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

When Should HFOV be Initiated?

- If FIO_2 > .60 and PEEP > 10 cmH2O and unable to maintain SpO2 > 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!!!!

Derdak S et al. Am J Respir Crit Care Med. 2002;166:801-808.

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

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

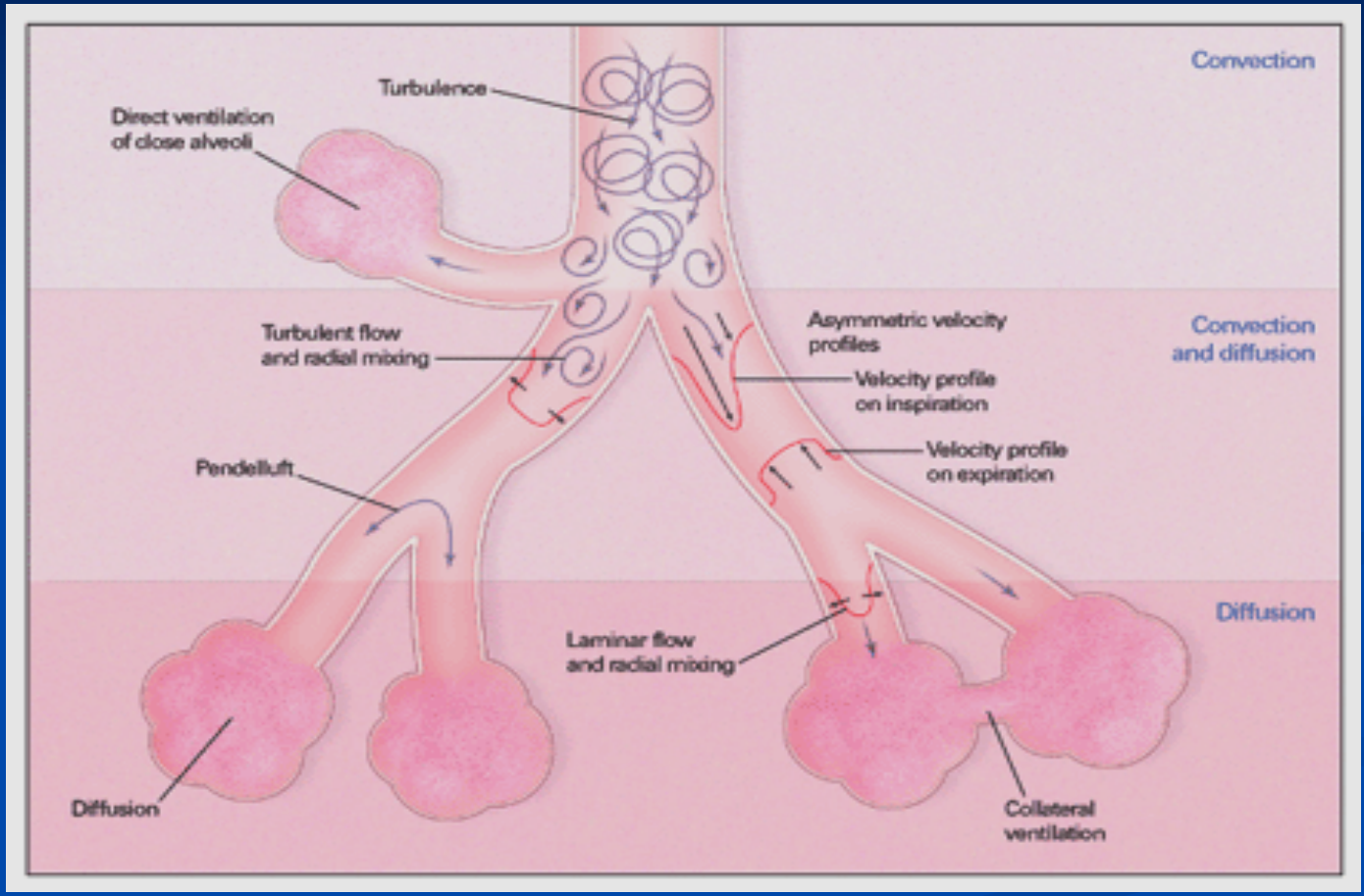
