Assisted ventilation

Objective:
Optimal gas exchange with minimal or no lung injuries or other adverse effects.

Support breathing until the patient’s respiratory efforts are sufficient.

Assisted ventilation

Required:
- During immediate care of the infant who is depressed or apneic
- During prolonged periods of treatment of respiratory failure.

Gas exchange

- Through alveolar-capillary membrane
- During expiration
- Newborn is very vulnerable because:
  - high metabolic rate,
  - propensity for decreased functional capacity (FRC)
  - decreased compliance
  - increased resistance
  - potential right-left shunt through PCA or Fo.Ov.

Hypercapnia

- Caused by
  - Hypoventilation
  - Severe ventilation/perfusion (V/Q) mismatch
- Elimination of CO2 is done by diffusion, directly proportional to alveolar minute ventilation (AMV)

AMV

- \[ AMV = (Tidal~volume - Dead~space) \times Frequency \]
- \(Tv = \) the vol. of gas inhaled with each breath
- \(Fr. = \) nr. of breaths per minute
- Dead space = part of the TV not involved in gas exchange (vol. of conducting airways) – rel. cst.
- Thus: \(Tv/F \quad AMV \quad PaCO2\)

- Use small \(Tv\) but high \(Fr\). frequency will minimize barotrauma
- Use small \(Tv\) but high \(Fr\). ventilation
- High frequency

Hypoxemia

- the result of V/Q mismatch (SDR) or right-left shunt (intrapulmonary or intracardiac);
- diffusion anomalies
- hypoventilation (e.g. apnea)

Correction:
- Increase FiO2;
- Increase MAP – risk for overdistention;
- Transfuse if low Hb level (less than 7-10 g%)
Pulmonary mechanisms

• A pressure gradient between the airway opening and the alveoli must exist to drive the flow of gases during both inspiration and expiration:
  \[ \text{Pressure} = \frac{\text{Volume}}{\text{Flow}} + \text{Resistance} \times \text{Compliance} \]

Airway Resistance

\[ R = \frac{\Delta \text{P}}{\Delta \text{F}} \]

Pressure Difference = Flow Rate \times Resistance of the Tube

Factors Affecting Resistance

Physiologic

• Bronchospasm
• Emphysema
• Foreign body/obstruction
• Excessive secretions
• Tracheobronchial malacia

• Airway resistance depends on:
  ✓ (1) radii of the airways (total cross-sectional area),
  ✓ (2) length of airways,
  ✓ (3) flow rate, and
  ✓ (4) density and viscosity of gas.

Resistance

• Small ETTs that may contribute significantly to airway resistance also are important, especially when high flow rates that lead to turbulent flow are used.
• The range for total airway plus tissue respiratory resistance values for healthy newborns is 20-40 cm H₂O/L/s; in intubated newborns this range is 50-150 cm H₂O/L/s.

Factors Affecting Resistance

Mechanical

• Filters/HME
• Endotracheal tube size
• Flow
• Water in tubing
• Expiratory valve of ventilator
Compliance

\[ C = \frac{\Delta V}{\Delta P} \]

Volume Change = Pressure Difference × Compliance of the Balloon

Compliance and Resistance

\[ C = \frac{\Delta V}{\Delta P} \quad R = \frac{\Delta P}{\Delta F} \]

Static Compliance

- Most common calculation accepted by clinicians.
- Measured during periods of zero flow.
- Can be accomplished using inspiratory hold or adding pause time to the mechanical breath.
- Patient position, degree of muscle relaxation and the pattern of breathing preceding the measurement can alter the value.

