



Mechanical Ventilation: It Is Easier Than You Think

After every intubation, we attach the patient to a mechanical ventilator. “Setting up” the ventilator, troubleshooting, and knowing what the dials can do are things you really need to know. The instructor will take you through the key steps of understanding the mechanics of ventilation, the myriad of machines, and some of the latest strategies in mechanical ventilation.

- Review the mechanics of the machine.
- Discuss set-up and troubleshooting.
- Describe key strategies and emergency concepts in mechanical ventilation.

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FACULTY

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Mechanical Ventilator Management of Acute Respiratory Failure

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I. Course Description

- A. Recognition and management of respiratory failure is considered a vital skill for practicing emergency medicine physicians.
- B. Specific indications for ventilatory support exist in the literature and an understanding of these and the recommendations for the use of such devices is applicable to the practice of emergency medicine.

II. Objectives

Using a case presentation format, participants should be able to:

- A. Understand the etiologies and symptoms of respiratory failure.
- B. Develop a working understanding of the types of mechanical ventilation.
- C. Review clinical opportunities for the application of mechanical ventilation. Including set up and troubleshooting.
- D. Discuss the possible adverse consequences of mechanical ventilation.

III. Target Audience

The target audience is emergency medicine physicians with a basic knowledge of respiratory failure and initiation of mechanical ventilation.

IV. Respiratory Failure

CASE ONE:

A 67-year-old male with a longstanding history of COPD presents with SOB, wheezing and agitation. His respiratory rate is 38, pulse 134, blood pressure is 110/68, and his room air pulse oximetry is 85%.

What is respiratory failure?

- A. A functional disorder caused by a condition that impairs the respiratory system's ability to remove carbon dioxide *from* and deliver oxygen *to* the pulmonary capillary bed.
- B. Respiratory failure can be acute or chronic, depending on when the process develops with varying pathogenic, physiologic and therapeutic distinctions.
- C. Two main groups distinguishable by arterial blood gas analysis; *hypoxic* respiratory failure and *hypercapnic-hypoxic* respiratory failure.
- D. ***Hypoxic respiratory failure*** – results from severe arterial hypoxemia ($\text{PaO}_2 < 50$ mm Hg) that cannot be corrected by increasing the inspired oxygen concentration to $> 50\% \text{ FiO}_2$.
 - At a PaO_2 of 50 mmHg, hemoglobin is approximately 80% saturated and further reductions in PaO_2 produce marked reductions in arterial oxygen content.
 - Low PaO_2 predominantly due to significant right-to-left shunt that improves minimally with increasing FiO_2 .
 - Common etiologies include:
 - ARDS
 - Aspiration
 - Atelectasis (lobar)
 - Cardiogenic pulmonary edema
 - Lung contusion or hemorrhage
 - Pneumonia
 - Pulmonary embolus

- E. ***Hypercapnic-hypoxic respiratory failure*** – results from a reduction in alveolar ventilation.
- During hypoventilation, the PCO_2 and PaO_2 levels change in opposite directions by nearly the same amount, with no significant increase above normal in the alveolar-arterial oxygen gradient.
 - Even with a severe degree of alveolar hypoventilation, resulting in a doubling of PCO_2 , hypoxemia will not be a dominant feature in the normal lung.
 - Classically, hypercapnic-hypoxic respiratory failure is a result of the failure of the structures of the lung including central nervous system, neuromuscular disorders, and fatigue.
 - Common etiologies include:
 - Central hypoventilation
 - Drugs, poisons, toxins
 - Closed head injury
 - Acute polyneuritis
 - Myasthenia gravis
 - Spinal cord injuries
 - Hypokalemia, hypophosphatemia, hypomagnesemia
 - Obstructive sleep apnea
 - Asthma, COPD
 - Flail segment
 - Myxedema coma
- F. **Airway Protection** – not respiratory failure per se
- Loss of gag reflex
 - Risk for aspiration during lavage for toxins
 - Mechanical risks – angioedema, facial instability, mass lesions

V. Signs and Symptoms of Respiratory Failure

CASE TWO:

A 63-year-old female presents with respiratory rate of 36, heart rate 134, blood pressure 104/60, and confusion. Her oxygen saturation on 100% non-rebreather oxygen mask is 92%.