How

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

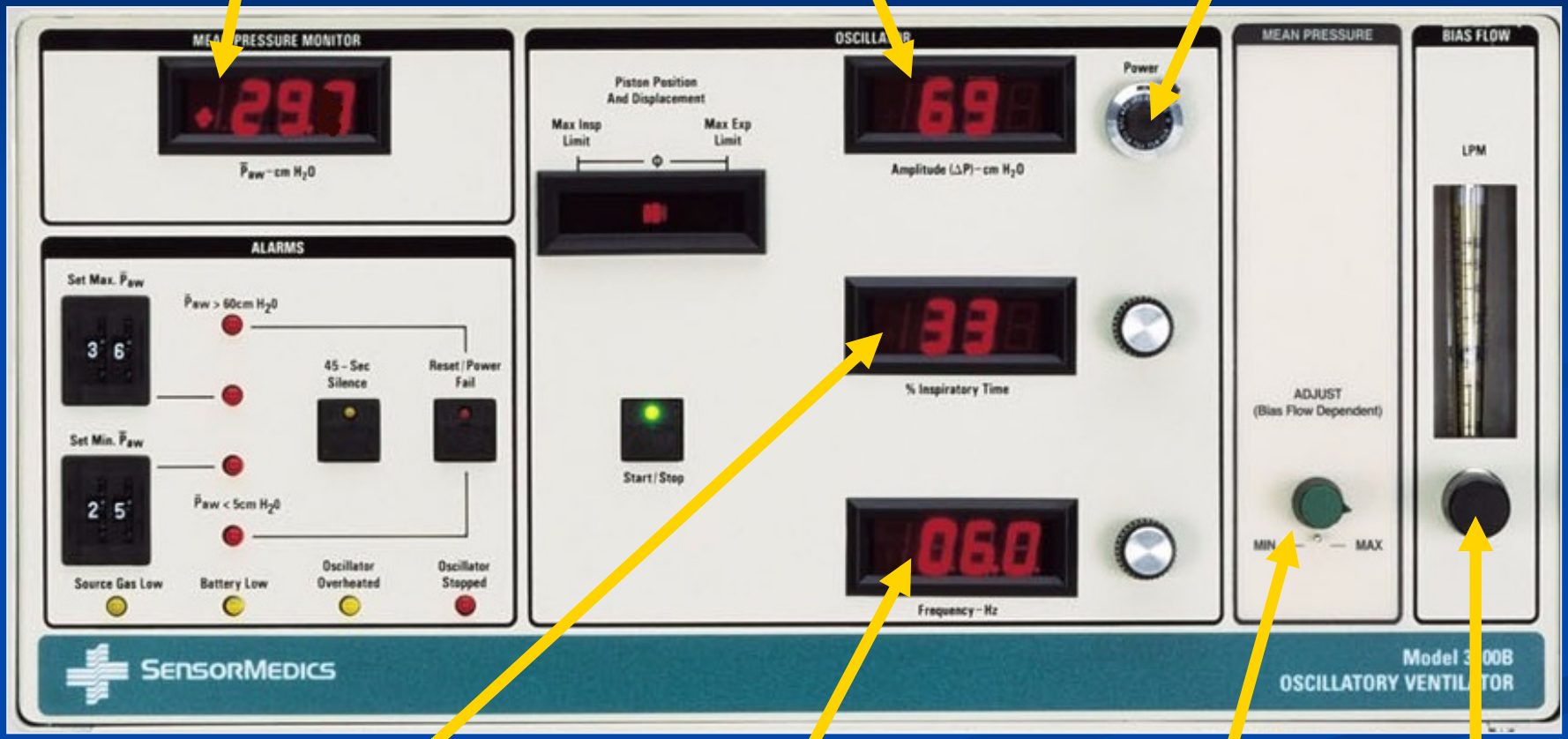
Theory of Operation

- Controls for Oxygenation and Ventilation are mutually exclusive
- Oxygenation is primarily controlled by the Mean Airway Pressure (mPaw) and the FiO_2
- Ventilation is primarily determined by the stroke volume (Delta-P) and the frequency of the ventilator.

Mean Airway Pressure (mPaw)

Amplitude (ΔP)