Static Compliance

\[ C_s = \frac{\text{expiratory tidal volume (ml)}}{\text{plateau pressure} - \text{PEEP (cm H2O)}} \]

Dynamic Compliance

- Measured during any positive pressure breath, assisted or unassisted, and does not require an inspiratory pause
- Taken when airflow is present
- Used as a gross measure and may result in a reduction of measured compliance of 10-15%

Dynamic Compliance

\[ C_D = \frac{\text{Inspiratory tidal volume (ml)}}{\text{peak pressure} - \text{PEEP (cm H2O)}} \]
Static and Dynamic Compliance

Dynamic Characteristics Curve

Effective Static Compliance Curve

Volume

Plateau Pr

Peak Pr

Pressure

TV

Time constant

• Compliance and resistance can be used to describe the time necessary for an instantaneous or step change in airway pressure to equilibrate throughout the lungs. The time constant of the respiratory system is a measure of the time necessary for the alveolar pressure to reach 63% of the change in airway pressure, which can be calculated as follows:

\[ \text{Time Constant} = \text{Resistance} \times \text{Compliance} \]

Ex: C: 0.004 and rez 30 have Tcst 0.12 sec. The longer the duration of the inspiratory (or expiratory) time allowed for equilibration, the higher the percentage of equilibration.

Time constant – clinical application

• Delivery of pressure and volume is complete (95-99%) after 3-5 time constants. The resulting time constant of 0.12 seconds indicates a need for an inspiratory or expiratory phase of 0.36-0.6 seconds.
• In contrast, lungs with decreased compliance (eg, in RDS) have a shorter time constant. Lungs with a shorter time constant complete inflation and deflation faster than normal lungs.

Gas trapping

• A short expiratory time, a prolonged time constant, or an elevated tidal volume can result in gas trapping.
• Gas trapping may decrease compliance and impair cardiac output.
• Gas trapping during mechanical ventilation may manifest as:
  • decreased tidal volume,
  • carbon dioxide retention,
  • and/or lung hyperexpansion,
  • venous return to the heart and cardiac output may be impaired,
  • oxygen delivery can be decreased.

Time constant

• Very short inspiratory times may lead to incomplete delivery of tidal volume and, therefore, lower PIP and MAP, leading to hypercapnia and hypoxemia.
• Similarly, insufficient expiratory time may lead to increases in FRC and inadvertent PEEP, which is evidence of gas trapping.

Gas trapping – clinical situations

• (1) use of a short expiratory time (eg, high ventilatory rates),
• (2) a prolonged time constant (eg, high resistance),
• (3) lung overexpansion on radiography,
• (4) decreased thoracic movement despite high PIP,
• (5) impaired cardiovascular function (increased central venous pressure, decreased systemic blood pressure, metabolic acidosis, peripheral edema, decreased urinary output).
Terminology: PIP & MAP

Terminology: PEEP, I:E Ratio

Inspiratory and expiratory time

• A short expiratory time leads to gas trapping. Lengthening expiration improves ventilation. However, a very prolonged expiratory time does not improve ventilation. Indeed, in the absence of gas trapping, shortening expiratory time allows for more breaths to be provided per minute, which improves ventilation.

Volume = Flow X Time

Classification

• Control variable
  – Flow (volume)
  – Pressure
• Phase variable
  – Trigger, limit, cycle, baseline
• Conditional variable
  – Patient effort and time
“Control Variable”

Which parameter remains constant despite changes in pulmonary mechanics?

**Pressure Generated Breath**

- Pressure
- Flow
- Time

Phase Variables

- A. Trigger mechanism
  - What causes the breath to begin?
- B. Limit variable
  - Which parameter is sustained at a preset level during the breath?
- C. Cycle mechanism
  - What causes the breath to end?

