing Matters, part 2

Animal Model:
- Spontaneous effort
  - dependent regional $P_{pl}$ more negative
  - Esophageal pressure dependent $P_{pl}$
  - Pendelluft: alveolar air moves from nondependent to dependent regions
- Injured, but not healthy lungs

Human with ARDS
- Spontaneous breath distributed toward the dependent regions more so than during passive breath

Yoshida, Am J Resp Crit Care Med 2017;196(5);590-601
Respiratory Drive

- Complex
  - Chemoreceptors
  - Stretch
  - Inflammation
  - Pain/anxiety/fear
  - Metabolic demands
- Excessive drive exists in
- Imbalance leads to asynchrony
- Normal gas exchange does not exclude asynchrony
- **Attempts to normalize gas exchange may worsen asynchrony**

Mitigating Asynchrony

- Change the Patient
  - Sedation
  - Paralysis
  - May not be sufficient
  - May have downsides

- Change the Ventilator
  - Overdrive
    - VE commonly set too low
    - Increase RR and Vt
    - May not be sufficient
      - Conflicting goals
  - Match Flow
  - Match Cycle

Respiratory Drive
Passive or Active?
<table>
<thead>
<tr>
<th>Volume Control</th>
<th>Admit patient</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. hold active</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 cmH₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 1/min BTPS</td>
<td></td>
<td></td>
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<tr>
<td>&lt;200</td>
<td></td>
<td></td>
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<tr>
<td>500 ml BTPS</td>
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<tr>
<td>Additional settings</td>
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<tr>
<td>O₂ conc.</td>
<td>PEEP</td>
<td>Resp. Rate</td>
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<tr>
<td>40</td>
<td>5 cmH₂O</td>
<td>8 b/min</td>
</tr>
<tr>
<td>21</td>
<td>50</td>
<td>60</td>
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<tr>
<td>Status: 0.57</td>
<td></td>
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</tr>
<tr>
<td>PEEP: 17</td>
<td></td>
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<tr>
<td>C static: 7.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E: 137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C dyn: 5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rl: 41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rv: 894</td>
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<tr>
<td>V̇O₂: 4.80</td>
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<td></td>
</tr>
<tr>
<td>P: 0.1 cmH₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tc: 0.32</td>
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<td>Next page</td>
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</tbody>
</table>
Trigger Asynchrony

- Fail to deliver a breath despite effort
- Negative Ppl insufficient for alveolar pressure and PEEP
- Up to 25% of patients
  - Obstructive lung diseases
  - Obesity
- Preceded by
  - Larger breaths
  - Shorter expiratory times
Trigger Asynchrony

- $P_{pl}$ inadequate for elevated $P_{alv}$
- Address with:
  - Decrease $P_{alv}$
  - Increase set PEEP
  - Sedation
  - NAVA mode
  - Acceptance

![Diagram showing lung ventilation with PEEP = 15, $P_{alv} = 15$, $P_{pl} = 1$, and elastic recoil.](image)
Unknown
Passive or active?
What is the flow?
Good enough?
Flow Asynchrony

- Demand >> Delivery
- Scalloped Pressure curve
- Can occur at any Q
- Common if Q < 50 L/min
- Who cares?
- Address with
  - Increase flow
  - overdrive
Concepts of Flow

• ~60 L/min for most critically ill, assess if right
• Q < 50 L/min rarely tolerated
• Flow too low risks
  • Flow dysynchrony, increased work of breathing
  • autoPEEP
• Flow too high risks
  • Tachypnea
  • High $P_{peak}$ (who cares?)
Mode and Work of Breathing

- 14 pts, randomized, cross-over
- WOB: pulm mechanics (Bicore CP-100)
- Vt target 6.4 mL/kg
- Vt increased in PC and PRVC
- WOB increased in PC and PRVC
- Ppeak increased VC (who cares?)