Power Knob



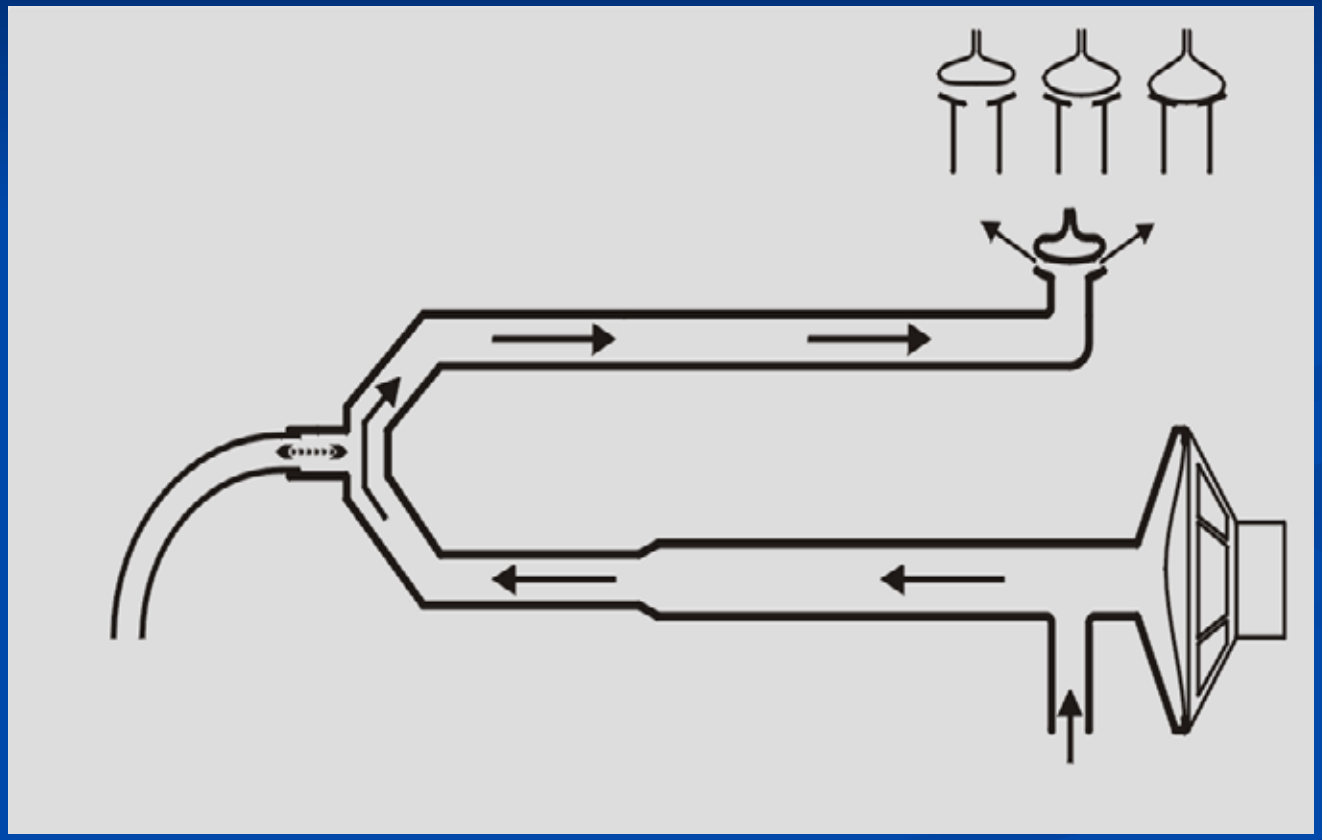
I-Time %

Frequency (Hz)

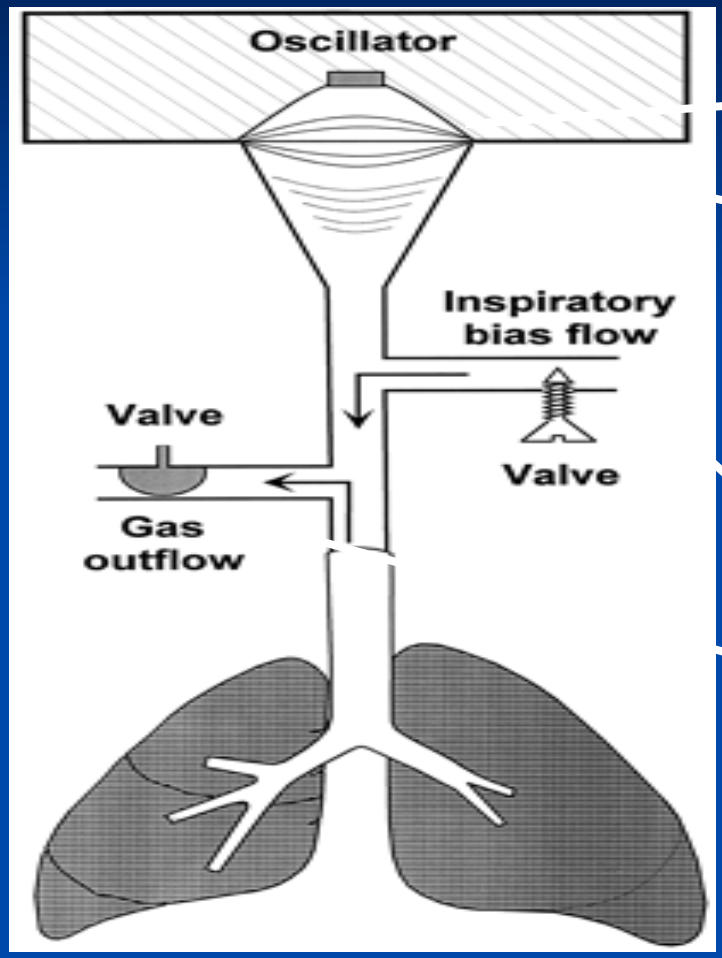
mPaw Adjust

Bias Flow

HFOV = Super CPAP



Oxygenation and Ventilation



ΔP (Amplitude)