Inspiratory Trigger Mechanism

- Time
  - Controlled Mechanical Ventilation
- Pressure
- Flow
- Chest impedance
- Abdominal movement

Cycle Mechanism

- Time
  - Conventional Neonatal ventilators
- Volume
  - Adult / Pediatric ventilators
- Pressure
  - Bird Mark series
- Flow
  - Pressure Support
  - Advanced neonatal modalities (FSV)

Cycling vs. Limiting

- Limited
- Cycled

Pressure Ventilation

Guaranteed pressure, is not affected by the changes in pulmonary mechanics

- Compliance
- Decreased Tidal Volume
- Volume
- Pressure
TCPL

- Constant inspiratory pressure
- Continuous circuit flow capability
- Directly adjustable inspiratory time
- Decelerating inspiratory flow waveform
- Easy to use, compact system
- Delivered volume is varying, based on patient’s lung mechanics

Pressure Ventilation

Constant insp. pressure
Decelerating, variable inspiratory flow rate

Time cycled: (A)
Pressure Control
Flow cycled: (B)
Pressure Support

Pressure ventilation

- There are three fundamentally different modes of ventilation:
  - "pressure ventilators",
  - "volume ventilators",
  - " high frequency ventilators ".
- They all serve to support adequate ventilation and oxygenation, but each has its own particular niche.

Ventilation

- Ventilation (CO₂ removal) is a function of minute ventilation which is respiratory rate (RR) multiplied by tidal volume (VT).

Remember:
- MINUTE VENTILATION = RATE x TIDAL VOLUME

Arterial Oxygenation

- Arterial Oxygenation improves when either the fraction of inspired oxygen concentration (FiO₂) and/or mean airway pressure (MAP) are increased.

Choose appropriate goals for ventilation and oxygenation (i.e. blood gases).
- These goals depend on the patient’s disease state:
  - healthy term infant intubated for choanal atresia -- goal pH = 7.40, PaCO₂ = 40, PaO₂ = 60.
  - small preterm infant (<1000g), to minimize lung injury due to mechanical ventilation, a strategy of mild permissive hypercapnea may be followed.
  - severe chronic lung disease gases with PaCO₂ of 60-65 torr and SaO₂ >88% may be acceptable. In contrast, a patient with persistent pulmonary hypertension of the newborn might have as a goal pH>7.45, PaCO₂<30, PaO₂>100 in an attempt to attenuate hypoxic pulmonary vasoconstriction.
### Ventilation

- **Ventilation** goals can be a range of pH values and/or a range of PaCO\(_2\) values.
- Extreme acidosis (pH<7.10) is to be avoided.
- Mild acidosis alone appears to be relatively well tolerated.
- Wide swings in PaCO\(_2\) avoided because of significant effects on cerebral blood flow.
- Treating the underlying cause of the acidosis.

- Ventilation can best be monitored using arterial blood gases.
- Capillary blood gases (and even more so venous) tend to give low values for pH (~0.05-0.1 lower depending on perfusion).
- The difference between arterial and capillary or venous pH is variable over time and between patients: BPD, infants with hydrops, and other conditions that impair transcutaneous passage of capillary gas.
- End tidal CO\(_2\) monitoring (capnography) is another valuable non-invasive method of estimating ventilation when using conventional ventilation.

### Oxygenation

- **Oxygenation** goals can either be a range of arterial oxygen saturation or PaO\(_2\) values.
- Oxygen saturation (SaO\(_2\)) best reflects arterial blood oxygen content (SaO\(_2\) x Hemoglobin x 1.34) and thus is of direct physiologic interest.
- PaO\(_2\) better reflects degree of shunt, and is more accurate than SaO\(_2\) at the lower range. Oxygenation can best be monitored by pulse oximetry or arterial blood gases. Capillary and venous blood gases are never useful measures of arterial PaO\(_2\).

