Mechanical Ventilation

Cardiovascular Effects

PPV $\rightarrow$ $\downarrow$ $Q_T$

1. $\uparrow$ intrathoracic pressure
2. card. tamponade effect
3. loss of $\pm$ press chg in lungs w/spont breathing

normal $\rightarrow$ $\uparrow$ HR
$\uparrow$ contractility
vasoconstriction
maintain BP

Blood Pressure Drop

Drops if:
- normal compensatory mechanism lost
  - Anesthesia, sedation
  - Polyneuritis
  - Anti-adrenergic drugs
    - Catapres, Aldomet, Inderol, etc.
- hypovolemia
Effects of MV

Cardiovascular Effects

1. ↑ intrathoracic pressure
2. Card. tamponade effect
3. Loss of +/- press change in lungs w/spont breathing

↑ contractility
vasoconstriction
maintain BP

↓ BP

Fix Drop in BP

- Patient positioning
- IV fluids
- Digitalis
- Dopamine
- Dobutamine
- Levophed
- Epinephrine

Cardiac Output Drop

- Will be greater:
  - 1
  - 2
  - 3
Effects of MV

To lessen drop in $Q_T$

- 1-
- 2-
- 3-

Why Maintain BP?

decreased $Q_T$ & BP

Assessment of Cardiovascular Effects

- Blood pressure
  - normal =
- Cardiac output
  - normal =
ICP and Cerebral Perfusion

- Amount of blood flow to the brain determined by:
  - 1.
  - 2.
  - 3. **
  - 4. **

Cerebral Perfusion Pressure

\[ \text{CPP} = \text{BP} - \text{ICP} \]

\[ \text{BP} = \frac{\text{systolic} + (2 \times \text{diastolic})}{3} \]

normal CPP =

Decreased CPP

Decreased CPP → ↓ cerebral blood flow
↓ cerebral hypoxemia
cerebral edema
Effects of MV

Causes of ↓ CPP
- ↓ BP
  - uncommon in head injury
  - seen more with spinal injuries and multiple trauma
- ↓ QT
  - CMV
  - PEEP
  - CPAP
  - Hemorrhagic shock
  - Heart failure
- Vasodilation

Causes of ↓ CPP
- ↑ ICP
  (pressure in CSF in subarachnoid space, ventricles)

Intracranial Pressure
- Skull is closed container
- Contains brain, blood, CSF
- Room for some expansion but not much
- Any increase in volume of 1 content without a decrease in volume of another →
Effects of MV

Intracranial Pressure

- Normally: if blood or brain volume ↑, same volume of CSF is displaced so that ICP is maintained =

Intracranial Pressure

- ↑ ICP → compresses brain tissue
- ↓ cerebral blood flow
- ↓ if sustained → irreversible brain damage & death

Causes of ↑ ICP

- Closed head injury
- Tumors
- Craniotomy
- Cerebral hemorrhage
- CVA (ABI)
- Reyes Syndrome
- Meningitis
- Encephalitis
- Near-drowning or any severe anoxic episode

- CMV w/PEEP
- Cough
- Valsalva maneuver
- Trend position
- Elevated CVP
- Hypoventilation (↑PaCO₂)
- Acidosis
- Profound hypoxia
- Vasodilating drugs
Prevent ↑ ICP

• Maintain BP if patient is at risk for increased ICP

↓ Elevated ICP

• head near mid-line, no pillow, HOB ↑ 30-45°
• sedatives, muscle relaxants
• low PEEP if possible
• hyperventilation → ↑ pH → cerebral vasoconstriction
  – PaCO₂ 25-30 mmHg X 24-48 hrs.