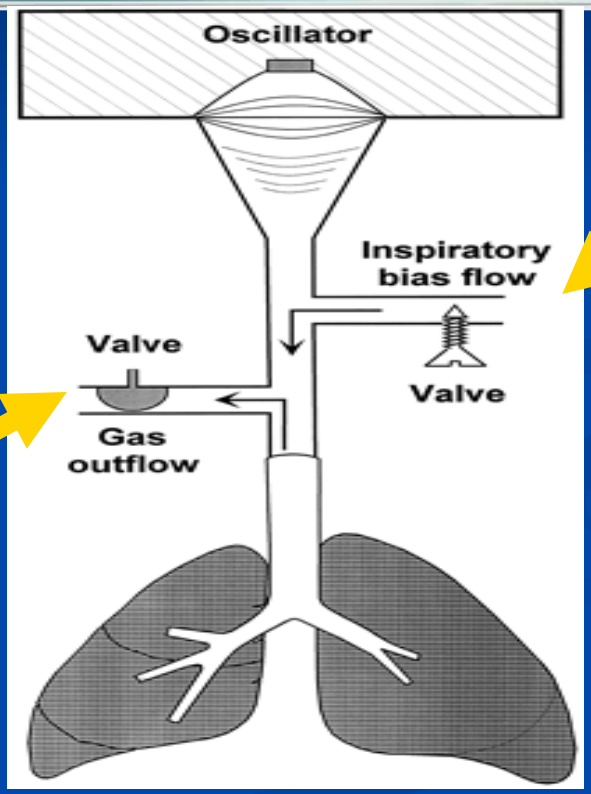
Hz (Frequency)

mPaw (Mean Airway)

HFOV 3100B

Mean Airway Pressure

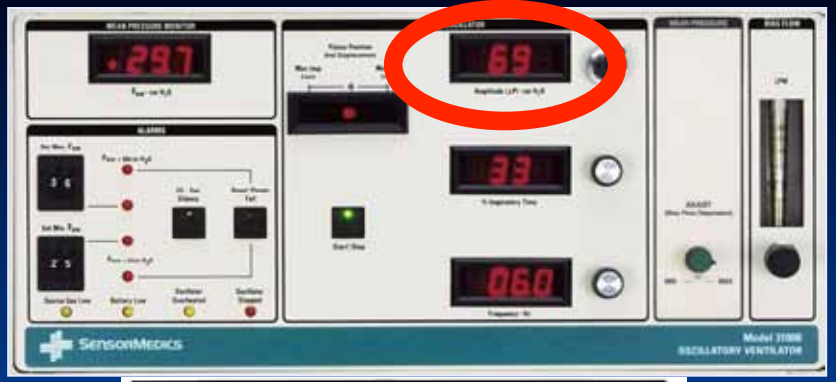
- Mean Airway Pressure (mPaw) is created by the continuous flow of gas past the resistance (inflation) of the balloon on the expiratory valve