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### Blood Gases

- determine your goals for pH, PaCO\(_2\), and PaO\(_2\).
- determine the type of specimen to decide if any correction for capillary or venous specimen is in order.
- evaluate the blood gas to see if any changes in inspired oxygen concentration or ventilator settings are needed.
- determin whether the gas is significantly different from previous gases and, if so, why (i.e

### Strategy

- If PaO\(_2\) is low then FiO\(_2\) or MAP need to be increased.
- If the pH is low, one should determine if the acidosis is respiratory (PaCO\(_2\) high) and/or metabolic (calculated HCO\(_3\) low).
- Increasing ventilation is merely a temporizing act until the cause of the acidosis is determined. If the pH is low and/or the PaCO\(_2\) is high, indicative of a respiratory acidosis, then ventilation needs to be increased by increasing rate and/or tidal volume - how this is accomplished again varies from ventilator to ventilator.
"Pressure Ventilators"

- The most frequently used ventilators in the NICU. Traditional "pressure ventilators" are:
  - Constant flow,
  - Time cycled,
  - Pressure limited devices.
- Constant flow: there is a constant flow of gas past the top of the endotracheal tube.
- Pressure limited: once the pre-set PIP has been reached, it is maintained for the duration of the inspiratory cycle.
- Time cycled: breaths are given at fixed intervals, independent of the infant's respiratory efforts.

Newer "pressure ventilators" can sense infants' breaths and synchronize to them.

- Trigger
  - Needs a flow sensor attached between the endotracheal tube and system tubing

There may be some added work of breathing due to the need to trigger breaths.

Advantages

- The constant flow permits the infant to easily take spontaneous breaths.
- Simple, reliable mechanical design.
- Pressure limitation prevents sudden changes in PIP as compliance changes (i.e., on a pressure ventilator if compliance falls by 50% PIP does not change - though tidal volume drops, for example ETT slipping down right mainstem).

Disadvantages

- Variable tidal volume as lung compliance changes.
- Should lung compliance worsen then Vt will drop (if the ETT plugs Vt drops to zero, but the ventilator does not sense it).
- Should compliance improve (following surfactant for example) this may result in overdistention.
- If the child is exhaling during a non-synchronized ventilator breath, then the breath is ineffective.

Adjusting ventilation/oxygenation:

- Key determinants of oxygenation (MAP) and ventilation (tidal volume) are not directly adjustable, but are derived from related parameters.
- There are interactions between the various parameters.
- Driving pressure is proportional to the difference between PIP and PEEP.

To increase ventilation

- **Increase Rate**, or **Increase PIP**, or **Increase Inspiratory Time**, or **Decrease PEEP** (rarely done)

- **MINUTE**: \( \text{VENTILATION} = \text{RATE} \times \text{TIDAL VOLUME} \)

\[
\begin{align*}
\text{Driving pres} & \quad \text{Time} \\
\text{PIP-PEEP} & \quad \text{Rez} \\
\end{align*}
\]

\[
\begin{align*}
\text{Compl} & \quad \text{const} \\
T_T & \quad T_T \\
\end{align*}
\]
To increase oxygenation:

- **Increase FiO₂**, or **Increase MAP**
- OXYGENATION is proportional to $\text{MAP} \times \text{FiO}_2$
  
$$\text{MAP} = \frac{\text{Ti} \times \text{PIP} + \text{Te} \times \text{PEEP}}{\text{Ti} + \text{Te}}$$

Ways to increase MAP

1. Increase PEEP
2. Increase PIP
3. Increase Ti
4. Increase RR
5. Increase Flow

### Ways to increase MAP

**1. Increase PEEP**

**2. Increase PIP**

**3. Increase Ti**

**4. Increase RR**

**5. Increase Flow**

**Drugs for intubation and mechanical ventilation**

<table>
<thead>
<tr>
<th>Substance</th>
<th>route</th>
<th>dose/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sedation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>midazolam</td>
<td>iv</td>
<td>0.05 mg</td>
</tr>
<tr>
<td><strong>Analgesia</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>morphine</td>
<td>iv</td>
<td>0.1 mg</td>
</tr>
<tr>
<td>fentanyl</td>
<td>iv</td>
<td>0.05 mg</td>
</tr>
<tr>
<td><strong>Curare</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vecuronium</td>
<td>iv</td>
<td>0.1 mg</td>
</tr>
<tr>
<td>suxamethonium</td>
<td>iv</td>
<td>3 mg</td>
</tr>
<tr>
<td>+ atropine</td>
<td>iv</td>
<td>0.03 mg</td>
</tr>
</tbody>
</table>

