Mechanical Ventilation in the NICU

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BCHO MORNING LECTURE

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History

- Commonly used in neonates in the 1960s
- Reduced mortality
  - Improved gas exchange (recruits lung, improves VQ matching)
  - Decreased work of breathing
  - Guarantees minute ventilation
- But increased morbidity (chronic lung disease)
  - Volutrauma
  - Barotrauma

Who Needs Mechanical Ventilation?

- Failed non-invasive support
- Inadequate ventilation
- Inadequate oxygenation
- Persistent apnea

Conventional Mechanical Ventilation

- Intermittent exchange of bulk volumes of gas
- Minute ventilation = frequency of breaths (rate) x tidal volume
  - Normal respiratory rate in neonates 30-50
  - Normal tidal volume in neonates: 4-6 ml/kg
- Breath can be ventilator or patient triggered
  - Breaths can be volume, time, or flow regulated
- The tidal volume can be regulated by pressure or volume

High Frequency Ventilation

- Delivers small volumes (~ equal to the anatomic dead space) at a very rapid rate
- Minute ventilation = frequency of breaths x tidal volume^2
- Also applies a continuous distending pressure to maintain expansion (mean airway pressure)
- Two modes:
  - High frequency oscillatory ventilation (HFOV)
  - High Frequency jet ventilation (HFJV)

Conventional Ventilation: Modes

- Time-cycled, pressure-limited (TCPL) Ventilation
  - Provides a continuous flow of heated, humidified gas, allowing the patient to breathe spontaneously at any time
  - IMV: Intermittent mandatory ventilation
  - SIMV: Synchronized intermittent mandatory ventilation
    - breaths delivered at a given rate in synchrony with the patient
    - Patient can breathe above this rate for unsupported
- Pressure Control/Pressure Support
- Automode
- Volume Guarantee

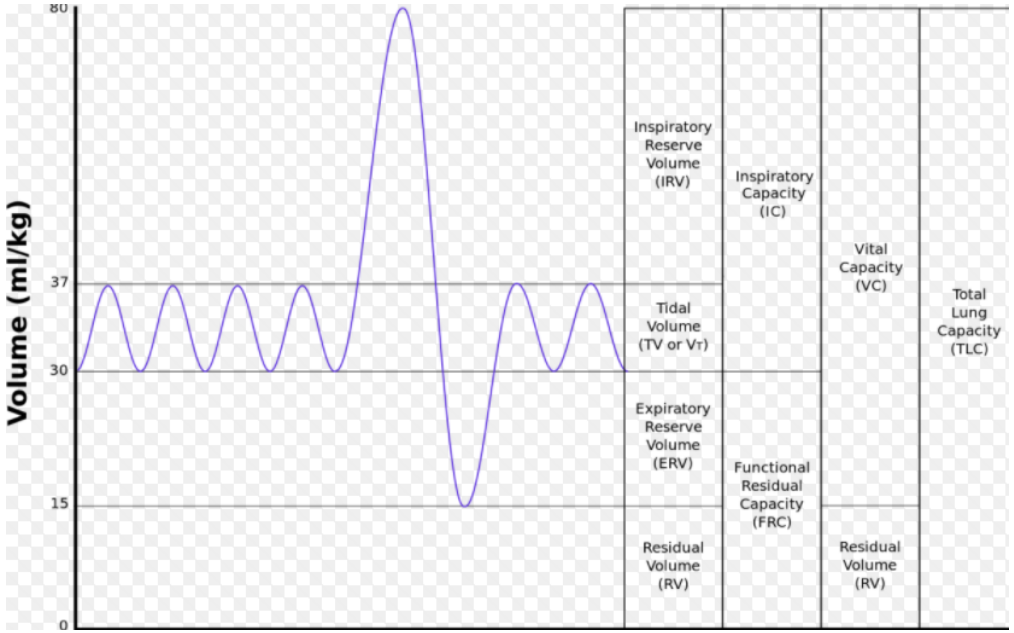
Conventional Ventilation: Modes

- Patient-triggered ventilation
  - Breaths are delivered in response to a sensor that detects airflow, airway pressure, or chest wall movement.
  - Improves patient comfort
  - Ventilates with lower mean airway pressure (MAP)
  - Reduces the need for sedatives
- But does not reduce mortality or incidence of BPD
  - Or rate of air leak, severe IVF, or extubation failure
- Shorter duration of ventilation with synchronized vs conventional ventilation
  - Which could benefit the extremely preterm infants most susceptible to mechanical ventilatory lung injury

