Mechanical Ventilation

Respiratory Failure

Definition

Any condition in which the respiratory system fails to do its primary function
Oxygenate arterial blood and eliminate CO₂

Function of Respiratory System

Oxygenate arterial blood and eliminate CO₂
Clinical Assessment

Usually a combination of the clinical features of the underlying disease plus signs & symptoms of hypoxemia & hypercapnia

• Dyspnea

Clinical Assessment

• Respiratory rate

Clinical Assessment

• Alveolar ventilation
  – Adequate measure cannot be made at bedside
  – Nothing can be assumed about alveolar ventilation by looking at RR & Vr
Clinical Assessment

• Use of accessory muscles &/or retractions

Clinical Assessment

• Cyanosis

Clinical Assessment

Signs & symptoms of hypoxemia and hypercarbia

• Dyspnea
• Increased RR
• Use of accessory muscles
• Cyanosis (?)
• Alteration in mental status
• Weakness
• Muscle tremor or twitching
• Drowsiness, lethargy
• Somnolence
• Irritability
• Coma
Clinical Assessment
Signs & symptoms of hypoxemia and hypercarbia

- Agitation, restlessness
- Increased ICP
- Cardiac arrhythmias
- Tachycardia
- Increased BP
- Peripheral vasoconstriction
  - Hard to draw ABG
  - Hard to do PO
  - Pallor
- Diaphoresis

Assessing the Mechanics of Ventilation

- Spontaneous inspiration
  - Diaphragm contracts
  - Intercostal muscles pull outward to enlarge thorax
  - Intrapleural pressure drops
    (-4 to -10 cmH₂O)
  - Air rushes in until alveolar pressure = atmospheric pressure

Assessing the Mechanics of Ventilation

- Expiration

  WOB = amount of effort required to overcome compliance and resistance of lungs and thorax
Assessing the Mechanics of Ventilation

Evaluation of ventilatory mechanics provides information about the ease with which the lungs may be inflated and the effectiveness of the respiratory muscles.

- Compliance
- Airway resistance
- Respiratory rate
- Lung volumes
- Airway pressures

Compliance

- Lung normally very compliant
- Compliance = volume/ pressure
- If lung, thorax is more difficult to distend = decreased compliance leads to increased WOB
Compliance

• Causes of decreased compliance:
  – Fibrotic lungs (Pulmonary Fibrosis)

Compliance

• Secretions, fluid

Compliance

• Restriction of chest wall motion
Respiratory Failure

Airway Resistance

- $R_{AW}$ is the relationship between

- Airway resistance $= \frac{\text{pressure}}{\text{flow}}$
- Increased $R_{AW} \Rightarrow \uparrow \text{WOB}$

Airway Resistance

- Causes of increased $R_{AW}$

Spontaneous Parameters

- Reliable indicators of patient’s ability to:
  - Maintain spontaneous ventilation
  - Reverse atelectasis
  - Mobilize secretions with effective cough
- Measurement is
  - Quick
  - Easy
  - Low cost
Spontaneous Parameters

• Respiratory rate
  – Normal = 12 - 20 BPM
  – Most accurate to measure x 1 minute
  – If RR ↓ need to ↑ VT to maintain adequate minute ventilation
  – If RR ↑ ↑ VT
  – >35 = impending RF

Spontaneous Parameters

• Lung volumes - Minute Ventilation
  – Total volume of air exhaled in 1 minute
  – Normal = 5 - 7 LPM
  – If adequate - PaCO₂ will remain normal
  – ↑ will normally cause PaCO₂ to ↓
  – Indirect evaluation of mechanical ability to maintain ventilation

Spontaneous Parameters

Lung volumes - Minute Ventilation
↑ MV caused by:

• Pain, anxiety
• Fever
• Hypoxemia
• Hypercarbia
• Acidosis
  • ↑ shunt
  • ↑ Vo
  • Early stage of RF
  • Diet high in carbohydrates
**Spontaneous Parameters**

