Respiratory Failure

Critical Care Monitoring
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
Respiratory Failure

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 (?)
• Δ 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

- 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 = $\Delta$ volume/ $\Delta$ pressure
- If lung, thorax is more difficult to distend = decreased compliance $\rightarrow$ leads to increased WOB
• Causes of decreased compliance:
  – Fibrotic lungs (Pulmonary Fibrosis)

• Secretions, fluid

• Restriction of chest wall motion
Airway Resistance

- $R_{AW}$ is the relationship between

- Airway resistance = Δ pressure/flow
- Increased $R_{AW} \rightarrow \uparrow$ WOB

Causes of increased $R_{AW}$

Reliable indicators of patient’s ability to:
- Maintain spontaneous ventilation
- Reverse atelectasis
- Mobilize secretions with effective cough

Measurement is
- Quick
- Easy
- Low cost
Respiratory Failure

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 ↑ → ↑ Vo
  - >35 = impending RF

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

Pain, anxiety
Fever
Hypoxemia
Hypercarbia
Acidosis

↑ MV caused by:

- ↑ shunt
- ↑ Vo
- Early stage of RF
- Diet high in carbohydrates

Diet high in carbohydrates
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
  \[ V_T = \dot{V}_E ÷ RR \]
Respiratory Failure

Spontaneous Parameters
Lung volumes - Tidal Volume
↑ V↑ due to:

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

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
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
Respiratory Failure

**Spontaneous Parameters**

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

- 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
Respiratory Failure

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

Expansory Flow Rate

- **PEFR, MEFR**
  - Normal $\geq$ 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

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

• 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

- Thermal units
  - Heated wire is cooled by gas flow which changes electrical resistance of the wire
  - Converted to volume
Respiratory Failure

Equipment to Measure Volume

Thermistor bead
Exhaled gases
Electronic connection