**Initial ventilator settings for pressure ventilators**

- Initial ventilator settings for pressure ventilators are typically chosen based on what types of pressures and rates were required when hand bagging.
- Parameters available to fix on a pressure ventilator:
  - PIP
  - PEEP
  - Rate
  - Ti
  - FiO2
  - Flow

**PIP**

- A useful clinical indicator of adequate PIP is gentle chest rise with every breath, which should not be much more than the chest expansion with spontaneous breathing. While absent breath sounds may indicate inadequate PIP (or a blocked and/or displaced ETT or even ventilator malfunction), the presence of breath sounds is not very helpful in determining optimal PIP. Adventitious sounds, such as crackles, often indicate disorders of lung parenchyma associated with poor compliance (requiring higher PIP), while wheezes often indicate increased resistance (affects the time constant).
<table>
<thead>
<tr>
<th>PIP</th>
<th>PIP – clinical aproaches</th>
</tr>
</thead>
</table>
| • Changes in PIP affect both \( \text{PaO}_2 \) (by altering MAP) and \( \text{PaCO}_2 \) (by its effects on tidal volume and thus, alveolar ventilation).  
• An increase in PIP improves oxygenation and decreases \( \text{PaCO}_2 \). Use of a high PIP may increase the risk of volutrauma with resultant air leaks and BPD; thus, exercise caution when using high levels of PIP.  
• The level of PIP required in an infant depends largely on the compliance of the respiratory system.  
| • A useful clinical indicator of adequate PIP is gentle chest rise with every breath, which should not be much more than the chest expansion with spontaneous breathing.  
• Absent breath sounds may indicate inadequate PIP (or a blocked and/or displaced ETT or even ventilator malfunction).  
• The presence of breath sounds is not very helpful in determining optimal PIP. Adventitious sounds, such as crackles, often indicate disorders of lung parenchyma associated with poor compliance (requiring higher PIP).  
• Wheezes often indicate increased resistance (affects the time constant). |

<table>
<thead>
<tr>
<th>PIP – clinical strategies</th>
<th>PEEP</th>
</tr>
</thead>
</table>
| • Always use the minimum effective PIP.  
• Making frequent changes in PIP in the presence of changing pulmonary mechanics, such as after the administration of surfactant in the management of RDS, may be necessary.  
• Chronic lung disease often have nonhomogeneous lung disease, leading to varying compliance of different regions of the lung and differing requirements for PIP. This partially accounts for the coexistence of atelectasis and hyperinflation in the same lung.  
| • PEEP helps to prevent alveolar collapse, maintains lung volume at end-expiration, and improves V/Q matching.  
• Increases in PEEP usually increase oxygenation associated with increases in MAP. However, in infants with RDS, a very elevated PEEP (>5-6 cm H\(_2\)O) may not improve oxygenation further and, in fact, may decrease venous return, cardiac output, and oxygen transport. |

<table>
<thead>
<tr>
<th>PEEP</th>
<th>PEEP</th>
</tr>
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</table>
| • High levels of PEEP also may decrease pulmonary perfusion by increasing pulmonary vascular resistance.  
• By reducing DP (PIP minus PEEP), an elevation of PEEP may decrease tidal volume and increase \( \text{PaCO}_2 \).  
• While both PIP and PEEP increase MAP and may improve oxygenation, they usually have opposite effects on \( \text{PaCO}_2 \).  
| • With RDS, an improvement in compliance occurs with low levels of PEEP, followed by a worsening of compliance at higher levels of PEEP (>5-6 cm H\(_2\)O).  
• A minimum PEEP of 2-3 cm H\(_2\)O is recommended, since endotracheal intubation eliminates the active maintenance of FRC accomplished by vocal cord adduction and closure of the glottis. |
Rate

• Changes in frequency alter alveolar minute ventilation and, thus, PaCO₂.
• Increases in rate and, therefore, in alveolar minute ventilation decrease PaCO₂ proportionally.
• Decreases in rate increase PaCO₂.
• Frequency changes alone (with a constant I/E ratio) usually do not alter MAP nor substantially alter PaO₂.
• Any changes in inspiratory time that accompany frequency adjustments may change the airway pressure waveform and thus alter MAP and oxygenation.