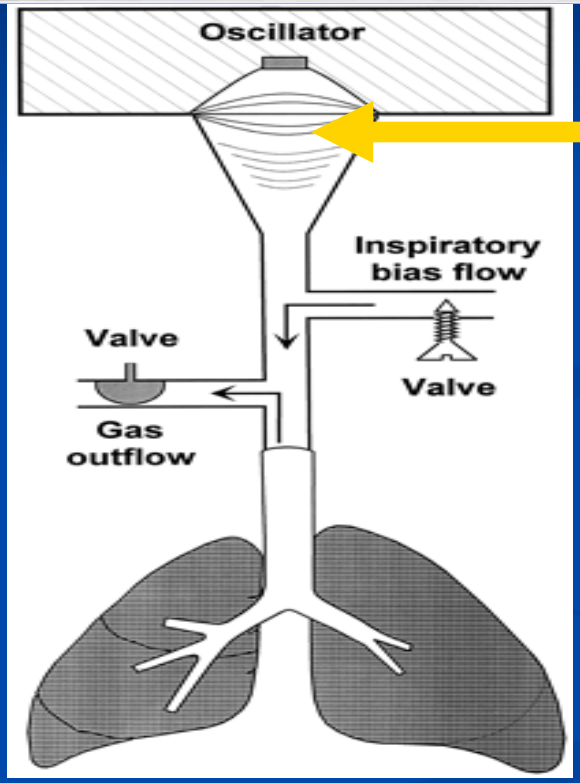
25-40 LPM

HFOV 3100B

Power/Amplitude



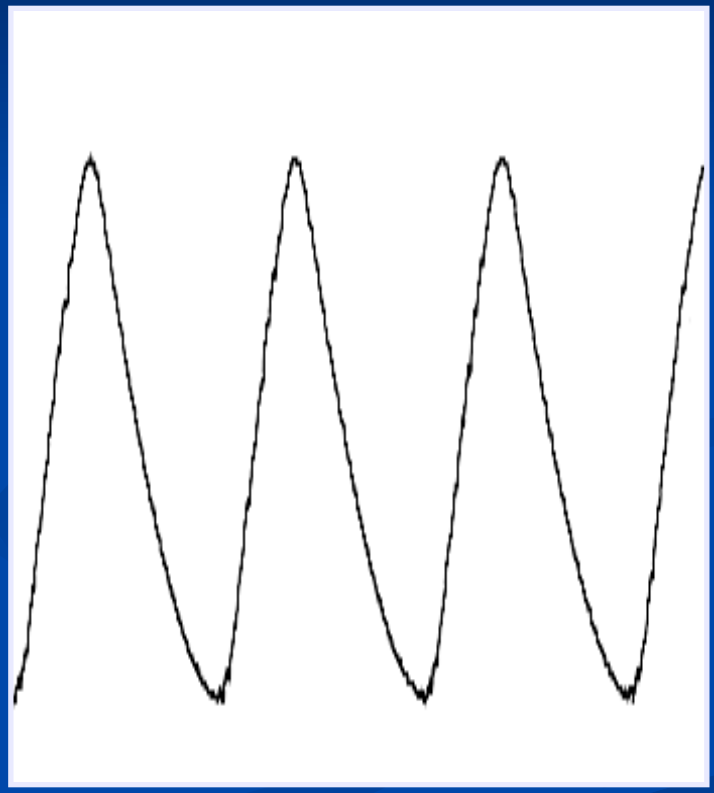
- Higher power piston (up to 140 cmH2O for amplitude)
- Primary control for ventilation (PaCO2 removal)
- Piston displacement delivers tidal volume
- Amplitude changes reflect pulmonary mechanics changes