- Lung volumes - Tidal Volume
  - Volume of air inspired or expired passively in a respiratory cycle
  - Normal = 5 - 7 ml/kg
  - Most accurate to measure exhaled minute volume, then divide by RR

\[ V_T = V_E + RR \]
Spontaneous Parameters

Lung volumes - Tidal Volume

↑ Vt due to:

ARF

Spontaneous Parameters

• Lung volumes - Vital Capacity
  – Maximum volume exhaled after a maximal inspiration
  – Normal = 65 - 75 ml/kg
  – <15 ml/kg = impending RF
  – SVC measured with spirometer
  – Requires patient cooperation

ARF

Spontaneous Parameters

• Lung volumes - Vital Capacity
  – Best determinant of ventilatory reserves i.e. respiratory muscle strength & volume capacity for:
    • adequate cough
    • secretion clearance
    • prevent & reverse atelectasis
Respiratory Failure

Spontaneous Parameters
Lung volumes - Vital Capacity
VC due to: Loss of distensible lung tissue

Spontaneous Parameters
Lung volumes - Vital Capacity
VC due to: Interference with chest-wall motion

Spontaneous Parameters
• Lung volumes - Why monitor?
  – Changes in lung volumes have a direct effect on gas exchange at the alveolar-capillary level
  – Reflects:
    • Mechanical function of pulmonary system
    • Changes in disease process
    • Responsiveness to therapy
Spontaneous Parameters

- Lung volumes - Who is monitored?
  - Intubated patients
    - Being considered for MVS
    - Receiving MVS
    - Being weaned from MVS
    - With abnormal respiratory patterns

Spontaneous Parameters

- Lung volumes - Who is monitored?
  - Non-intubated patients
    - Pre-op evaluation
    - With RR > 30
    - With neuromuscular disease
    - With CNS depression
    - With deteriorating ABGs

Airway Pressures

- NIP, NIF
  - Normal = > -80 cmH2O
  - < -25 cmH2O = need for MVS
  - Reflects muscular strength for cough & prevention of atelectasis
  - Patient instructed to inhale through occluded airway attached to NIP gauge
  - Record negative pressure generated
Airway Pressures

- **PEP**
  - Normal > +100 cmH₂O
  - < +40 cmH₂O = need for MVS
  - Reflects muscular strength for cough & prevention of atelectasis
  - Patient instructed to blow through occluded airway attached to pressure gauge
  - Record positive pressure generated

Expiratory Flow Rate

- **PEFR, MEFR**
  - Normal = > 350 LPM
  - Maximum flow generated during FVC
  - Use peak flow meter
  - Assesses:
    - Degree of airway obstruction present
    - Response to bronchodilator therapy
    - Ability to generate high flow rates for coughing

Equipment to Measure Volume

- **Spirometers**
Equipment to Measure Volume

• Bellows
  – Water-sealed spirometer (Collins)
  – Exhaled volume spirometer (Puritan Bennett)
  – Volume collectors

Equipment to Measure Volume

• Turbine-driven
  – Wrights, Draeger, Fraser Harlake
  – Use miniature vanes or rotors that revolve when exposed to gas flow which then moves a needle on the gauge to record volume

Equipment to Measure Volume

[Diagram of a two-bladed rotor with tangential slots, inlet ports, and needle pivot]
Equipment to Measure Volume

• Flow transducers
  – Calculate volume by flow/time
  – Small, lightweight
  – 2 types

Equipment to Measure Volume

• Flow transducer
  – Pressure differential
    • Measure pressure difference across a membranes
    • Fleisch pneumotach, V-O pneumotach
Equipment to Measure Volume

• Flow transducer
  – Vortex-shedding
    • Vortex created by struts
    • Ultrasonic beam altered by vortex
    • Converts changes in turbulence to volume

Equipment to Measure Volume

• Thermal units
  – Heated wire is cooled by gas flow which changes electrical resistance of the wire
  – Converted to volume
Equipment to Measure Volume

- Exhaled Gases
- Thermistor Bead
- Electronic Connection