↓ Elevated ICP

• hyperosmolar agents (osmotic diuretics)
  – reduce brain water
  – reduce total body water
  – Mannitol
• loop diuretics
  – furosemide (Lasix)
  – acetazolamide (Diamox)
Effects of MV

↓ Elevated ICP
• barbiturate coma
• use of steroids is controversial
• removal of CSF in some cases
• hypothermia

Assessment of ICP
• 1-
• 2-

Renal Effects

Positive pressure ventilation has 3 renal effects........
Effects of MV

Renal Effects

1. decreased cardiac output
   \[\downarrow\] renal blood flow
   \[\downarrow\] glomerular rate

2. redistribution of blood inside kidney

3. ↑ release of Antidiuretic Hormone (ADH)
   2 mechanisms:
   • receptors in LA sense ↓ blood volume → ↑ ADH
   • receptors in carotid bodies, aortic arch sense change in blood pressure, intrathoracic pressure → ↑ ADH
Renal Effects

• ABGs also affect renal function:
  \[ \downarrow \text{PaO}_2 \rightarrow \]
  \[ \uparrow \text{PaCO}_2 \rightarrow \]

Assessment of Renal Function

• I & O

• BUN
  – 1-
  – 2-
  – Normal =
  – 4-

Assessment of Renal Function

• Creatinine
  – Metabolic waste-product
  – Normal = < 2 mg/dl
  – Increased in renal failure
  – More sensitive than BUN
Assessment of Renal Function

- Osmolarity
  - Particles in solution
  - Renal failure → retain $H_2O$ → particles
diluted → ↓ osmolarity in blood, ↑ in urine

- Specific gravity
  - $1/\propto$ urine output
  - Normal =

Hepatic System

- Liver
  - 1-
  - 2-

- Dysfunction caused by:
  - 1-
  - 2-

Assessment of Hepatic System

- Bilirubin
  - Produced by breakdown of RBC
    - Hgb → bilirubin + heme
    - Converted to $H_2O$ used to make soluble by liver new RBC
    - Broken down by bacteria in intestines
  - Normal =
  - If increased →
Effects of MV

Assessment of Hepatic System

- Total serum protein
  - Normal =
  - Albumin =
  - ↓ albumin →
  - ↓ total protein →

- Skin color
- Mental status

Gastric, Splanchnic Effects

- PPV →↑ resistance to blood flow
- ↓ may contribute to gastric mucosal edema
- ↓ GI bleeding
- ↓ altered GI function & bowel absorption properties
- ↓ malnutrition
- ↓ protein depletion
- ↓ altered healing
- metabolic acidosis ← diarrhea
- fluid depletion

Assessment

- 1-
- 2-
- 3-
- 4-
- 5-

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35

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Neurological Effects

• Neuro system affected by
  – Hypoxia
  – Decreased Q_f
  – Changes in acid-base status
  – Build-up of metabolic waste products
  – Decreased glucose levels

Neurological Effects

• PPV can → ↑ ICP if:
  venous pressure ↑
  Q_f ↓

Assessment

• Observe ventilatory pattern
• Airway reflexes
• Response to pain
• Purposeful movement
• Anxiety level, restlessness
• Level of consciousness (Glasgow Coma Scale)
Effects of MV

Glasgow Coma Scale

<table>
<thead>
<tr>
<th>TEST</th>
<th>RESPONSE</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>Oriented and converses</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Disoriented and converses</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Incomprehensible sounds</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>1</td>
</tr>
<tr>
<td>Best verbal response</td>
<td>Obey verbal command</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Localizes painful stimuli</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Flexion/withdrawal to pain</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Decorticate response to pain</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Decerebrate response to pain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>No response to pain</td>
<td>1</td>
</tr>
</tbody>
</table>

Pulmonary Effects

- Ventilation
- Pulmonary Perfusion

To the Blackboard!

Pulmonary Effects

- V/Q mismatch → ↑ \( V_D \)
- ↑ shunt
Pulmonary Effects - PVR

- ↑ airway pressure \( \rightarrow \) thinning & compression
- ↑ alveolar pressure \( \rightarrow \) of capillaries ↓

However -

- If \( T_e \) long enough & no PEEP or exp resistance, the drop in pulmonary perfusion is offset by normal flow during exp \( \Rightarrow \) no net effect on PVR

Remember!