END-Flow in PRVC and PC << 60 L/m

| Table 2. Differences in Patient Work of Breathing and Other Variables During Lung-Protective Ventilation Using Volume-Regulated Modes and Pressure-Regulated Modes |
|---------------------------------|-----------------|-----------------|
|                                 | PRVC            | PCV             | VCV             |
| WOB (J/L)                       | 1.35 ± 0.60     | 1.27 ± 0.58     | 1.09 ± 0.59     |
| PTP (cm H₂O/s/min)              | 229 ± 116       | 195 ± 94        | 180 ± 112       |
| W (J/min)                       | 16.4 ± 10.7     | 15.7 ± 9.0      | 13.2 ± 8.9      |
| P_{D1} (cm H₂O)                 | 5.5 ± 3.1       | 4.4 ± 2.1       | 4.8 ± 3.1       |
| Δ P_{es} (cm H₂O)               | 17.0 ± 5.9      | 14.8 ± 4.1      | 14.6 ± 6.3      |
| V_T (mL)                        | 418 ± 83        | 436 ± 106       | 398 ± 79        |
| V_T (mL/kg)                     | 6.9 ± 1.1       | 7.2 ± 1.4       | 6.5 ± 0.7       |
| V_{I} (L/min)                   | 57 ± 14*        | 61 ± 16         | 76 ± 5          |
| V_E (L/min)                     | 11.6 ± 3.3      | 12.3 ± 3.6      | 11.3 ± 2.6      |
| T_I (s)                         | 0.63 ± 0.08     | 0.64 ± 0.09     | 0.62 ± 0.09†    |
| f (breaths/min)                 | 28 ± 7          | 28 ± 7          | 29 ± 6          |
| P_{ETCO₂} (mm Hg)              | 42 ± 6          | 41 ± 6          | 42 ± 6          |
| Peak P_{aw} (cm H₂O)            | 22 ± 9*         | 23 ± 8*         | 34 ± 13         |
| PEEP (cm H₂O)                   | 7.7 ± 2.6       | 7.7 ± 2.9       | 7.8 ± 3.2       |
| PEEPi (cm H₂O)                  | 2.0 ± 1.4       | 1.6 ± 1.5       | 2.6 ± 3.9       |

ARDS, Proned, Paralyzed

- What abnormalities do you see?
- Passive or Active?
- What is the flow?
- Why is the Ppeak high?
- Is exp phase normal?
Influenza, MRSA pneumonia
Cycle Asynchrony

• Discrepancy re: change from Insp-Exp
• Neural time const. > i-Time
• Persistent insp effort
Cycle Asynchrony

• Extreme form: Stacked Breaths
  • $V_t \times 1.6 \times \text{set } V_t$
  • 10.1 cc/kg IBW
  • > 6 SB/min * 12 hours 45% of patients

• Risk factor is Low $V_t$

• Asynchrony more common in VC ventilation
  • WOB if unchecked
  • Asynchrony (unconscious) = Discomfort (conscious)

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Excessive tidal volume from breath stacking during lung-protective ventilation for acute lung injury
Mark C. Pohlman, MD; Kathryn E. McCallister, BS; William D. Schweickert, MD; Anne S. Pohlman, MSN; Celina P. Nigos, BSN; Jerry A. Krishnan, MD, PhD; Jeff T. Charbeneau, MS; Brian K. Gehlback, MD; John P. Kress, MD; Jesse B. Hall, MD

Pohlman, Crit Care Med 2008;36:3019-23
Responses to Cycle Asynchrony

- Adjust the Patient
  - Sedation
  - Paralytics
- Adjust the Ventilator
  - Increase Vt
  - Change to Pressure Support
  - Increase insp time

Figueroa-Casas, Ann Am Thorac Soc 2016;133:2207
Adjust Ventilator, not the patient

- Asynchrony (subconscious) less responsive to sedation/analgesia
- Vent Changes:
  - Change mode
  - Change iTime

Chanques, et al, Critical Care Medicine, 2013; 41(9):2177-2187
Adjust Ventilator, not Patient

Add Insp Pause in Volume-Control Ventilation
- Asynchrony 50%-0%
- Vt 800cc-400cc

Switch to Pressure Supprt ventilation
- Asynchrony 50%-0%
- Vt 800cc-550cc
Adjust Ventilator, not Patient

- Changing to PSV lead to increase in Vt despite attempts to lower pressure

<table>
<thead>
<tr>
<th></th>
<th>Δ ACV to PSV</th>
<th>Insp Time</th>
<th>↑ Vt</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Airway Pressure</td>
<td>-2 [4-0]</td>
<td>+1 [0-1]</td>
<td>+1</td>
<td>0.02</td>
</tr>
<tr>
<td>Vt ml/kg PBW</td>
<td>+4 [2-6]</td>
<td>0 [0-0]</td>
<td>+1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Insp Time (s)</td>
<td>+0.3 [2.6]</td>
<td>+0.6 [5.6]</td>
<td>+0.1</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Chanques, et al, Critical Care Medicine, 2013; 41(9):2177-2187
Inspiratory Pause

• .1-.2 seconds
• Beware of falsely elevated P_{plat} when short
• Beware autoPEEP
Influenza, MRSA pneumonia, part 2

ABG: 7.32 / 28 / 63

What do you see?
What would you do?

Make only 1 change!
Influenza, MRSA pneumonia, part 3
50 YO woman with encephalopathy

- Intubated for airway protection
- 6.0 ETT, kinked
Another influenza
Change in Flow, Asynchrony, and Injurious Vt
Conclusions

• Asynchrony IS increased work of breathing
• Asynchrony (esp Flow) can contribute to lung injury
• Over-reliance on ABG can distract, confuse, and frustrate
• Waveforms provide more useful information than ABG
• Vent adjustments fix asynchrony better than sedation