Ventilator Management of ALI/ARDS Patient
Terry L. Forrette, M.H.S., RRT

We Have All Seen This Patient
- 48 hours on vent
- $\text{PaO}_2/\text{FIO}_2$ 185
- $C_{LT}$ 17 mL/cmH₂O
- Febrile and tachy
- Distant to absent breath sounds
- and the news keeps on getting worse …

Your dealing with ALI/ARDS

1st Published Scientific Paper on Mechanical Ventilation
"But that life may ... be restored to the animal, an opening must be attempted in the trunk of the trachea, in which a tube of reed or cane should be put; you will then blow into this, so that the lung may rise again and the animal take in air ... And as I do this, and take care that the lung is inflated in intervals, the motion of the heart and arteries does not stop..."
Andreas Weselius Vesalius, 1543

Early Examples of Ventilation
- Spirophore”, the first whole body negative pressure device, constructed in 1876
- The Poliomyelitis epidemic results in “Iron Lung Ward”

A Quick Overview of ALI/ARDS
- First describe in 1967
- Large $V_T$ and low rates
- Super PEEP and PCIRV
- Up to the early 1990's 90% mortality

“You mean we can actually dial in PEEP!”
…and there was IMV! What would they think of next?

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Ventilator Management of ALI/ARDS

Patient

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Our Intentions were good but we just didn’t know

So Now It Is Decision Time

- Which Type of Ventilator? Conventional or High Frequency
- Select a Mode: CMV (A/C) or SIMV
- Choose your Breath Delivery: Volume control (VC), Pressure Control (PC) or Hybrid
- Which Management Protocol? PLV, Open lung ventilation

Look How Far We Come

Fell-O'Dwyer Device (1888)

Breath Type Characteristics

Volume
- Guaranteed Volume
- Flow limited by settings
- Uneven gas distribution
- Barotrauma ??

Pressure
- Constant Pressure
- Variable flow with improved synchrony
- Better slow space ventilation
- Shear stress ??

Wave Forms

Flow
- Peak flow is pre-set
- Pressure is variable
- Volume Control

Flow
- Peak flow is variable
- Pressure is constant
- Pressure Control

Asynchrony During Volume Ventilation

Wave

P

Expiration

Increased WOB

Active Ventilation

Inadequate Flow

Quite Ventilation

Inspiratory Flow

Paw cmH2O

1 2 3 4 5 6 7 Sec

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PCV Response to Increased Demand

Even Gas Distribution
PCV with Decelerating Waveform

The Problem

...and then you end up with this

The Solution:
Try a decelerating flow pattern with constant pressure

Avoid Derecruitment and Optimize FRC

Initiating and Monitoring PCV

- Selecting Modes
  - A/C, SIMV, APRV or a Dual Mode
- Selecting PC Level
  - Limit Paw < 30 cm H2O
  - Adjust to achieve VT 6 - 8 mL/kg IBW
  - Set Rate, T I:E ratio
  - FIO2, alarms, PEEP, etc..
- Monitor VT and note changes in Raw & CLT
- Evaluate ABG's
- Reduce PIP
  - as PaO2↑
  - V̇E↓
- Adjust rate to maintain CO2
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Rationale for Using PCV
• Improved patient ventilator synchrony
• Lower inflation pressures
• Improved gas distribution
• Protect the lung?

All this is fine but...
• Why use PC when VC works so well?
• Are there really any true benefits with PC?
• How do I explain this to the doctors?
• What about tidal volume delivery?

Pressure Ventilation With A Volume Guarantee
Two different breath types that guarantee preset targeted tidal volume while allowing free spontaneous breathing

Pressure Control Ventilation
The breath starts out looking like PCV

Characteristics Of A Dual Mode Ventilator Breath
• Variable inspiratory flow with a decelerating pattern
• Constant “regulated” pressure
• Volume guarantee with changes in demand, compliance and resistance

A marriage between PC and VC Breath Types

What Happens if Compliance Decreases?
Pressure then raises to assure that the set tidal volume is delivered if C or Raw change
Pressure will decrease as necessary to assure that the set tidal volume is not exceeded.

What Are the Actual Advantages of a Dual Mode?
- It cures cancer, can make the blind see, and will likely end worldwide hunger in our lifetime.
  - Sorry, but no
- But it may … Reduce trauma, be more comfortable, easier, and safer than conventional modes.

What Is APRV?
- Similar to PC Ventilation with a prolonged inspiratory time if there is no spontaneous breathing.

