Principles of Ventilation
Section One
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Topics
Section One
• Chronic respiratory failure
• Conditions requiring long term mechanical ventilation
Section Two
• Basic ventilatory concepts
• Modes of ventilation

Respiratory Failure
• Inadequate gas exchange with:
  - increase in carbon dioxide (hypercarbia)
  - decrease in oxygen (hypoxia)
  - in the blood and, therefore, body tissues
• Considered chronic if the condition develops gradually and persists
Causes of Respiratory Failure

- Emphysema
- Central Hypoventilation Syndrome
- Pneumonia

Hypoventilation

- CNS abnormality
  - decreased drive to breathe
- Muscle weakness
  - inability to breathe
- Lung or airway disease
  - ↑ work of breathing

Diseases Needing Long Term Mechanical Ventilation

- Congenital central hypoventilation syndrome
- Neuromuscular diseases
- Spinal cord injury
- Bronchopulmonary dysplasia
- Complex congenital cardiac disease

http://www.aic.cuhk.edu.hk/web8/respfa~1.htm
**Congenital Central Hypoventilation Syndrome**

- Adequate ventilation when awake
- Hypoventilation when asleep
- Genetic disorder
- Life long need for ventilation
- Can be life threatening

**Neuromuscular Diseases**

- Spinal muscular atrophy
  - 3 types
  - Genetic, motor neuron disease
  - Weakness of the voluntary muscles
- Duchenne muscular dystrophy
  - Affects boys in teenage years
  - Progressive weakness

**Cervical Spinal Cord Injury**

- Traumatic injury to spinal cord
  - C5 level or above
  - Tetraplegia
  - Paralysis of diaphragm and accessory muscles


Bronchopulmonary Dysplasia
Lung or airway disease - ↑ work of breathing

Chronic lung disease of infancy
- Most severe require vent
- Caused by lung injury from oxygen & barotrauma
- Can usually be outgrown

Complex Congenital Cardiac Disease
Lung or airway disease - ↑ work of breathing

- Often have cyanotic heart disease
- unable to adequately oxygenate
- May have ↑ pulmonary blood flow
- May have malacia of the airways

Physiology of Ventilation
Exhaling
- passive process
  - diaphragm moves up
  - reduces size of chest cavity
  - increases air pressure

Inhaling
- active process
  - moves diaphragm down
  - enlarges size of chest cavity
  - reduces air pressure

Physiology of Ventilation

• Volume: amount of air going into the lungs
  - Tidal volume: amount of air inhaled and exhaled with each breath

• Flow: movement of air
  - Inspiratory time: length of time for inspiration

Physiology of Ventilation

• Pressure: force needed to move the air
  - Two levels of pressure with each breath: inspiratory and expiratory

• Minute Ventilation (MV):
  - Total ventilation per minute
  - $MV = \text{Tidal volume} \times \text{breaths per minute}$

Physiology of Ventilation

• Compliance: the ability of the lung to stretch
  - Higher compliance: easier inflation of the lungs
  - Lower compliance: difficult inflation of the lungs

• Airway resistance: obstruction of airflow by the airways
  - Diameter of airway determines resistance
  - Smaller diameter: higher resistance
Physiology of Ventilation

- Work of breathing
  - energy needed to overcome compliance of lung and airway resistance
- Represented on a diagram of a pressure-volume curve

Key Points: Ventilation

- Chronic respiratory failure has a variety of causes
- Children require mechanical ventilation for a variety of reasons
  - understand the physiology
  - understand the underlying disease

Principles of Ventilation
Section Two

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Topics

- Components of mechanical ventilation
- Basic ventilatory concepts
- Modes of ventilation
- Ventilator alarms
- Trouble shooting problems with the ventilator

Normal vs Mechanical Ventilation

- Normal ventilation
  - Negative pressure system
    - Air is pulled into the lungs
- Mechanical ventilation
  - Positive pressure system
    - Air is pushed into the lungs

Mechanical Ventilation

- Long term mechanical ventilation is most commonly delivered by positive pressure,
- Air is delivered into the lungs in one of two ways
  - Non-invasively via mask
  - Invasively via a tracheostomy
Mechanical Ventilator System

- Variety of ventilators
- Regulates flow, pressure, volume
- Use microprocessor technology

Method of Air Flow

- Intermittent flow triggered by patient
- Continuous flow always available to patient

Mechanical Ventilator System

- Variety of circuits disposable or non-disposable, heated wire circuit, test lung
- Test lung
Humidity

- Heated System
  - AC power source

- Heat Moisture Exchanger (HME)
  - In-line passive humidity

Fischer & Paykel Healthcare
MR850 Heated Humidifier

HUDSON Concha III
Heated Humidifier

Definitions and Modes

- WARNING!
- There is little standardization of terms on the ventilators
- Some things that are slightly different are given the same names
- Some things that are the same are given different names

Breath Types

- Spontaneous Breath
  - Inspiration is both initiated and terminated by the patient

- Mandatory Breath
  - Inspiration is either initiated or terminated by the ventilator

Retrieved from:

Retrieved from:
http://www.hudsonrci.com/Products/product_indiv.asp?catalog=1&PageId=259&prod_cat=20&prod_subcat=85&keywords=
**Trigger**
- How does the vent know when to give a breath? - “Trigger”
  - patient effort
  - elapsed time
- The patient’s effort can be “sensed” as a change in pressure or a change in flow (in the circuit)

