

Modes of Invasive Ventilation

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Definition and Classification

Definition

Mode refers to the characteristics of mechanical ventilation which mainly include trigger (how inspiration begins), cycle (how inspiration ends), and limit (when inspiration should be aborted). The most commonly used modes are assist control ventilation (ACV), especially for initiating ventilation, and synchronized intermittent mandatory ventilation (SIMV) with pressure support, especially for maintaining patients on and weaning them off ventilation.

Ventilator mode is described based on 3 characteristics: trigger, cycle, and limit.

- **Trigger:** The type of signal that initiates the inspiratory phase by the ventilator.
 - Patient-triggered: patient's inspiratory effort triggers the inspiratory phase by the ventilator.
 - Time-triggered: a time interval set by the operator determines when the ventilator initiates an inspiratory phase.
- **Cycle:** The type of signal that ends the inspiratory phase delivered by the

ventilator.

- Volume-cycled ventilation: the inspiratory phase ends once a preset volume exits the ventilator.
- Other types include time-cycled ventilation and pressure-cycled ventilation.
- **Limit:** A value (e.g., pressure) that should not be exceeded and which is specified by the operator to protect the lung.

Classification (common modes)

- **Controlled:** Commonly used in critically ill patients with a significantly suppressed or absent respiratory drive. All spontaneous patient breaths sensed by the ventilator are assisted with a preset volume (or less commonly preset pressure) specified by the operator. These modes are patient-/time-triggered and volume-/pressure-cycled.
 - Assist-control ventilation (ACV), also known as volume-control (VC) ventilation (VCV): more commonly used
 - Pressure-control (PC) ventilation (PCV)
- **Spontaneous/Supported:** Used after significant improvement of the critical state in patients who are able to breathe spontaneously and are being considered for weaning. These modes are patient-triggered and flow-cycled.
 - Pressure support (PS): all spontaneous patient breaths sensed by the ventilator are supported with a preset pressure specified by the operator.
 - Continuous positive airway pressure (CPAP) \pm PS: ventilator provides a continuous circuit pressure \pm PS
- **Combined** (controlled + spontaneous/supported): commonly used in patients for maintenance on ventilation and weaning. A preset number (not all) of patient breaths are assisted by the ventilator, as described for controlled + remaining spontaneous patient breaths are supported as described for the spontaneous/supported mode PS.
 - Synchronized intermittent mandatory ventilation (SIMV)-VC + PS: more commonly used
 - SIMV-PC + PS

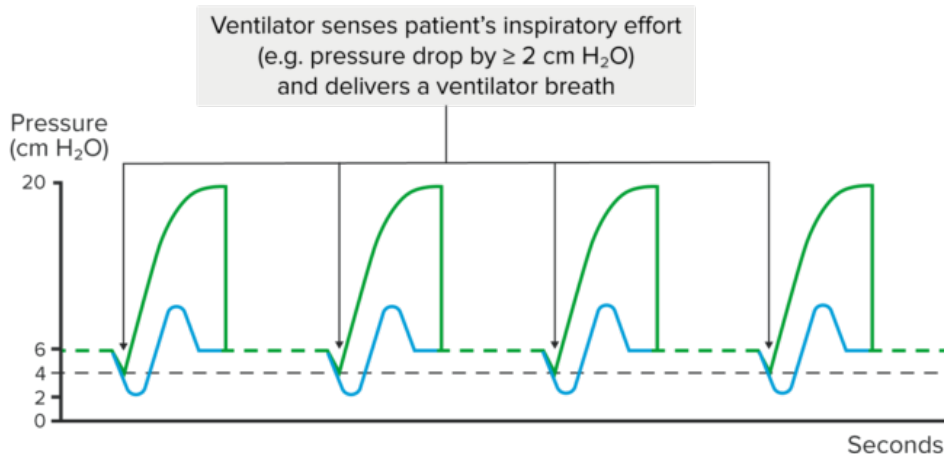
Common Modes

ACV (VCV)

- Most commonly used initial mode of ventilation because it assists every sensed inspiratory effort made by the patient and reduces work of breathing.
- Trigger:
 - Time-triggered if patient's inspiratory effort is not sensed: ventilator delivers a preset number of mandatory breaths per minute.
 - Patient-triggered if patient's inspiratory effort is sensed: ALL inspiratory efforts are assisted by the ventilator. (Image 1)
- Volume-cycled:
 - Inspiratory phase ends when a preset volume exits the ventilator.
 - Inspiratory volume is an independent variable because it is set by the operator and does not vary between breaths
 - Inspiratory pressure is a dependent variable because it is not set by