Rate

• Generally, a high-rate, low-tidal volume strategy is preferred (see below).
• However, if a very short expiratory time is employed, expiration may be incomplete. The gas trapped in the lungs can increase FRC, thus decreasing lung compliance.
• Tidal volume decreases as inspiratory time is reduced beyond a critical level depending on the time constant of the respiratory system.

Rate

• High rate, low Tv (low PIP)

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased air leaks</td>
<td>Gas trapping or inadvertent PEEP</td>
</tr>
<tr>
<td>Decreased volutrauma</td>
<td>Generalized atelectasis</td>
</tr>
<tr>
<td>Decreased cardiovascular adverse effect</td>
<td>Maldistribution of gases</td>
</tr>
<tr>
<td>Decreased risk of pulmonary edema</td>
<td>Increased resistance</td>
</tr>
</tbody>
</table>

Inspiratory and expiratory times

• An inspiratory time 3-5 times longer than the time constant of the respiratory system allows relatively complete inspiration.
• A long inspiratory time increases the risk of pneumothorax.
• Shortening inspiratory time is advantageous during weaning.
• When corrected for MAP, changes in the I/E ratio are not as effective in increasing oxygenation as are changes in PIP or PEEP.

High I/E ratio/long Ti

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased oxigenation</td>
<td>Gas trapping/inadvertent PEEP</td>
</tr>
<tr>
<td>May improve gas distribution in lungs with atelectasis</td>
<td>Increased risk of volutrauma and air leaks</td>
</tr>
<tr>
<td></td>
<td>Impaired venous return</td>
</tr>
<tr>
<td></td>
<td>Increased pulmonary vascular resistance</td>
</tr>
</tbody>
</table>

Short Ti

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster weaning</td>
<td>Insufficient tidal volume</td>
</tr>
<tr>
<td>Decreased risk for pneumothorax</td>
<td>May need high flow rates</td>
</tr>
<tr>
<td>Allows use of higher ventilator rate</td>
<td></td>
</tr>
</tbody>
</table>
FiO2

- Changes in FiO2 alter alveolar oxygen pressure and thus, oxygenation. Because FiO2 and MAP both determine oxygenation, they can be balanced as follows:
  - During increasing support, first increase FiO2 until approximately 0.6-0.7, when additional increases in MAP are warranted.
  - During weaning, first decrease FiO2 (to approximately 0.4-0.7) before reducing MAP (maintenance of an appropriate MAP may allow a substantial reduction in FiO2).
  - Reduce MAP before a very low FiO2 is reached (higher incidence of air leaks has been observed if distending pressures are not weaned earlier).

Flow

- Although not well studied in infants, changes in flow probably impact arterial blood gases minimally as long as a sufficient flow is used.
- Flows of 5-12 L/min are sufficient in most newborns, depending upon the mechanical ventilator and ETT being used.
- To maintain an adequate tidal volume, high flows are needed when inspiratory time is shortened.

Strategies to prevent lung injuries

- Studies consistently demonstrate that markers of lung injury (pulmonary edema, epithelial injury, hyaline membrane formation) are present with the use of high volumes and low pressures but not with the use of low volumes and high pressures.
- Many investigators and clinicians prefer the term volutrauma to the more classic term barotrauma.
- Oxidant injury may be another serious cause of lung injury.
- Immature and developing lungs are particularly susceptible to acquired injury.

