**Objectives**

- What is HFOV
- Who will benefit from HFOV
- When should you initiate HFOV
- How do you manage HFOV
  - Oxygen strategies
  - Ventilation strategies
  - Assessment Strategies
  - Weaning Strategies

**What is High Frequency Ventilation?**
High Frequency Ventilation

- Defined by FDA
  - A ventilator that delivers more than 150 breaths per minute
  - Small tidal volume, usually less than or equal to anatomical dead space volume
  - While HFV’s are frequently described by their delivery method, they are usually classified by their exhalation mechanism
    - Active or passive

3100A Oscillator

- Approved in 1991 for Neonatal Application for the treatment of all forms of respiratory failure
- Approved in 1995 for Pediatric Application, with no upper “weight limit”
- For treating selected patients failing conventional ventilation

3100B Oscillator

- Approved for sale outside the US in 1998 for patients weighing > 35 kg failing CMV
- Approved September 24, 2001 by the FDA for sale in the United States
HFOV 3100B: Another Tool for ARDS

Who
Will benefit from
HFOV 3100B?

Not-So-Normal Chest Radiograph
Etiology of ALI / ARDS

Direct Causes
- Aspiration
- Pneumonia
- Emboli
- Near Drowning
- Reperfusion Injury
- Inhalation Injury

Indirect Causes
- Sepsis
- Shock
- Trauma
- Pancreatitis
- Overdose
- Transfusion

Ventilator Induced Lung Injury
- All forms of positive pressure ventilation (PPV) can result in ventilator induced lung injury (VILI)
- VILI is the result of a combination of the following processes
  - Barotrauma
  - Volutrauma
  - Atelectrauma
  - Biotrauma

Why would you treat ARDS with HFOV?
Pressure and Volume Swings

During CMV, there are swings between the zones of injury from inspiration to expiration.

PCV 34, PEEP 9, mPaw 25

Gary Nieman, et al, SUNY Upstate Medical University, 2004

What about APRV or BiLevel?
During APRV, auto-PEEP occurs due to very small release times which in theory, prevents alveolar collapse.

APRV, TLOW .2 seconds, mPaw 25

Gary Nixon, et al. SUNY Upstate Medical University, 2004

Why Should you treat ARDS with HFOV?
During HFOV, the entire cycle operates in the “safe window” and avoids the injury zones.

Gary Nieman, et al., SUNY Upstate Medical University, 2004

“Open up the lung… and keep it open!”

Burkhard Lachmann 1992
Procedures

- **Sustained Inflation Maneuvers**
  - Prolonged periods of inflation (30-45 seconds) at pressures of 35-45 cm
  - May optimize recruitment
  - Features:
    - When initializing HFOV
    - Suctioning or disconnects
    - Periodically?

  Intensive Care Med. 1999;25:1297-1301

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**HFOV and Lung Recruitment**

**Experimental demonstration of dynamic sustained inflation for lung recruitment during HFOV**

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MARCH 2003

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Alexandre Rotta, M.D. 2004

**HFOV and Lung Recruitment**

Rotta, AT 2003

mPaw 15 cmH₂O Pre-recruitment

mPaw 15 cmH₂O Post-recruitment
HFOV 3100B: Another Tool for ARDS

What is our Goal??

- Break the pulmonary injury sequence!!!
  - Lung Recruitment
    - Open the lung with sustained inflation
    - Prevent alveolar collapse
  - Lung Protection
    - Provide small alveolar volume swings
    - Provide minimal alveolar pressure swings
    - Provide lower peak airway pressures

When Do you initiate HFOV?

Rescue Therapy with HFOV: Don't wait too late
HFOV 3100B: Another Tool for ARDS

When Should HFOV be Initiated?

- If FIO$_2$ > .60 and PEEP > 10 cmH2O and unable to maintain SpO$_2$ > 88%
- Unable to maintain Pplat < 30 cmH2O
- mPaw on CV is > 24 cmH2O
- Oxygen Index > 24
- Patient requiring paralysis for oxygenation
- ARDSnet or APRV not providing improvement

Earlier intervention produces better outcomes!!!!


Not a Rescue Device!!!

- Pulmonary injury sequence
  - We can attempt to prevent the sequence from beginning
  - We can attempt to put a stop to the sequence from progressing
  - Protection only occurs when used in the appropriate time frame of the pulmonary injury sequence

Current Strategies for ARDS

- Toolbox for this disease process
  - ARDSnet Study (6 ml/kg)
    - High PEEP lower Vt strategies
  - APRV, Bi-Level, Bi-Vent
  - HFOV
- Therapeutic Modalities
  - Lung Recruitment Maneuvers
  - Kinetic Therapy

Earlier intervention produces better outcomes!!!!