the operator and varies between breaths

- Pressure-limited: preset by the ventilator to abort the inspiratory phase if dangerous levels of airway pressure are reached.
- Example:
 - An intubated patient has 20 spontaneous breaths/min. All breaths are efficient enough to be sensed by the ventilator. On the ACV mode, all 20 breaths are assisted by the ventilator immediately after initiation by the patient. So the ventilator frequency is 20/min. If the patient's spontaneous breaths (respiratory rate) increases to 30/min, the ventilator frequency becomes 30/min.
 - An intubated patient has 4 spontaneous breaths per minute while the ventilator is set to 12 breaths per minute. On the ACV mode, the ventilator assists the patient's 4 breaths and adds 8 more breaths/min to reach the minimum number set by the operator. If the patient's spontaneous breaths equal or exceed the minimum number of 12/min, the ventilator assists all patient breaths without adding any further breaths.
- Problems:
 - Respiratory alkalemia: in patients with tachypnea, especially due to anxiety, pain, or airway irritation
 - Auto-positive end-expiratory pressure (auto-PEEP): dynamic hyperinflation of lungs when air builds up due to insufficient expiratory time; this limits venous return, decreases cardiac output, and predisposes to barotrauma.



Assist control ventilation (ACV)

Ventilator breaths do not occur at regular intervals and are triggered by patient breaths (all patient breaths are assisted)

Image 1, by Lecturio.

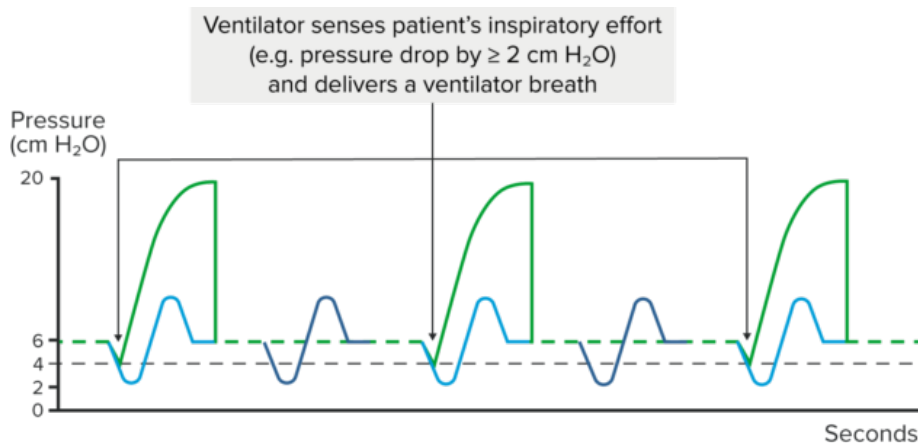
PCV

- Less commonly used
- Appropriate when control of peak airway pressures is important such as in patients with previous barotrauma or after thoracic surgery
- Time-triggered, time-cycled, and pressure-limited
- Inspiratory pressure is an independent variable because it is set by the operator and does not vary between breaths.

- Inspiratory volume is a dependent variable because it is not set by the operator and varies between breaths

SIMV-VC

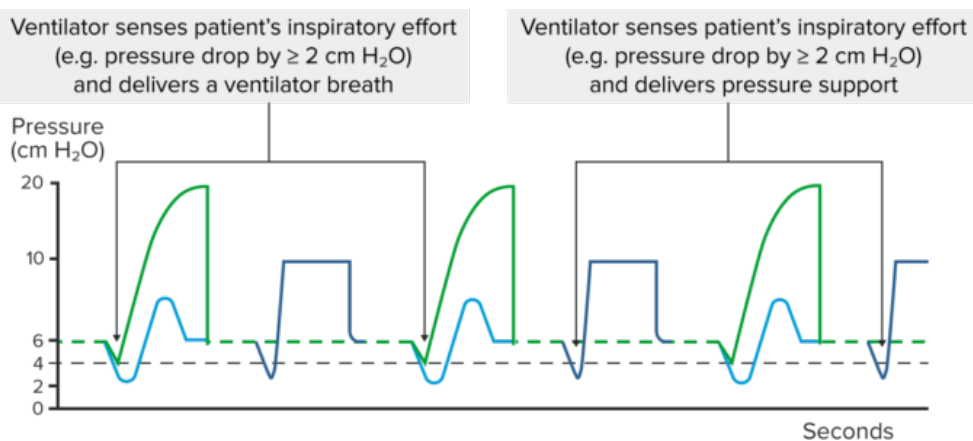
- More commonly used than SIMV-PC
- Appropriate mode for both supporting and weaning patients off the ventilator: allows the patient to practice unassisted breathing between assisted synchronized mandatory breaths. (Image 2)
- Trigger:
 - Patient-triggered if patient's inspiratory effort is sensed: *SOME* (i.e. intermittent) of the sensed inspiratory efforts are assisted by the ventilator
 - Number of assisted breaths per minute is determined by the operator.
 - Other patient breaths remain unassisted.
 - Time-triggered if patient's inspiratory effort is not sensed: Ventilator delivers a preset number of mandatory breaths per minute.
- Volume-cycled:
 - Inspiratory phase ends when a preset volume exits the ventilator.
 - Inspiratory volume is an independent variable because it is set by the operator and does not vary between breaths.
 - Inspiratory pressure is a dependent variable because it is not set by the operator and varies between breaths.
- Pressure-limited: preset by the ventilator to abort the inspiratory phase if dangerous levels of airway pressure are reached.
- Example: A patient has 20 spontaneous breaths while intubated, and the ventilator frequency is set to 12 breaths per minute:
 - On the SIMV mode, the ventilator delivers each of the 12 mandatory breaths in a synchronized fashion when the patient initiates a spontaneous breath. Therefore, out of the patient's total 20 spontaneous breaths per minute, 12 are assisted by the ventilator and 8 remain unassisted. The total number of breaths remains 20/min.
 - On the IMV mode, the respirator delivers 12 mandatory breaths per minute unsynchronized with the patient's 20 spontaneous breaths. Some mandatory breaths fall on the patient's spontaneous breaths and others fall in between. Therefore, the total number of breaths is close to the sum of mandatory and spontaneous breaths (i.e. 20-32/min).
- Problem:
 - Reduced minute ventilation: When tachypneic, patient exhales during ventilator inspiratory phase \Rightarrow rapid rise in airway pressure beyond the pressure limits set by the operator \Rightarrow abortion of ventilator breath. A switch to ACV mode would increase the number of assisted breaths and minute ventilation.
- SIMV is usually delivered in combination with PS to support unassisted breaths with a preset pressure (Image 3).