Permissive hypercarbia (Pa CO2 60 mmHg)

- Give priority to the prevention or limitation of overventilation rather than maintenance of normal blood gases and the high alveolar ventilation that frequently is used. Respiratory acidosis and alveolar hypoventilation may be an acceptable price for the prevention of pulmonary volutrauma.
- Ventilatory strategies leading to hypocapnia during the early neonatal course resulted in an increased risk of lung (and possibly brain) injury.
- Tolerating mild hypercapnia and/or prevent hypocapnia (particularly during the first days of life), result in a reduced incidence and/or severity of lung injury.

Low tidal volumes

- Because high maximal lung volume appears to correlate best with lung injury, selection of an appropriate PIP and the FRC (or operating lung volume) are critical for the prevention of lung injury during pressure-limited ventilation.
- Relatively small tidal volumes now are recommended.
- Healthy infants: tidal volume ranges of 5-8 cc/kg.
- Infants with RDS have tidal volumes of 4-6 cc/kg.

Insufficient data are available to recommend a specific size of tidal volume in these infants.

PATHOPHYSIOLOGY-BASED VENTILATORY STRATEGIES

Respiratory distress syndrome

- Low compliance and low FRC.
- An optimal conventional ventilation strategy may include conservative indications for conventional ventilation:
  - the lowest PIP and tidal volume required.
  - modest PEEP (3-5 cm H2O).
  - permissive hypercapnia (PaCO2 45-60 mm Hg).
  - judicious use of sedation/paralysis.
  - aggressive weaning.
PATHOPHYSIOLOGY-BASED VENTILATORY STRATEGIES

Chronic lung disease
• BPD usually has heterogeneous time constants among lung areas.
• Resistance may be increased markedly.
• Frequent exacerbations may occur.
  ➡ a higher PEEP (4-6 cm H\textsubscript{2}O) often is used, and
  ➡ longer inspiratory and expiratory times with
  ➡ slow rates are preferred.
  ➡ hypercarbia with compensated respiratory acidosis
    often is tolerated to avoid lung injury secondary to
    aggressive mechanical ventilation.

Persistent pulmonary hypertension of the newborn
• primary or associated with
• aspiration syndrome,
• prolonged intrauterine hypoxia,
• congenital diaphragmatic hernia, or
• other causes.

PPHN
• Controversial strategies and varies markedly among centers.
  ➡ adjust FiO\textsubscript{2} to maintain PaO\textsubscript{2} at 80-100 mm Hg to
    minimize hypoxia-mediated pulmonary vasoconstriction;
  ➡ adjust ventilatory rates and pressures to maintain an
    arterial pH of 7.45-7.55 (sometimes combined with
    bicarbonate infusion).
  ➡ prevent extremely low PaCO\textsubscript{2} (<20 mm Hg), which
    can cause cerebral vasoconstriction and subsequent
    neurologic injury.

IMV Intermittent Mandatory Ventilation
• Intermittent breaths (fixed PIP or Vt) at a fixed rate.
• Not synchronized to patient.
• Beyond the set rate, the infant is on his/her own.
• Standard on most ventilators, but infrequently used.
• Generally good for small premature infants but
  when rates are high (>60) or large infant
  "fighting" ventilator (exhaling during ventilator's
  inspiratory cycle), the lack of synchronization
  may impair ventilation.
• Disadv: No synchronization.

INTERMITTENT MANDATORY VENTILATION (IMV)
Intermittent Mandatory Ventilation (IMV)

- Like IMV but **synchronized** (senses infant's spontaneous breaths).
- Beyond the set rate the infant is on his/her own. Since it is synchronized to the patients effort, it is the preferable mode. It will function exactly like IMV if the infant is apneic or the trigger/synchronization fails.
- Typically used in infants who can reliably trigger demand valve and those fighting a preset rate.
- Usually lower rates/pressures since at higher spontaneous rates (>60) may get inadvertent PEEP and air trapping.
- Also good for older ventilator dependent patients.
- **Adv:** Synchronized to patient effort.
- **Disadv:** None, at worst is like IMV.