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What Is APRV?
- Similar to PC Ventilation with a prolonged inspiratory time if there is no spontaneous breathing.
What if the Patient Has Spontaneous Efforts?
• Similar to PCV with no spontaneous ventilation
• Substantial improvements for spontaneous breathing
  – Allows spontaneous breathing at both levels

Is Dysynchrony an Issue in ARDS?
• Substantial improvements for spontaneous breathing
  – Allows spontaneous breathing at both levels
  – Better synchronization

Airway Pressure Release Ventilation (APRV)
• Substantial improvements for spontaneous breathing
  – Allows spontaneous breathing at both levels
  – Better synchronization
  – Tidal volume monitoring of spontaneous ventilation at $P_H$ and $P_L$

Why Use APRV Instead of …?
• Isn’t it the same thing as PCV with PEEP or PSV with CPAP? No!
  – APRV provides less WOB at the high pressure level and improved synchrony between pressure levels.
  – Why would I want my patient to breathe spontaneously at the high pressure level?
    – Promotes a more physiological distribution of ventilation and perfusion

Candidates for APRV

APRV Initial Settings
• Set high and low times to establish release rate: (caution with OAD patients)
  – Starting frequency typically 15 – 20/min
• Set high and low PEEP levels to establish gradient for $V_T$ exchange
  – Use protective lung strategies in determining lung volumes ($V, 6 – 8 \text{ mL/kg}$)
  – Maintain $\text{PEEP}_L$ of 5 cm H$_2$O 
  – Keep $P_{Plat} < 30$ cm H$_2$O
• Patient may need initial sedation
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**Upper And Lower Inflection Points**

- Alveolar over-distention
- Alveolar collapse

**APRV and CO₂ Adjustments**
- Release rate and PEEPₗ - H gradient are used to manipulate PaCO₂

**Improving Oxygenation**
- Use MAP as method to manipulate oxygenation
  - Increase the time at PEEPₗ but monitor PaCO₂
  - Decrease PEEPₗ time to avoid derecruitment and FRC loss

**Managing The Patient On APRV**
- Oxygenation: Stabilize FRC with PEEPₗ and use Tᵢ and frequency to manipulate MAP.
- Ventilation: PEEPₗ - H gradient and release frequency
- Reduce MAP by manipulating PEEPₗ, PEEPₗ and frequency
- Use TimeᵣISE and EₕSENS to maximize synchrony

**What Are The Options to Avoid This?**

- Lungs of dogs ventilated for a few hours with large tidal volume demonstrate extensive hemorrhagic injury
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The ARDS “Solution”
- Protective Lung Ventilation Strategies
  - Minimal tidal volumes using PC
- Open Lung Ventilation
  - Alveolar recruitment maneuver

Lung Protective Strategy Patients
- ARDSNet Study
  - 6 mL/Kg IBW
  - RR up to 35 to maintain a pH > 7.30, then HCO₃ if <7.15
  - Plateau Pressure < 30 cm H₂O
  - Oxygenation Saturation 88 – 95%
  - PEEP/FIO₂ Algorithm
    - FIO₂: 0.3–0.4, 0.4–0.5, 0.5–0.7, 0.7–0.8, 0.9, 1.0
    - PEEP: 5, 8–10, 10–12, 12–14, 16–18, 20–24
- Reduces lung inflammation, improves oxygenation and gas distribution, prevents destruction of lung with repetitive opening and closing of the alveoli.

But! Is alveolar recruitment/derecruitment going to be a problem?

Looking for that Sweet Spot

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Recruitment Maneuvers (RMs)
Open Lung Strategies

- Proposed for improving arterial oxygenation and enhancing alveolar recruitment
- All consisting of short-lasting increases in intrathoracic pressures
  - Vital capacity maneuver (inflation of the lungs up to 40 cm H$_2$O maintained for 15 - 26 seconds) (Rothen HU. BJA. 1999; BJA 1993.)
  - Intermittent sighs (Pelosi P. Am J Respir Crit Care Med. 2003.)
  - Extended sighs (Lim CM. Crit Care Med. 2004.)
  - Intermittent increase of PEEP (Foti G. Intensive Care Med. 2003.)
  - Increasing the ventilatory pressures to a plateau pressure of 50 cm H$_2$O for 1-2 minutes (Marini JJ. Crit Care Med. 2004; Maggiore SM. Am J Respir Crit Care Med. 2003.)

Search for the Best Protective Lung Strategies Continues

- Positive pressure ventilation may injure the lung via several different mechanisms
  - Alveolar distension "VOLutrauma"
  - Repeated closing and opening of collapsed alveolar units "ATELECTRauma"
  - Oxygen toxicity
  - Lung inflammation "BIOTRauma"
  - Multiple organ dysfunction syndrome

So What is Really Important When Looking at a Ventilation Strategy?

- Support Gas Exchange and Protect the Lung
- Select a Mode and Breath Type Based on Patient Need
- Is there evidence to support your selection?

Comments and Questions

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