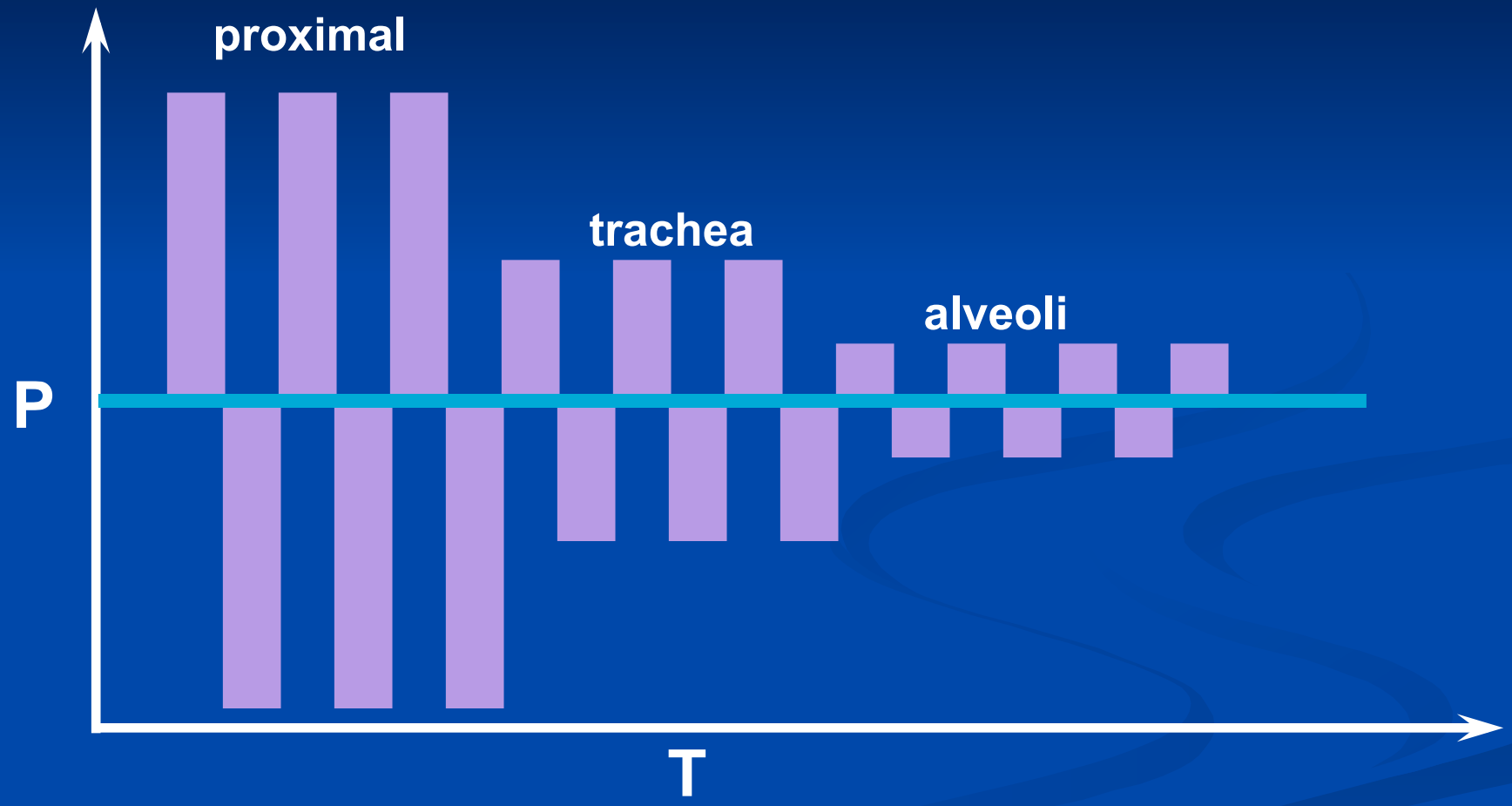
Principles of Ventilation

- **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***

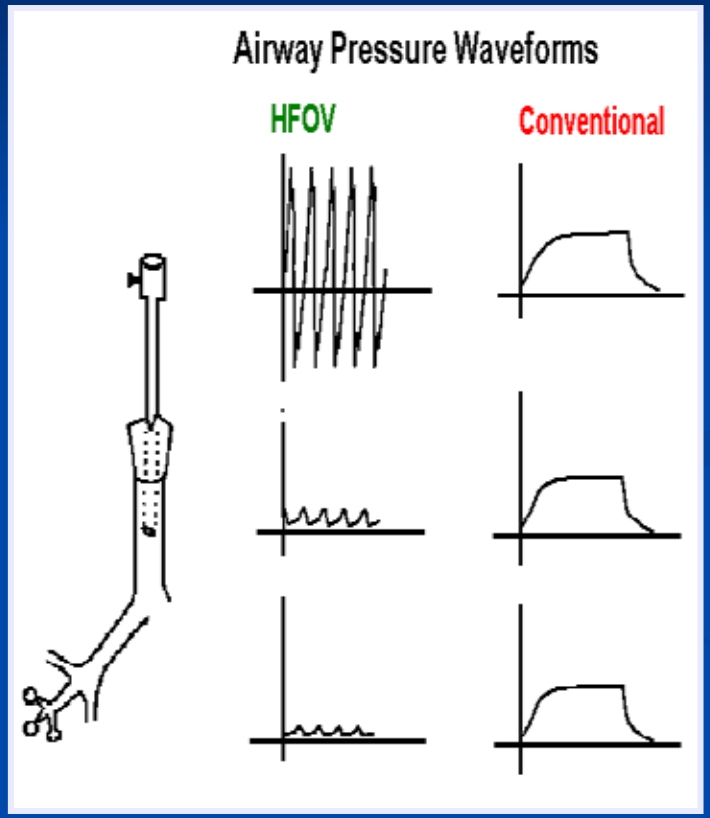
- It is represented by a peak-to-trough pressure swing across the mean airway pressure