What are the signs and symptoms of respiratory failure?

- A. Not one *single* indicator for respiratory failure, but a combination of factors.
- B. Hypoxemia results in sympathetic nervous system activation and an outflow of endogenous catecholamines.
- C. Acute hypercapnia causes central nervous system depression by lowering cerebrospinal fluid pH.
- D. Symptoms of hypercapnia overlap those of hypoxia:

Hypoxemia

Tachycardia
Tachypnea
Anxiety
Confusion
Hypertension
Hypotension

Hypercapnia

Somnolence
Lethargy
Restlessness
Slurred speech
Tremor
Coma

- E. Signs of impending respiratory failure;
 - Respiratory rate > 35 breaths per minute
 - $\text{PaO}_2 < 55 \text{ mmHg}$ on $\text{FiO}_2 > 50\%$
 - Hemodynamic instability
 - Paradoxical respiratory efforts
 - Mental status deterioration
 - Rising $\text{PCO}_2 > 55 \text{ mmHg}$ with respiratory acidosis

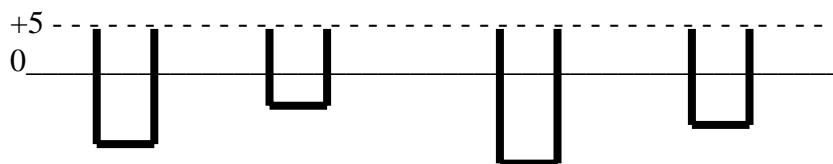
- F. Comorbid conditions may play a major role in limiting cardiopulmonary reserve.
- G. Drugs associated with potential adverse effects in respiratory failure include:
 - Beta-blockers
 - Narcotics
 - Sedative-hypnotics
 - Nitrates

VI. Invasive Mechanical Ventilation

- A. Volume cycled
- B. Pressure cycled
- C. Combined Pressure and Volume cycled

VII. Modes of Invasive Mechanical Ventilation

- A. **CPAP** – continuous positive airway pressure, no mandatory ventilation, or tidal volume. Equivalent to PEEP. A preset level of airway pressure that is delivered in a static fashion during inspiration and expiration. May be used in conjunction with pressure support as a weaning tool or trial. Patient must be alert and requiring minimal support.

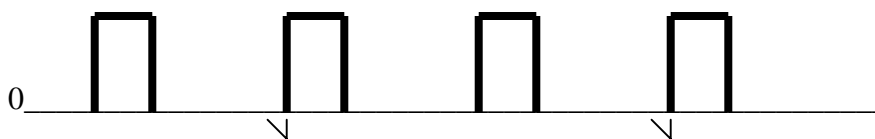


- B. **Control** – a volume cycled mode whereby every breath is machine initiated and dictated, including rate and tidal

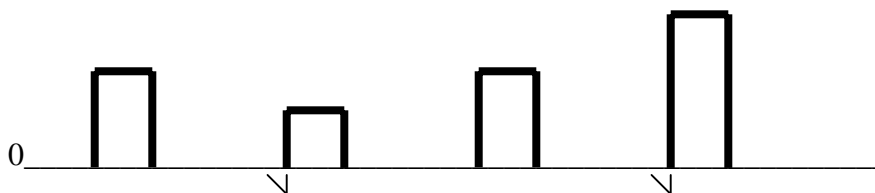
volume. There is no utility outside of the operating room setting on paralyzed patients.



- C. **Assist Control** – volume cycled mode with a preset tidal volume and rate. If the patient can generate sufficient negative inspiratory force, there will be delivery of additional tidal volume breaths of the identical preset volume. The patient can dictate their own rate, but not tidal volume. The mode of choice for respiratory failure, but cautious use in reactive airways disease due to dynamic hyperinflation-“breath stacking”.

