Ventilation Assist Control

Andres L. Mora Carpio; Jorge I. Mora[1].

[1] University of Pennsylvania

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Introduction

Mechanical ventilation is a lifesaving procedure that is often performed when patients require respiratory support. Assist-Control (AC) mode is one of the most common methods of mechanical ventilation in the intensive care unit.

AC ventilation is a volume-cycled mode of ventilation. It works by setting a fixed tidal Volume (VT) that the ventilator will deliver at set intervals of time or when the patient initiates a breath. The VT delivered by the ventilator in AC always will be the same regardless of compliance, peak, or plateau pressures in the lungs.

When AC mode is selected in the ventilator, four parameters may be quickly modified:

Tidal Volume (VT): This is the set amount of volume that will be delivered with each breath. Changing the VT will, in turn, change the minute ventilation (VT x RR); an increase in minute ventilation will result in a decrease in carbon dioxide (CO2), by the same token a decreased VT will result in a decreased minute ventilation and increase in the patient's blood CO2.

Respiratory Rate (RR): This is the set rate for delivering breaths per minute (bpm). For example, if the set rate is 15 then the delivery is 15 bpm or 1 breath every 4 seconds. This is called time-triggered control. In AC, this set rate can be overturned by the patient, meaning that, if the patient inhales, the ventilator will sense the drop in pressure and deliver that breath, even if the patient is breathing above the set rate. For example, if a patient is breathing at 20 bpm and the ventilator is set at 15 bpm, the ventilator will follow the patient and deliver 20 bpm (one each time the patient initiates a breath). This is called patient-triggered breaths. The ventilator will only deliver breaths at the set RR if the patient does not trigger it faster. As with VT, increasing RR will increase minute ventilation and decrease the patient's blood CO2. A caveat on this is that by increasing the RR, the dead space is also increased, so increasing RR may not be as effective as increasing VT in improving ventilation.

The ventilator in AC mode is programmed to sense changes in the system pressure when a patient initiates a breath. When the diaphragm contracts, the intrathoracic pressure becomes more negative. The negative pressure is transmitted to the airways and then to the ventilator tubing, where sensors detect the change in pressure and deliver a breath to the set tidal volume. The amount of negative pressure needed to trigger a breath is called the trigger sensitivity and is usually set up by the respiratory therapist.

The Fraction of Inspired Oxygen (FiO2): This is the percentage of oxygen in the air mix that is delivered by the ventilator during each respiratory cycle. Increasing the FiO2 will increase the patient's oxygen saturation.

Positive End Expiratory Pressure (PEEP): The positive pressure that will remain in the system at the end of the respiratory cycle (end of expiration) is the PEEP. As with FiO2, PEEP can be used to increase oxygenation. By Henry's law, we know that the solubility of a gas in a liquid is directly proportional to the pressure of that gas above the surface of the solution. This applies to mechanical ventilation in that increasing PEEP will increase the pressure in the system. This increases the solubility of oxygen and its ability to cross the alveolocapillary membrane and increase the oxygen content in the blood. PEEP also can be used to improve ventilation-perfusion mismatches by opening or "splinting" airways to improve ventilation throughout the system.

Apart from these four main parameters, the way the ventilation is delivered also can be adjusted. For every setting, regardless of the rate and volume, the breath will always be delivered to the patient in the same way. The ventilator allows flow change; the flow may be constant through the inhalation (square waveform) or decelerating as the breath is delivered (ramp waveform).

1. **Square waveform** will allow for a faster delivery of the inspiration, decreasing the inspiratory time and increasing the expiratory time. This can be useful for patients with asthma or COPD or in cases of increased RR to prevent auto-PEEP & allow for enough time for exhaling.
2. **Ramp waveform** will decrease the flow as the delivered volume increases. This usually is more comfortable for the patient and allows for a **better volume distribution and equalization** in patients with heterogeneous lung such as with **ARDS**.

The speed at which this flow is delivered also can be controlled by setting inspiratory and expiratory times. This can be adjusted for patient comfort or to prevent auto-PEEP.

After the inspiration is finished, the expiratory valve of the ventilator opens and the air is allowed to come out until the pressure in the system reaches PEEP. (figure 1)

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Function

AC mode is an excellent method to assure good ventilation. It is frequently used in cases of metabolic or respiratory acidosis.

AC was the mode used in the landmark study "Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome" from where the ARDSNET protocol came to be. For this reason, it is the only proven mode with survival benefit in ARDS patients and should be the mode of choice to use as it allows for the operator to administer low tidal volumes and adjust PEEP as necessary.

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Issues of Concern

An important concept to understand in AC mode is that, because the system is volume-cycled and a set volume will always be delivered, the pressure that will be generated in the system will be determined by lung compliance. A very compliant lung will generate low plateau pressures, while a stiff lung does not distend well with the set volume and will generate a much higher pressure (i.e., patients with pulmonary edema, ARDS, pneumonia, or pulmonary fibrosis). It is important to understand this to prevent ventilator-induced lung injury or barotrauma. Peak pressure in the system is usually determined by airway resistance and not by compliance, while plateau pressure or the pressure in the system at the end of inspiration is determined by compliance and volume delivered.