**What Is a “Mode”?**

* Mode
  - a manner, way, or method of doing or acting.
  - a given condition of functioning: a status, or...
  - how the ventilator gives a breath

**Modes**
- Control Mode
  - every breath is fully supported by the ventilator
  - preset respiratory rate
  - patient efforts ignored
- AC Assist/Control Mode
  - a minimum set rate and all triggered breaths above that rate also fully supported
Modes

- SIMV Modes
  - Synchronized intermittent mandatory ventilation
  - breaths “above” set rate not supported
  - vent synchronizes the IMV “breath” with the patient’s effort

Control of Breaths

Whenever a breath is supported by the ventilator, regardless of the mode, the control or limit of the support is determined by either a preset volume OR a preset pressure.

- Volume Control: preset tidal volume
- Pressure Control: preset peak inspiratory pressure

Volume Control

- Set parameter
  - specific tidal volume of air during inspiration
  - The ventilator uses a flow of air for a set period of time to deliver the volume
  - Respiratory rate
- Variable parameter
  - Pressure is a product of lung compliance, airway resistance and flow rate
  - The ventilator does not react to the variable pressures unless the high or low pressure alarm limits are violated
- Good mode to ensure adequate volumes for patients unable to breathe deeply
**Pressure Control**

- **Set parameter**
  - Fixed airway pressure
  - Ventilator adjusts flow to maintain pressure
  - Respiratory rate
- **Variable parameter**
  - Volume delivered depends upon the inspiratory pressure and time, pulmonary compliance and airway resistance
  - Delivered volume can vary from breath-to-breath
  - Low minute volume alarm warns of low volumes
- **Good mode to use if patient has large air leak**
  - Ventilator will increase the flow to compensate

**Pressure Terms**

- **Peak Inspiratory Pressure (PIP)**
  - Maximum pressure measured by the ventilator during inspiration
- **Pressure Support (PS)**
  - Amount of pressure applied to the airway during spontaneous inspiration by the patient
  - Helps to overcome airway resistance and inadequate pulmonary effort and is added on top of the PEEP during inspiration
  - Increased flow during inspiration to reach the target pressure to make it easier for the patient to take a breath

**Continuous positive airway pressure (CPAP)**

- Amount of pressure applied to the airway during all phases of the respiratory cycle
- Can maintain oxygenation and decrease work of breathing
- No cycling of pressures - patient initiates all breaths

**Positive end-expiratory pressure (PEEP)**

- Pressure present in the airways at the end of expiration
- Used to help prevent alveolar collapse at end inspiration
- Can stent open floppy airways
Pressure vs. Volume

- Pressure
  - tidal volume may change suddenly as patient’s compliance changes
  - can lead to hypoventilation or overexpansion of the lung
  - if trach is obstructed acutely, delivered tidal volume will decrease

- Volume
  - no limit per se on PIP (usually vent will have upper pressure limit)
  - constant flow pattern results in higher PIP for some tidal volume as compared to Pressure modes

Ventilator Alarms

- Low pressure
- High pressure
- Low volume
- High volume
- Change in power (to a lesser power source)
- Low power

Low-Pressure Alarms

Volume Mode

- Patient disconnection
- Circuit leaks
- Airway leaks
- Use test lung
High-Pressure Alarms
Volume Mode
- Patient coughing, talking or fighting the ventilator breaths
- Secretions or mucus in the airway
- Reduced lung compliance (may be due to pneumothorax or pneumonia)
- Increased airway resistance
- Accumulation of water in the circuit
- A kink in the ventilator circuit

Volume Alarms
Pressure Mode
- More difficult to have accurate alarms in pressure mode
  - Ventilator may continue to deliver breaths despite disconnection from ventilator
- Volume alarms can alert to changes in volume indicating inadequate ventilation

Power source alarms
- Change in power (to a lesser power source)
- Low power
Ventilator Troubleshooting

• Determine what is the problem?
  - Look at the patient!!
  - Listen to the patient!!

• Check settings, readings and alarms

Ventilator Troubleshooting

• When in doubt.....
  • DISCONNECT THE PATIENT FROM THE VENTILATOR and begin bag ventilation
    - Eliminates the vent circuit as the source of the problem
  • Giving breaths with the resuscitation bag...
    - Helps you identify airway issues
    - Provides ventilatory support to the child while you identify the problem

Weaning

• Is the cause of respiratory failure gone or getting better?
  • Children with chronic lung disease most likely to wean
  • Children with neurological involvement least likely to wean
Weaning

- Decrease vent settings
  - decrease the PEEP (4-5)
  - decrease the rate
  - decrease the PIP (as needed)
- Decrease time on the vent

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Weaning

- Can the child make up the difference?
- Is the child well oxygenated and ventilated?
- Can the child tolerate the increased work of breathing?

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Key Points: Ventilation

- The most common mechanical ventilation is a positive pressure system
- Understand the specifics of the ventilator in use
  - Brand
  - Circuit
  - Mode & settings
- When in doubt, DISCONNECT THE PATIENT FROM THE VENTILATOR and begin bag ventilation