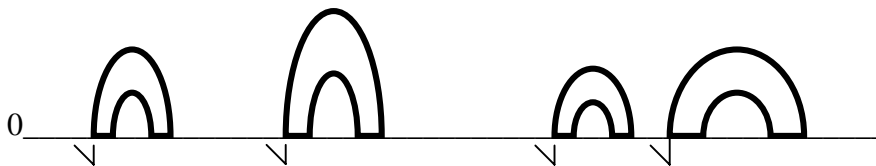


- D. **SIMV** – synchronized, intermittent mandatory ventilation; a volume cycled mode with a preset tidal volume and rate synchronized to the patients respiratory efforts. If the patient can generate sufficient negative inspiratory force, there will be delivery of a variable tidal volume based on patient effort. This tidal volume may be greater or less than the preset tidal volume. The patient can dictate their own additional breaths and tidal volumes over the preset values.



- E. **Pressure Support** – a pressure cycled mode with a preset pressure boost or pressure limit. If the patient generates a

sufficient negative inspiratory effort, a pressure boost will deliver a variable tidal volume based on lung, chest wall and ventilator system compliance and patient effort. Requires a spontaneously breathing patient. Caution in those patients with reactive airways disease due to increased incidence of dynamic hyperinflation.



- F. ***SIMV with Pressure Support*** – Combination of the above two modes. For additional breaths above preset rate (SIMV rate), pressure augmented boost (Pressure Support) is delivered when the patient generates a negative inspiratory effort. Offers the benefits of pressure support with the assurance of having a backup rate.



VIII. Set Up for Invasive Mechanical Ventilation

“What knobs do I need to know, and where do I set them???”

- A. ***Respiratory Rate*** – must be set with consideration for tidal volume as the product of these two result in minute ventilation (VE). A minute ventilation of 10 L approximates normocapnia PCO_2 40 mm Hg in a 70 kg person. Typically, rates are set between 10-20 bpm with caution in reactive airways disease.
- B. ***Tidal Volume*** – current recommendations are 8-10 cc/kg

ideal body weight. This volume factors directly into minute ventilation = $RR \times TV$. Reduced in reactive airways disease, 6-8 cc/kg.

- C. **Positive End Expiratory Pressure (PEEP)** – a constant, minimal alveolar distending pressure delivered by the ventilator. PEEP increases residual volume and total lung volumes and may improve oxygenation based on lung compliance. A level of 5 cm H₂O is deemed physiologic by some and unnecessary by others. Such a level in adults is not harmful, but of no reported benefit. PEEP. High levels of PEEP can limit venous return and cardiac output and may injure the lung.
- D. **Peak Flow** – the speed of delivery of the tidal volume breath in L/min. Typically set at 60-80 L/min. Consider increasing to 80-120+ in cases of reactive airways disease.
- E. **Sensitivity** – The ventilator's ability to sense the patient's inspiratory efforts. Measured in negative pressure cm H₂O and typically set at the highest sensitivity about -2 cm H₂O to reduce the patient's work of breathing. The more negative the pressure setting, the greater the work of breathing for a spontaneously generated breath.
- F. **Pressure Manometer** – A pressure gauge or digital recording that is read as positive pressure cm H₂O.
- **Peak Inspiratory Pressure (PIP)** – the highest inflection point reached during delivery of a breath. A product of compliance of the ventilator system, endotracheal tube, lungs and chest wall. This number or pressure measurement has no predictive value regarding the risk for baro/volutrauma.
 - **Plateau Pressure**-if an inspiratory pause is placed at end inspiration (directly after the delivery of a mechanical breath) the needle will rise to the PIP and come to rest at the- plateau pressure. This reflects the pressure at the alveolus and correlates well with the risk for baro/volutrauma. Values > 35 cm H₂O place the patient at significant risk for acute lung injury and baro/volutrauma. The inspiratory pause should be removed *immediately* after measurement of the plateau

pressure to prevent breath stacking.