Synchronized intermittent mandatory ventilation (SIMV)

Ventilator breaths occur at regular intervals but are triggered by patient breaths (only some patient breaths are assisted)

Image 2, by Lecturio.



Synchronized intermittent mandatory ventilation (SIMV) + pressure support (PS)

Ventilator breaths occur at regular intervals but are triggered by patient breaths (only some patient breaths are assisted) + unassisted breaths are supported by pressure

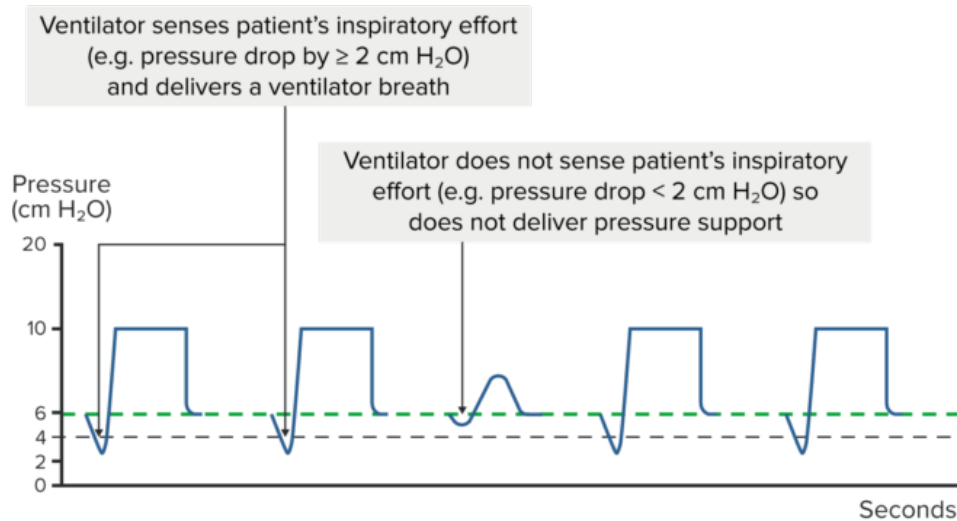
Image 3, by Lecturio.

SIMV-PC

- Less commonly used than SIMV-VC
- Similar to PCV:
 - Appropriate when control of peak airway pressures is important such as in patients with previous barotrauma or after thoracic surgery
 - Inspiratory pressure is an independent variable.
 - Inspiratory volume is a dependent variable.
- Different from PCV:
 - Allows spontaneous breathing without assistance

PS

- Commonly used in combination with SIMV to ensure volume-cycled backup
- Patient-triggered, flow-cycled, pressure-limited
- Operator sets the pressure that must be reached during each ventilator inspiratory phase.
- PS is always patient-triggered: ALL sensed inspiratory efforts are supported by the pressure set by the operator. (Image 4)
- Once flow in the airway reaches a level below a minimum threshold the pressure support is terminated.



Pressure support (PS)

All sensed patient breaths are supported by pressure

Image 4, by Lecturio.

CPAP

- Commonly used to assess the potential for extubation in patients who require little support for ventilation
- Provides constant circuit pressure specified by the operator throughout ventilation
- Commonly used in combination with PS

References

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