How Hard Is Your Patient Working?
Terry L. Forrette, MHS, RRT, FAARC

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1. Work of breathing & Patient- Ventilator Synchrony
2. Liberating the patient from the ventilator
3. Becoming part of the solution

It's almost time for lunch. Am I early, or is he late?
... and the lunch appointments turns into this!

- PaO$_2$/FIO$_2$ 185
- 22 PaCO$_2$ – PetCO$_2$
- Increased VE requirements
- Distant to absent breath sounds

Diagnosis: ARDS

The ARDS “Solution”

- Protective Lung Ventilation Strategies
  - Minimal tidal volumes using PC
- Open Lung Ventilation
  - Alveolar recruitment maneuver
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The Mechanics
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What type ...

and how much?
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Imposed Work

Physiologic Work

Airways Resistance (non-elastic work)

Elastic Work (lung – cw compliance)
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WOB is frequency related

![Graph showing work of breathing (WOB) in normal, restrictive disease, and COPD conditions]

Restrictive Disease
- Increased elastic resistance

COPD
- Increased air flow resistance

Work of breathing (arbitrary units)

Respiratory frequency (breaths per minute)

![Image of a muscular person lifting weights]
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Diaphragmatic Function

Elastic Work
Costal fibers
Crural fibers
Non-Elastic Work

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Where is your patient?

Assessment and Monitoring
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Esophageal Pressure Monitoring
- TTdi – tension time index and indicator of fatigue
- Pdi – trans-diaphragmatic to measure work
- Independent measurements of lung and chest wall mechanics

Clinical Assessment

Strength
- NIF > -20 to 30
- VC - 70 - 80 mL/kg/IBW

Endurance
- RR 24 - 38 br/min
- VT 5 - 7 mL/kg IBW
- RSBI < 105 br/L
- VE 200 mL/kg IBW

Patient Comfort

“Rapid pulse, sweating, shallow breathing... According to the computer, you’ve got gallstones.”
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Patient - Ventilator Synchrony

What the brain demands the ventilator delivers

Neuro-mechanical synchronization

Data from Jubran et al and Panthenarthy et al
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Asynchrony

Data from Jayrnan et al and Parthasarathy et al
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Using Graphics to Assess Asynchrony

- Delayed Trigger
- Cycle-off Asynchrony
- Flow Asynchrony

AC-VC

- P_{peak}: 22
- P_{mean}: 8.1
- PEEP: 5.8
- I:E: 1:6.1
- f_{TOT}: 22
- V_{IF}: 445
- V_{TOT}: 11.0

AC-VC

Circuit Type: HME
Humidification Type: HME

16:59 19 Dec 2013
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This may happen

- Asynchrony
- Frequent setting changes
- Sedation
- Prolonged ventilation time
- Possible muscle atrophy and VAP
- Increased patient risk and length of stay


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Liberating the Patient

Pressure Support ...

How much is enough?
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Try this!
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Knowledge Based Ventilation

- Adaptive Support Ventilation (ASV)©
- SmartCare©
- Proportional Assist Ventilation (PAV+)©
- Neurally Adjusted Ventilatory Assist (NAVA)©

Closing The Loop

Patient brain – Practitioner brain

Information

Patient - Ventilator Synchrony

Response
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Proportional Assist Ventilation (PAV+)©

One Simple Setting
Work of Breathing

<table>
<thead>
<tr>
<th>SPONT</th>
<th>VC Manual Insp only</th>
<th>P</th>
<th>V-TRIG</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>% Supp</td>
<td>Vamins</td>
</tr>
<tr>
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<td></td>
<td>50%</td>
<td>3.0 l/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tins 0.0 s</td>
<td>RAMP</td>
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<tr>
<td></td>
<td></td>
<td>Eins 3 l/min</td>
<td>PEEP 3.0 cmH₂O</td>
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</table>
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PAV+ 80% with Varying Demand

Support Pressure

Increase demand

Decrease demand

% Support = 80 (Patient does 20%)
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Ventilator Work Decreased to 50%
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WOB Bar

Pt=25% of work
Vent=75% of work
% Supp 75%

Suppose there is an improvement in airflow resistance.

Pt=40% of work, Vent=60% of work.
% Supp 70%
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- Tube size: 6.0–10.0.
- No leaks
- Ideal body weight is > 25 kg

Okay but does PAV make a difference?
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Consider other possibilities

If you can’t think outside of the box ...

... you’re going to get trapped in it.
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Keep it Simple!
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W O B and PAV References


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The WOB is Primarily Rate Dependent

- Restrictive disease favors faster rates
- COPD patients have less WOB at lower rates

Using Graphics To Assess Lung Mechanics

- Decreased compliance, increased WOB
- Increased Raw WOB
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**Normal Compliance**

\[ C = \frac{\text{volume}}{\text{pressure}} \]

\[ = \frac{600}{20} \]

\[ = 30 \text{ mL/cmH}_2\text{O} \]

**Decreased Compliance**

\[ C = \frac{\text{volume}}{\text{pressure}} \]

\[ = \frac{600}{30} \]

\[ = 20 \text{ mL/cmH}_2\text{O} \]
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Airways Resistance

Pressure

Volume

Expiratory Resistance

Inspiratory Resistance

Increased Inspiratory Resistance

Pressure

Volume
In Summary

- If flow dys-synchrony present adjust flow rate in VC or switch patient to a PC breath or a dual mode such as PRVC or VC+

- Adjust trigger sensitivity to remedy cycle on dys-synchrony

- If cycle off dys-synchrony is evident the shorten Ti either by increasing flow rate in VC or decreasing Ti in PC, PRVC/VC+

... and if you don't, then ...
Timing Asynchrony: Cycle On

- Delayed Trigger
- Auto-Trigger
- Ineffective Trigger

<table>
<thead>
<tr>
<th>C</th>
<th>P_{PEAK}</th>
<th>P_{IMFAN}</th>
<th>PEEP</th>
<th>I:E</th>
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<th>V_{IP}</th>
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Timing Asynchrony: Cycle Off

- Delayed Cycle
- Early Cycle