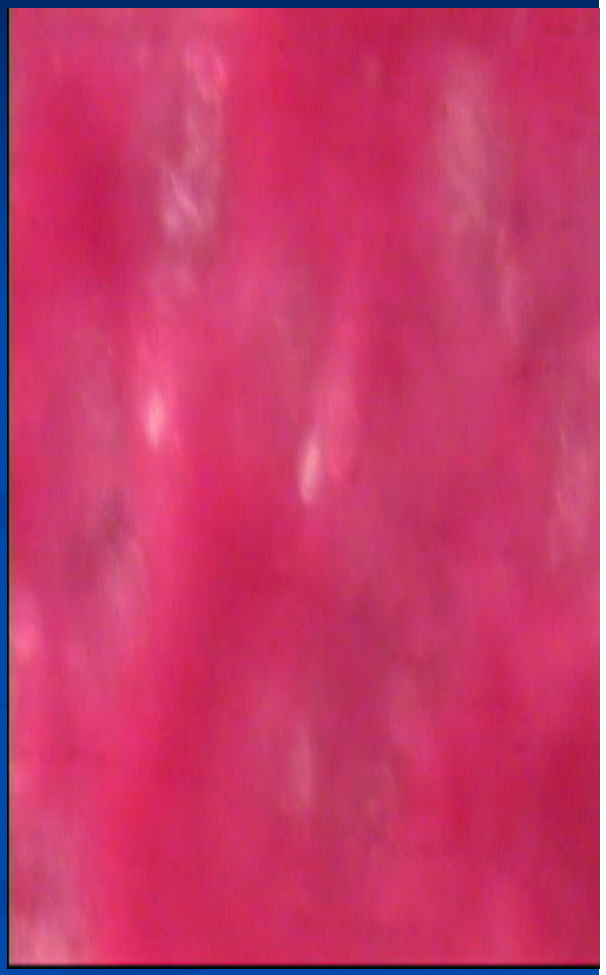


HFOV Amplitude Attenuation



Principles of Ventilation

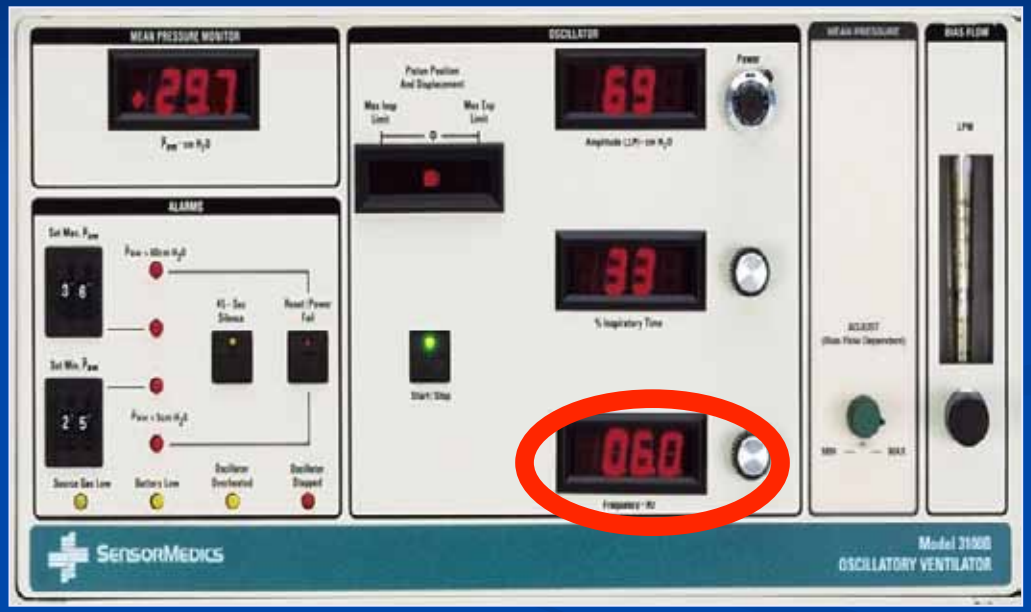




HFOV 3100B

Frequency/Hertz

- 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

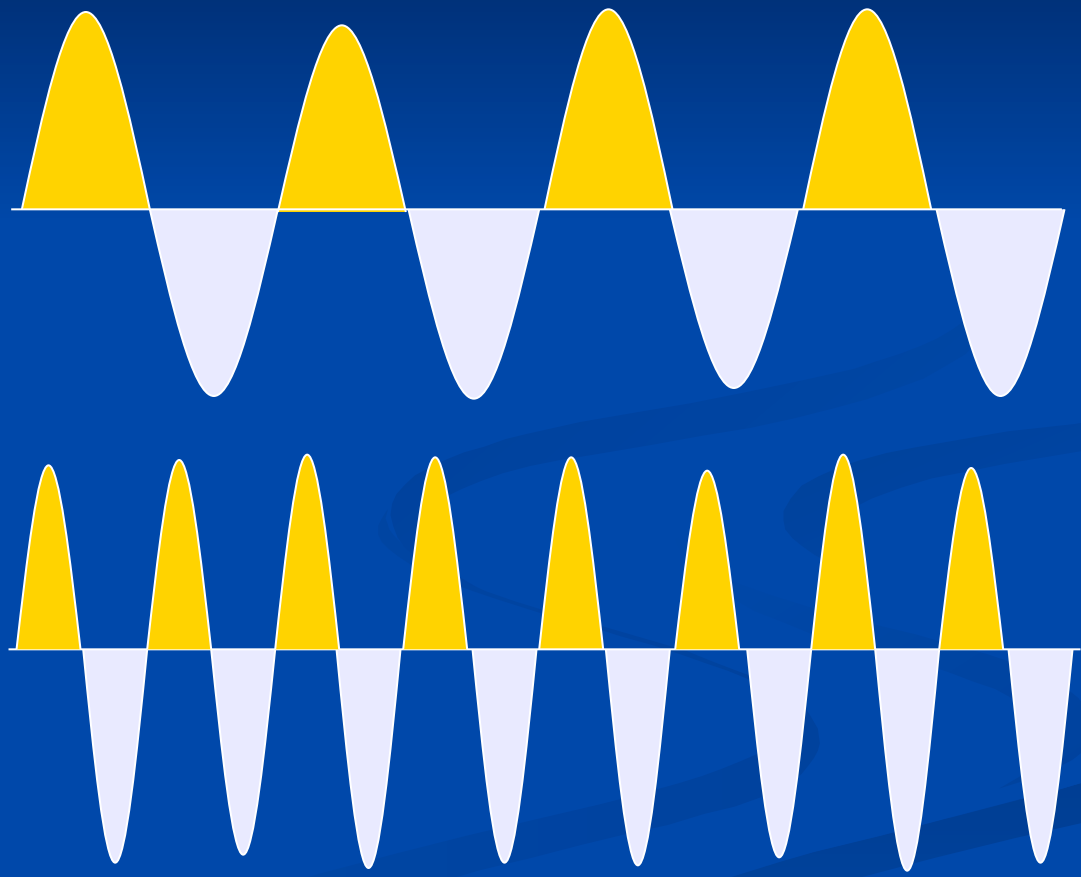


Principles of Ventilation

- Frequency
  - To evaluate the effects of changes in frequency with regards to CO_2 elimination, let us look at 2 different frequencies
    - 4 Hz
    - 8 Hz

Principles of Ventilation

Therefore, lower frequencies result in larger volume displacement which improves CO_2 elimination



Inspiratory Time%

- The Inspiratory Time %
  - Controls the amount of time the piston is in forward position versus the time it is in the backward movement
  - By increasing the Inspiratory Time %, a larger volume displacement occurs therefore decreasing the PaCO2
  - Should always verify that lung is not hyperinflated, to decrease risk of pneumothoraces.