Severe hypoxia \( \Rightarrow \) ↑ PVR by vasoconstriction causing pulmonary hypertension ↓
- if PPV improves oxygenation ↓
- reverses vasoconstriction
Using PEEP When FRC ↓

• Alveoli open improving V/Q
• If too high: $C_L \downarrow$ & PVR $\uparrow$

Effect on Ventilatory Status

• Goal of eucapneic ventilation is not achieved if ventilator is mismanaged inducing abnormalities
  – Hypoventilation
  – Hyperventilation

Effect on Ventilatory Status

Hypoventilation $\downarrow \downarrow \text{PaO}_2$
  $\leftarrow$
$\uparrow \text{PaCO}_2$
  $\leftarrow$
  / right shift oxyHgb curve
$\downarrow \text{pH}$
cellular damage
coma
$\uparrow$ plasma $K^+$ $\uparrow$ cardiac dysfunction
cerebral vasodilation $\downarrow$ $\uparrow$ ICP
Effects of MV

Rx Hypoventilation

• 1-

• 2-

Effect on Ventilatory Status

Hyperventilation

- \( \downarrow \text{PaCO}_2 \)
- \( \uparrow \text{pH} \)
- \( \downarrow \text{plasma K}^+ \) ◊ cardiac arrhythmias
- cerebral vasoconstriction ◊ \( \downarrow \text{ICP} \)
- if sustained ◊ tetany
- \( \downarrow \) drive to breathe = "alkalotic apnea"

Rx Hyperventilation

• 1-

• 2-
Effects of MV

Body Position

• Change position frequently to avoid atelectasis

• If unilateral lung disease - place patient how?

Hazards of O$_2$ Therapy

• O$_2$-induced bradypnea
  – Hypoxic drive (COPD)
  – Problem if inadequate ventilation not provided

Hazards of O$_2$ Therapy

• Absorption atelectasis
  – Esp. if F,O$_2$ > 0.70
  – Leads to shunt
Hazards of O₂ Therapy

- Oxygen toxicity
  - Adults: F₁O₂ > 0.60 > 6 hrs ⇒ damage to pulmonary tissue
  - Infants: PaO₂ > 80 mmHg ⇒ ROP
  - Best to use least F₁O₂ necessary
  - Use PEEP if F₁O₂ > 0.60

Barotrauma

- Normal lungs can withstand 80-140 cmH₂O
- Increased risk of barotrauma with:
  - High MAP, high PIP, large V₁ with PEEP
- Monitor Cₐ
- Pneumothorax, pneumomediastinum, pneumopericardium, pneumoperitoneum, subcutaneous emphysema

Metabolic Acid-Base Imbalance

- Happens when PaCO₂ is near patient’s normal but pH is not -

<table>
<thead>
<tr>
<th>pH</th>
<th>PaCO₂</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.20</td>
<td>40 mmHg</td>
<td>15 mEq/l</td>
</tr>
</tbody>
</table>
Metabolic Acidosis

- May require administration of bicarb -

\[ \text{mEq req} = \frac{\text{base deficit} \times \text{BW}}{4} \]

- Give 1/2, then repeat ABG
- Treat cause

Metabolic Alkalosis

- pH 7.58
- \( \text{PaCO}_2 \) 40 mmHg
- \( \text{HCO}_3^- \) 32 mEq/l

- 1-
- 2-

Mechanical Failure

- Good monitoring
- Alarms on & functioning
Effects of MV

Psychological Complications

- Patients in ICU are very ill
  - High noise level
  - Patient-staff interaction
  - 24 hrs of “day”
  - Isolation from family
- Leads to
  - Acute sleep deprivation
  - Increasing confusion
  - Lethargy
  - Less responsiveness

Psychological Complications

- Now add ventilator, lose control over:
  - Breathing
  - Mobility
  - Privacy
  - Speech
  - Eating

Psychological Complications

- Plus, inadequate knowledge of
  - Machines
  - Tubes
  - Monitors
  - Alarms
- Decreased confidence in staff
Effects of MV

To Help

- EXPLAIN
- Talk to
- Calendars, clocks
- Windows
- Quiet periods
- Coordinated care
- Communication boards

Nutritional Complications

- Critical illness need ↑ nutrition
- If malnourished -
  - Altered healing of wounds, infections
  - Weakened respiratory muscles
  - Decreased surfactant production
  - Decreased albumin levels
- Overfeed → ↑ VO₂, ↑ VCO₂
- Feed emulsified fats