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Clinical Significance

Advantages of AC mode:

- Increased patient comfort through the ability to trigger breaths as needed.
- Operator-managed patient CO_2 levels allow easy corrections for respiratory acidosis/alkalosis.
- Low work breathing for the patient.

Disadvantages of AC mode:

- The system is volume-cycled, and barotrauma is a concern in stiff lungs. Routinely following plateau pressures should help prevent this.
- If a patient is tachypneic or if not enough time is allowed for exhaling, the patient can develop breath stacking and auto-PEEP. In this process, not all volume is exhaled in every breath which increases the amount of air in patient's lung and the plateau and intrathoracic pressure. This can lead to hypotension due to diminished venous return. Disconnecting the patient from the ventilator to allow enough time for complete exhalation and then readjusting the settings is a solution.
- Since the patient can initiate breaths, hyperventilation can lead to respiratory alkalosis. This may be solved by assuring good sedation.

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Other Issues

New ventilator modes are designed to improve some of the shortfalls of AC:

- **NAVA (neurally adjusted ventilator assist):** In this mode, sensors in the diaphragm measure the timing and intensity of the patient's respiratory effort and couple it with the timing and intensity of the ventilator assist thereby preventing barotrauma and ensuring ventilator demand fulfillment.
- **ASV (Adaptive support ventilation):** This mode automatically adapts inspiratory pressure and respiratory rate with minimum work on the part of the patient to assure a target minute ventilation is reached.
- **APRV (Airwar pressure release ventilation):** This pressure-cycled mode of ventilation delivers a continuous set pressure for a set amount of time and then "releases," giving time for the lung to deflate for a shorter period. In theory, this maintains alveoli inflation to prevent alveolar damage. This mode sometimes is used in patients where AC cannot be effectively & safely continued due to persistently elevated plateau pressures and continuously poor oxygenation.

These and other methods currently are being studied as alternative modes of mechanical ventilation, but ***none have shown clear superiority over the others***.

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Questions

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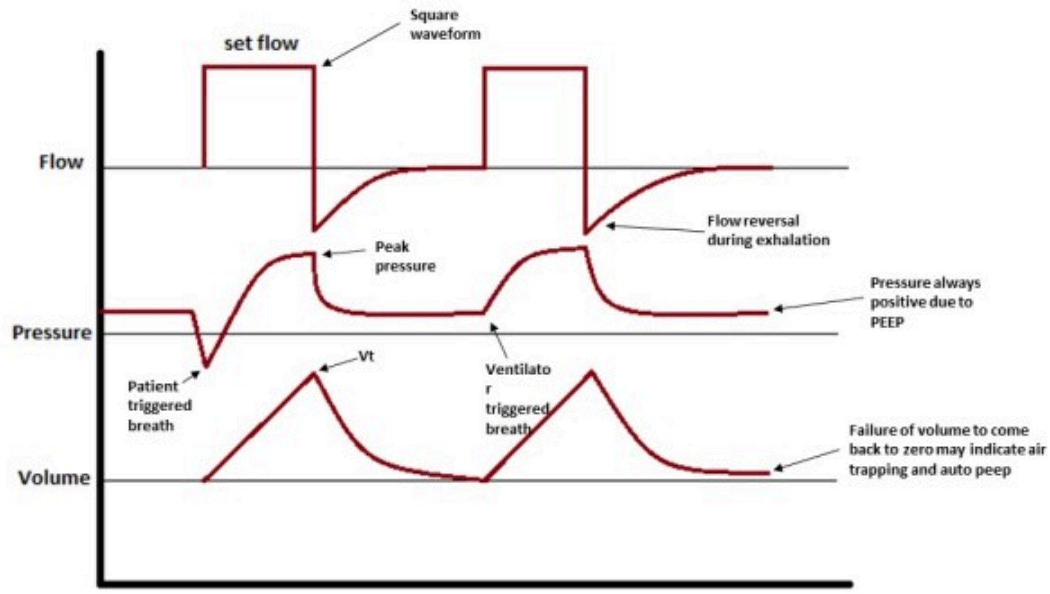
Figure



Assist control (AC) ventilation. Contributed by Andres Mora, MD

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A 43-year-old male with a history of hypertension and chronic kidney disease stage 5 was admitted to the intensive care unit for sepsis from urinary source. He is placed on volume cycled assist control ventilation with an initial tidal volume of 500 and respiratory rate of 12. On day two after admission, he is found to be over breathing the vent to 25 bpm. Which of the following complications is most likely to occur in patients who become tachypneic while on volume-cycled assist control ventilation?

