DATA
CALIBRATION

BILOGIC SIGNAL

INSTRUMENT RESPONSE

NOISE FILTERS

SIGNAL PROCESSING

MEASURED SIGNAL (GRAPHIC OR NUMERICAL)

DATA ANALYSIS

CLINICAL INTERPRETATION
DONN'S GRAPHIC MONITOR
The Importance of Graphics
Why is it Important?

• Assists in optimizing mechanical ventilation parameters (PIP, PEEP, Ti, tidal volume, flow rate)
• Allows evaluation of spontaneous respiratory effort and interaction with the ventilator
• Determines infant’s response to pharmacologic agents (surfactant, diuretics, steroids, bronchodilators)
• Trends monitored events and ventilator parameters over time
Basic Principles

• Oxygenation is proportional to mean airway pressure (PIP, PEEP, Ti, and rate)

• Ventilation is proportional to the product of frequency and Vt (amplitude, or PIP-PEEP)
  – In CMV, carbon dioxide removal = f X Vt
  – In HFV, carbon dioxide removal = f X (Vt)^2
Ways to increase Mean Paw

1. Increase PIP
2. Increase PEEP
3. Increase I-time
4. Increase flow rate
5. Increase vent rate
Overview

• Pulmonary waveforms
  – Pressure waveform
  – Flow waveform
  – Volume waveform

• Pulmonary loops and mechanics
  – Pressure-volume loop
  – Flow-volume loop
Pulmonary Waveforms

Pressure vs Time
Flow vs Time
Volume vs Time

Pressure Waveform

Area under the curve = mean airway pressure

Inspiration (red)  Expiration (blue)  PIP  Ti

Peek

Flow Waveform

Inspiratory phase (positive)

Peak inspiratory flow

Accelerating flow

Expiratory phase (negative)

Peak expiratory flow

Decelerating flow

Before the decelerating expiratory waveform reaches baseline (0 flow), the accelerating inspiratory flow wave of the next breath begins (below 0 flow).
Flow Waveform – Distinguishing Breath Types

Sinusoidal waveform seen in pressure ventilation

Square waveform seen in volume ventilation

Flow Waveform – Expiratory Resistance

Lower resistance has a steeper decelerating expiratory waveform

“Noisy” appearance of the waveform
Volume Waveform

Similar to the previously viewed pressure waveform with the exception that the volume waveform should start and end at a baseline of 0 volume.
Autocycling

Rhythmic breaths without a pause and a large ETT leak shown by the expiratory volumes not returning to baseline (0 volume)

Pressure-Volume Loop

Pressure-Volume Loop

Compliance = \frac{\Delta \text{Volume}}{\Delta \text{Pressure}}

Good compliance will have a compliance axis >45° if axes are properly scaled.

Pressure-Volume Loop - Compliance

Delay in volume delivery despite increasing pressure, indicating suboptimal opening pressure

Sinha SK, Nicks JJ, Donn SM. Graphic analysis of pulmonary mechanics in neonates receiving assisted ventilation. *Arch Dis Child Fetal Neonatal Ed* 1996; 75: F213-F218
Flattening of the volume curve indicates:
- The ventilator delivers volume that is in excess of lung capacity
- Excessive pressure without an increase in volume

This can be numerically depicted by using the C20/C as shown.

Figure courtesy of Dr. Mark Mammel
Pressure-Volume Loop – Lung Overinflation

Pressure-Volume Loop – Inadequate Flow

Inadequate flow as evidenced by:
- Narrow loop
- Little separation between the inspiratory and expiratory limbs
- "Figure 8" appearance at the end of inspiration

Flow-Volume Loop

- Peak inspiratory flow
- Peak expiratory flow

Inspiration (positive)
Expiration (negative)

Flow-Volume Loop - Resistance

Increased resistance (lower peak inspiratory and expiratory flows)

Decreased resistance (higher peak inspiratory and expiratory flows)

Flow-Volume Loop – ETT Leak

The expiratory flow loop does not reach the origin

Flow-Volume Loop - Turbulence

“Noisy” appearance of the loops

Time Constant

Time constant (sec) = Resistance (cm H$_2$O/L/sec) X Compliance (L/cm H$_2$O)

One time constant is defined as the time necessary for alveolar pressure to reach 63% of the change in airway pressure.
Time Constant: Healthy Infant

Resistance $= 30 \text{ cm H}_2\text{O/L/sec}$

$x$ Compliance $= 0.004 \text{ L/cm H}_2\text{O}$

Time Constant $= 0.12 \text{ sec}$

For near complete equilibration (5 TC)

$= 5 \times 0.12 \text{ sec} = 0.6 \text{ sec}$
Time Constant: RDS

**Resistance** = 100 cm H$_2$O/L/sec

x **Compliance** = 0.0005 L/cm H$_2$O

**Time Constant** = 0.05 sec

For near complete equilibration (5 TC)

= 5 x 0.05 sec = 0.25 sec

Lungs with decreased compliance will complete inflation & deflation quicker
Time Constant

- Time constant becomes critical when Ti or Te is so short that it is insufficient for pressure equilibration.
  - If Ti is too short (<5 TC)
    - incomplete tidal volume may be delivered
  - If Te is too short (<5 TC)
    - Incomplete expiration
    - Increase in FRC
    - Inadvertent PEEP
Practical Hints

- Make sure graphs are properly scaled
  - P and V axes should be equal
  - Wave forms should not be off scale
- Check for leaks, condensation, and secretions
- When all else fails, LOOK AT THE BABY!
Pulmonary Graphics

“You can observe a lot by watching.”

-Yogi Berra