IX. Most common types of noninvasive mechanical ventilation

- A. ***Continuous positive airway pressure (CPAP)*** – delivery of a static airway pressure that is maintained throughout the inspiratory and expiratory cycle. Equivalent to PEEP.
- Recruits alveoli to gas exchange and improves pulmonary compliance
 - Reduces inspiratory threshold pressures – the force needed to establish airflow.
 - Increases functional residual capacity
 - Reduces venous return
 - May positively or negatively effect cardiac output depending on the pathological state
- B. ***Bilevel positive airway pressure (BiPAP)*** – delivers inspiratory pressure support, coupled with continuous positive airway pressure. Permits a differential support of inspiratory and expiratory efforts with one machine.
- Inspiratory, pressure support component increases tidal volume and positively effects work of breathing.
 - Inspiratory component requires patient effort for activation.

XI. Requirements for and contraindications to noninvasive mechanical ventilation

- A. Requirements include:
- Cooperative patient
 - Spontaneously breathing patient
 - FiO_2 requirements < 50%
 - Availability of equipment

B. Contraindications

- Rapid deterioration
- Decreased mental status
- Aspiration risks
- Facial instability
- Need for a definitive airway
- Excess secretions

XIV. Specific indications for mechanical ventilation

CASE THREE:

A 38 year old male Presents with a history of MVC, sustaining a closed head injury. His presenting GCS was a 12 and during your secondary survey you note a decrease in responsiveness and a reduction in his GCS to 8, a dilated right pupil and paralysis of his left side. Quickly he is intubated and you are required to give mechanical ventilator settings.....

What are the recommendations for initial mechanical ventilator settings in a severely head injured patient?

A. Recommendations for the severely head injured patient with progressive deterioration of GCS, or evidence of frank herniation.

- Assist Control mode
- Respiratory rate of 20-24 bpm
- Tidal Volume 10 cc/kg
- Peak flow 60n L/min, FiO₂ 100%
- Maintain PCO₂ between 32-28 cm H₂O
- Temporary measure only to limit blood flow to the brain in hopes of reducing ICP; renal compensation within 12 hours.
- Hyperventilation in Tricyclic Antidepressant Overdoses – similar settings with goal of alkalotic pH @ 7.45-7.50.

CASE FOUR:

A 52 year-old male presents somnolent with a depressed mental status following the ingestion of a fifth of whiskey and a full prescription of Valium. He presented with a respiratory rate of 4 and no gag reflex.

What are the recommendations for initial mechanical ventilator settings in an intoxicated patient with depressed respiratory drive?

A. Standard mechanical ventilator settings

- Assist control mode
- Respiratory rate 12-20 bpm.
- Tidal volume 8-10 cc/kg ideal body weight
- PEEP 5 cm
- Peak flow 60 L/min
- FiO₂ 100%

B. Aspiration risks remain in intubated patients

- Depressed mental status
- Lavage and charcoal
- Supine positioning

CASE FIVE:

A 23 year old female with a history of asthma presents with acute onset of shortness of breath. Her respiratory rate is 34 and she has an initial peak expiratory flow rate of 100. Despite continuous aerosol therapy, steroids, oxygen, and magnesium her clinical exam and PEFR is unchanged. She is now anxious and confused.

What are the recommendations for mechanical ventilator settings in acute asthma exacerbations?

A. Mechanical ventilator settings in severe reactive airways disease – “*permissive hypercapnea*”

- Heavy sedation, consideration of paralysis
- Prolongation of the Inspiratory/Expiratory I/E ratio by:
 - Reduced respiratory rate 8-10 bpm
 - Reduced tidal volume 6-8 cc/kg ideal body weight
 - Increased peak flow 100-120 L/min
- Permit PCO₂ to slowly rise to levels < 90 mm Hg

- Maintain pH > 7.25
- FiO₂ 100%

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