- Hypercapnia
- Dynamic hyperinflation (auto-PEEP) ***
- Respiratory acidosis
- Ventilator induced lung injury (VILI)

A 35-year-old male is admitted to the intensive care unit after being found down with a needle in his arm. On arrival to the hospital, the patient was given naloxone with no response, and he needed to be intubated for airway protection. In the first 24 hours, the patient was febrile to greater than 38.5 C twice, and blood cultures were drawn that now are growing Methicillin-resistant Staphylococcus aureus (MRSA). The patient is started on appropriate antibiotic therapy but in his third day of hospitalization starts to develop hypoxic respiratory failure requiring placement on 100% oxygen. Vital signs show blood pressure of 80/55 mm, oxygen saturation of 88%, temperature of 39.4 C, heart rate of 120 bpm, and respiratory rate of 28/min. Chest x-ray shows bilateral lung whiteout. What is the best mechanical ventilation strategy for this patient?

- Volume cycled assist control with tidal volume of 6 to 10 ml/kg of ideal body weight
- Volume cycled assist control with tidal volume of 6 to 8 ml/kg of ideal body weight ***
- Volume cycled assist control with tidal volume of 6 to 8 ml/kg patients actual body weight
- Synchronized intermittent mandatory ventilation

A 21-year-old male with a past medical history of severe asthma, anxiety, and obesity presents to the emergency department with acute onset dyspnea. A review of the medical records shows that he has been hospitalized four times in the last year and required intubation once when he was 18 years of age. On the initial exam, he was found to be tachypneic with a respiratory rate of 34, diaphoretic, and using accessory muscles for respiration. An arterial blood gas (ABG) done in the

emergency department showed a pH of 7.35, PCO2 45, and PaO2 92 on room air. He was intubated and paralyzed due to difficulty syncing with the event. He was placed on AC mode ventilation with a tidal volume of 8cc/kg, respiratory rate 23, PEEP of 5, and FiO2 40%. A repeat ABG shows a pH of 7.19, PCO2 60, and PaO2 109. Apart from adjusting tidal volume and respiratory rate, what else can be done to improve his ventilation?

- Increase inspiration time
- Increase FiO2
- Increase PEEP
- Square the flow curve (increase inspiratory flow) ***

A 50-year-old male with a history of chronic obstructive pulmonary disease (COPD) was admitted for acute hypercapnic and hypoxic respiratory failure secondary to COPD exacerbation. He developed severe acidosis from hypercapnia and required immediate intubation and admission to the intensive care unit. On the second day of hospitalization, he was improving, and plans were made to start a weaning trial the next morning. Overnight the ventilator starts sounding alarms. When the clinician arrives, he sees that the ventilator shows a peak pressure of 58 and a plateau pressure of 26. A physical exam reveals bilateral breath sounds and good air movement. There is no engorgement of the jugular veins, and the blood pressure is within normal limits. What are the most likely diagnosis and the next step in management?

- Acute mucous plugging or kink in the airway; suction the patient and assess airway ***** resistance issue; PIP – Pplat > 10
- Worsening COPD; give a pulse dose of corticosteroids and start continuous nebulizer treatment
- Tension pneumothorax; place a needle in the second intercostal space followed by a chest tube
- Air trapping secondary to auto-PEEP; adjust the I:E (inspiratory:expiratory) ratio

80 yo male with the diagnosis of coronary artery disease, hypertension, chronic obstructive pulmonary disease is admitted to the intensive care unit for acute on chronic hypercapnic respiratory failure. On arrival to the emergency department, the patient was found to be acidotic. He was started on BiPAP, but his mental status deteriorated to the point where he was not responding and required intubation. Which of the following ventilation modes will be the most appropriate to use for this patient?

- Pressure support ventilation
- High frequency oscillatory ventilation (HFOV)
- Volume-cycled assist control ventilation (AC)
- Airway pressure release ventilation (APRV) *****

APRV may be used safely in patients with ALI/ARDS, and decreases the need for paralysis and sedation as compared with PCV-inverse ratio ventilation (IRV). APRV increases cardiac performance, with decreased pressor use and decreased airway pressure, in patients with ALI/ARDS.

APRV is essentially a high-level continuous positive airway pressure (CPAP) mode that is terminated for a very brief period of time. It is this short release period that allows carbon dioxide to be cleared. The lengthy time during which the high-level CPAP is present results in substantial recruitment of alveoli of markedly different regional time constants, at rather low gas flow rates and lower airway pressures. The establishment of intrinsic PEEP by the short release time enhances oxygenation. Carbon dioxide clearance is aided by recruitment of the patient's lung at close to total lung capacity; elastic recoil creates large volume gas flow during the release period.

This mode is fundamentally different from cyclic ventilation. It allows the patient to breathe spontaneously during all of the phases of the cycle. Given the spontaneous nature of the mode, it is hypothesized that there should be no need for continuous infusions of neuromuscular blocking agents in patients placed on this mode of ventilation.
This may result in a shorter duration of intensive care unit (ICU) stay and a reduced incidence of prolonged neuromuscular blockade syndrome. Furthermore, because patients may be ventilated at lower airway pressures than are required with cyclic ventilation, there may be a reduced need for pressor support of hemodynamics to ensure oxygen delivery.