Greenough et al, *Cochrane Review*, 2016

Ventilator Settings

- Peak Inspiratory Pressure (PIP): highest pressure delivered during inspiration
  - Excessive PIP can lead to air leaks, chronic lung disease, barotrauma, decreased venous return → decreased cardiac ouput
- Tidal Volume: the volume of air exchanged btwn unforced inhalation and exhalation
  - Affects both oxygenation and ventilation
  - Increased by increasing PIP or decreasing PEEP
  - Goal volumes are 4-6 ml/kg
  - Too large a tidal volume can cause damage to the alveoli, pulmonary edema, endothelial injury, inflammation



Ventilator Settings

- Positive End Expiratory Pressure (PEEP)
  - Maintains functional residual capacity
  - Recruits alveoli for gas exchange
  - Improves compliance
  - Improves V/Q mismatch
  - Physiologic PEEP is 2cm H_2O
  - Usually set PEEP on vent ~ 5-6

Ventilator Settings

- Inspiratory: Expiratory Ratio (I:E ratio): ratio between time spent in inspiration and exhalation
  - Physiologic I:E = 1:2 or 1:3
  - Longer expiratory times may improve ventilation and decrease air trapping
- Mean Airway Pressure: average distending pressure throughout a complete respiratory cycle
  - Major determinant of oxygenation
  - Affected by changes in PEEP, PIP, and I:E ratio
  - Too much mean airway pressure can cause barotrauma

Terminology

- SIMV: breaths delivered at a given rate in synchrony with the patient
  - Patient can breathe above this rate for unsupported breaths
- Pressure Control (AC): breaths delivered when the patient's inspiratory effort exceeds a preset threshold
  - Set iTime, PIP or TV, minimum mandatory vent rate if patient goes apneic
- Pressure support ventilation (PSV): breaths delivered when spontaneous breaths exceed a preset trigger, but support ends when inspiratory gas flow falls a certain percentage below peak flow (often 20%)
  - Patient determines rate and I:E ratio
  - Provides support against the resistance of the ETT
  - Often used in combination with SIMV

Modality

- Pressure limited
  - Set the PIP, iTime
  - TV varies as a function of lung compliance and resistance
  - Advantages: avoid barotrauma
  - Disadvantages: variation in tidal volume
    - TV > target in 25% of breaths (causing volutrauma) and < target in 36% of breaths (causing atelectotrauma)[1]
- Volume targeted
  - Set TV, PEEP, and rate
  - PIP varies as a function of lung compliance
  - Advantage: avoid volutrauma and atelectotrauma
    - Decreases combined outcome of death and BPD with NNT 8, pneumothorax with NNT 17, ventilation days by 2.36 days, hypocarbia with NNT 4, and grade 3 or 4 IVH/PVL with NNT 11[2]
  - Disadvantage: some machines only measure TV delivered, which does not account for leaks around ETTs; to avoid this, you need to measure the exhaled TV

[1] Keszler et al, *Pediatr Pulmonol*, 2004

[2] Wheeler et al, *Cochrane Database Syst Rev*, 2010

High Frequency Oscillatory Ventilator

- Delivers small volumes about equal to the anatomic dead space (amplitude) at a very rapid rate (frequency)
  - Typical frequencies are 8-15 Hz (480-900 breaths per minute)
  - Amplitude set to obtain good chest wiggle bilaterally, and titrated per CO_2
- Also applies a continuous distending pressure to maintain expansion (mean airway pressure)
- Expiration is active with HFOV

High Frequency Jet Ventilator

- Used in parallel with a conventional ventilator
- High frequency jet breaths are delivered through an adapter
- Set a PIP, PEEP, and frequency for jet breaths
- Set PIP, PEEP, and low rate (2-10 breaths per minute) as sigh breaths on the conventional vent
- Expiration is passive

When To Use What

- Conventional Vent
- High Frequency
  - Severe hypercarbia
  - Restrictive lung disease
  - Air leak
  - Unable to achieve adequate oxygenation on max conventional vent settings
  - High pressures on conventional vent