Synchronous Intermittent Mandatory Ventilation

- **Synchronized IMV A/C:** Synchronized (senses infant's spontaneous breaths) but with mandatory minimum set rate, all breaths the infant takes are a full assisted ventilator breaths
- Used in more active ventilator dependent infants not aggressively being weaned.
- **Adv:** Infant can increase minute ventilation easily on demand, based on need.
- **Disadv:** When weaning can't wean rate, only PIP or VT.

Assist/Control

- **SIMV vs. Assist/Control**

AC: Assist/Control.
Pressure support volume guarantee

• Pressure limited with a set tidal volume. The pressure will stairstep up to meet the set tidal volume. There are two sets of values:
  ➢ Set (ordered)
  ➢ Measured (spontaneous).
• Set values include tidal volume (4-8 mL/kg), inspiratory time, inspiratory pressure limit (PIP), rate, and PEEP. The set values are utilized when the infant is apneic. Otherwise, the infant regulates their own PIP to meet the set tidal volume. As infant's compliance improves, the PIP needed to deliver set tidal volume decreases.

Pressure support volume guarantee

• Adv: Adjusts for compliance automatically, compensates for ETT leaks, no need to correct for tubing volume
• Cautions: Weaning mode only. If infant needs increasing support, switch to another mode on ventilator.

SIMV + VG:

• The addition of VG (volume guarantee) to SIMV allows one to control the inspiratory time. The PIP still adjusts to meet the set tidal volume, but the inspiratory time is set by the therapist.
• Adv: More supportive and more control of ventilation than with PS + VG.
• Disadv: Less control over PIP, infant is still doing most of the work of breathing.

Weaning and discontinuation of ventilatory support

• Evidence for some reversal of the underlying cause of respiratory failure
• Adequate oxygenation: PaO2/FIO2 > 150-200
• PaCO2=50-60 mmHg
• Requiring PEEP less than 5 cm H2O;
• FiO2 < 0.4 for PaO2 50-70 mmHg;
• Rate < 20/min;
• PIP< 20 cm H2O
• pH > 7.25
• Hemodynamic stability (absence of clinically important hypotension)
• Actively breathing patient

Weaning and discontinuation of ventilatory support

• Once the tube out, succion the secretions from suppiriors airwaves;
  • Put on NCPAP 5 cm H2O et rise FiO2 with 5%;
  • Before extubating premies with extremely low birth weight, consider using caffeine
« Take home messages »

Indications for intubating and ventilating a baby:
- Important retractions under functional CPAP
- PaO2<50 mmHg at FiO2 80%
- PaCO2> 65 mmHg
- Frequent apnea and bradycardia under CPAP
- Metabolic acidosis: BE<-10 mmol/l despite NaHCO3
- Particular cases: difficult transports, diaphragmatic hernia

« Take home messages »

Initial settings for conventional ventilation:
- Flow: 7 l/min
- FiO2: PaO2 = 50-70 mmHg
- Rate: begin with 20-30/min (objective PaCO2 < 65 mmHg)
- PIP: 20-25 cm H2O
- Toracic movement visible
- Ti: 0.4-0.5 sec.
- PEEP: 5 cm H2O

Drager Babylog 8000:
- This ventilator is specifically designed for infants up to 10 kilograms.
- It is capable of both volume and pressure ventilation.
- A flow sensor at the patient wye accurately measures tidal volume and senses air flow initiated by the patient allowing triggering of the ventilator cycle. The sensor is able to compensate for small ETT leaks.

Drager Babylog 8000:
- Provides the following modes: AC, SIMV, PSV (pressure support ventilation), Volume guarantee (VG), and Independent Expiratory Flow (VIVE).
- VG is often used with SIMV, PS, and AC.
- The most important and commonly used modes are SIMV, PSV, VG, and CPAP.