HFOV 3100B

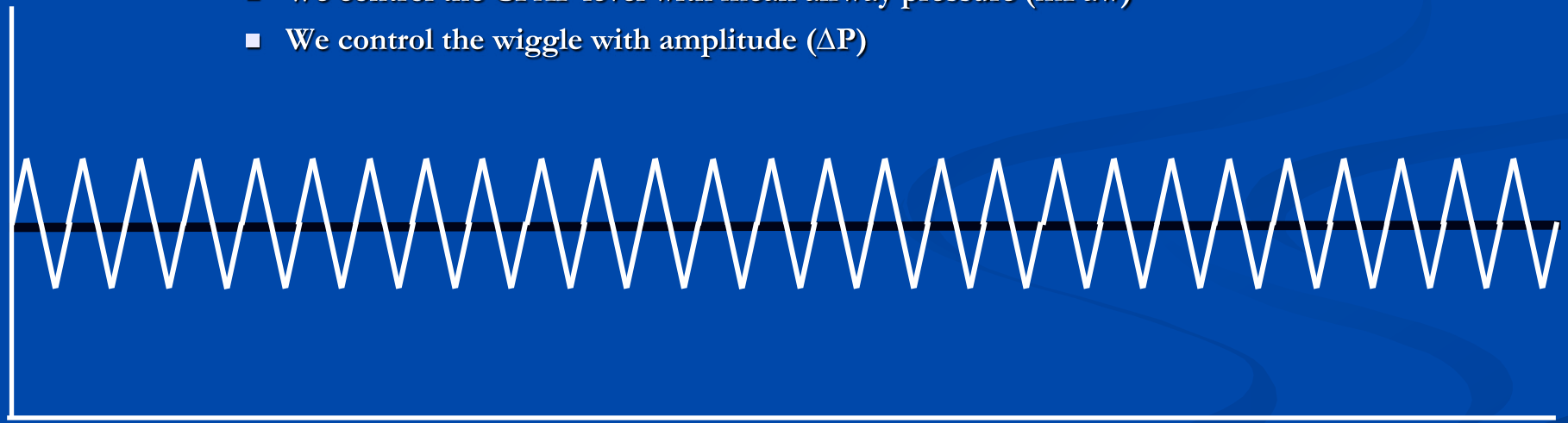
Inspiratory Time %

- % IT controls the time for the movement of the piston during inhalation and therefore can assist with ventilation
- Increasing % IT may also have an impact on lung recruitment by increasing delivered mPaw

Allows more time for piston travel resulting in larger tidal volume

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

Assessment

- *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

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

Acute effects of combined high-frequency oscillation
gas insufflation in severe acute respiratory distress sy

Spyros D. Mentzelopoulos, MD, PhD; Charis Roussos, MD, PhD; Antonia Koutsoukou, MD, PhD; Sotiris Sourlas, MD; Sotiris Malachias, MD; Alexandra Lachana, MD, PhD; Spyr

High-frequency oscillatory ventilation: Lessons learned from mechanical test lung models

Michael Van de Kieft, MD; David Dorsey, MD; David Morison, MD; Lazaro Bravo, MD; Steven Venticinque, MD; Stephen Derdak, DO

High-frequency oscillatory ventilation in adults: Respiratory

High-Frequency Oscillatory Ventilation for Acute Respiratory Distress Syndrome in Adults

A Randomized, Controlled Trial

Stephen Derdak, Sangeeta Mehta, Thomas E. Stewart, Terry Smith, Mark Rogers, Timothy G. Buchman, Brian Carlin, Stuart Lowson, John Granton, and the Multicenter Oscillatory Ventilation for Acute Respiratory Distress Syndrome Trial (MOAT) Study Investigators

Tidal volume delivery during high-frequ
in adults with acute respiratory distress

David N. Hager, MD; Henry E. Fessler, MD; David W. Kaczka, MD,

Use of high-frequency oscillatory ventilation in burn patients

Robert Cartotto, MD, FRCS(C); Sandi Ellis, RRT; Terry Smith, MD, FRCP(C)

ency oscillatory ventilation
syndrome*

High-frequency oscillatory ventilation

High-frequency oscillatory ventilation: Mechanisms of gas

neon

Alison E

High-frequency oscillatory ventilation and ventilator-in
lung injury

Yumiko Imai, MD, PhD; Arthur S. Slutsky, MD

High-frequency oscillatory ventilation and adjunctive therapies: Inhaled nitric oxide and prone positioning

Eddy Fan, MD; Sangeeta Mehta, MD, FRCPC

QUESTIONS???

jon.tucker@carefusion.com