How do you initiate HFOV?

TECHNOLOGY OF HFOV

- How does it work?
  - Gas Exchange
- MAP
- Power/Amplitude
- Frequency
- Inspiratory Time %

Mechanisms of gas exchange

Slutsky & Drazen NEJM 2002;347:630
Theory of Operation

- Controls for Oxygenation and Ventilation are mutually exclusive
- Oxygenation is primarily controlled by the Mean Airway Pressure (mPaw) and the FiO₂
- Ventilation is primarily determined by the stroke volume (ΔP) and the frequency of the ventilator.

HFOV = Super CPAP
Mean Airway Pressure

- Mean Airway Pressure (mPaw) is created by the continuous flow of gas past the resistance (inflation) of the balloon on the expiratory valve.

- Higher power piston (up to 140 cmH2O for amplitude)
- Primary control for ventilation (PaCO2 removal)
- Piston displacement delivers tidal volume
- Amplitude changes reflect pulmonary mechanics changes

Power/Amplitude

- Amplitude is a measurement created by the force that the piston moves with based on the POWER setting, resulting in a volume displacement and a visual CHEST WIGGLE.
- It is represented by a peak-to-trough pressure swing across the mean airway pressure.

Principles of Ventilation

- Amplitude is a measurement created by the force that the piston moves with based on the POWER setting, resulting in a volume displacement and a visual CHEST WIGGLE.
- It is represented by a peak-to-trough pressure swing across the mean airway pressure.
HFOV 3100B: Another Tool for ARDS

HFOV Amplitude Attenuation

Principles of Ventilation

- Secondary control for ventilation
- Frequency controls the time allowed for the piston to move forward and backward
- Frequency has the largest impact on tidal volume than any other setting
- The lower the frequency, the greater the volume displaced
To evaluate the effects of changes in frequency with regards to CO₂ elimination, let us look at two different frequencies:

- 4 Hz
- 8 Hz

Principles of Ventilation

Therefore, lower frequencies result in larger volume displacement which improves CO₂ elimination. Increasing % IT may also have an impact on lung recruitment by increasing delivered mPaw.
HFOV Simplified

- CPAP with a wiggle
  - CPAP used to oxygenate
  - Wiggle used to ventilate
  - We control the CPAP level with mean airway pressure (mPaw)
  - We control the wiggle with amplitude (ΔP)

Clinical Assessment, Monitoring and Procedures

- Chest Wiggle factor (CWF)
  - Evaluate upon initiation and follow closely after that
  - CWF absent or diminished
    - clinical sign that the airway or ET tube may be obstructed
  - CWF present on one side only
    - indication that the ET tube has slipped down a primary bronchus
    - pneumothorax may be present
    - Check the position of the ET tube or obtain a CXR
  - Reassess CWF following any position change

Assessment

2011 ISRC Seminar
Monitoring

- Chest X-rays Procedure
  - Do not stop the piston, or re-positioning the head
  - Do not remove the patient from HFOV and manually ventilate
  - A physician, nurse, or therapist should be at bedside to assure the patency of the airway and the patient’s position.
  - Always obtain a CXR – if unsure as to whether the patient is hyper-inflated or has a de-recruited lung

Procedures

- Positioning
  - Hemodynamically stable patients are generally positioned with the head of the bed elevated ~ 30 degrees
  - Assure position of head and ET tube to prevent risk of kink in ET tube or 3100B circuit
  - Longer, flexible circuit allows patient positioning to prevent skin breakdown
  - Prone positioning has been used successfully with the 3100B
  - “lay” the circuit in the bed with the patient (3100B circuit is longer and heavier)

Take Home Messages

- Ventilation Strategies do affect patient outcomes
- Volume and pressure swings promote lung injury and mediator release
- Identify patients at risk for developing VILI early
  - Before the fibroproliferative stage of ARDS
- HFOV and other forms of alternate support offer lung protection that may improve outcomes for patients with ARDS
Summary

- Treatment of ARDS continues to evolve
- The study and understanding of contributing factors to ARDS continues
- Past development and clinical study of HFOV has given a good foundation to move forward
- HFOV has been shown to be effective tool in treatment of ARDS

Evidence Based Medicine

High-Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adults
A Randomized, Controlled Trial

High-frequency oscillatory ventilation: lessons learned from mechanical ventilator models

High-frequency oscillatory ventilation in adults: Respiratory Distress Syndrome

Questions???

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