Chapter 3
Basic Modes of Ventilation

Each mode of ventilation is defined by its phase variable components: trigger, target, and cycle. These phase variables are explained in detail in Chap. 2. The three basic modes of ventilation include **volume-controlled ventilation (VCV), pressure-controlled ventilation (PCV),** and **pressure support ventilation (PSV)**.

Volume-Controlled Ventilation

The trigger variable for VCV is assist-control, a hybrid between a patient trigger and a ventilator trigger. The patient-triggered (assist) component of the trigger can utilize either a pressure or flow trigger. The ventilator-triggered (control) component of the trigger is set by selecting the respiratory rate, which dictates the time between control breaths (rate = 1/time).

The target variable is flow. Both the flow rate and the flow waveform pattern are selected on the ventilator. The most commonly used flow waveform patterns are the constant flow and the decelerating ramp.

The cycle variable is volume. Tidal volume is selected on the ventilator. Because flow is set, setting tidal volume will also determine inspiratory time (time = volume/flow);

H. Poor, *Basics of Mechanical Ventilation*,
https://doi.org/10.1007/978-3-319-89981-7_3

therefore, inspiratory time cannot be altered by patient respiratory effort or by changes in the respiratory system.

In summary, VCV is a flow-targeted, volume-cycled mode of ventilation in which the ventilator delivers a set flow waveform pattern to achieve a set tidal volume. The pressure waveform will vary depending on characteristics of the respiratory system and patient respiratory effort (Fig. 3.1 and Table 3.1).

Key Concept #1
VCV = **flow**-targeted, **volume**-cycled

Pressure-Controlled Ventilation

The trigger variable for PCV is assist-control, exactly the same as VCV. The target variable is pressure. Proximal airway pressure is selected on the ventilator. Flow is delivered by the ventilator to quickly achieve and maintain the set proximal airway pressure. As described in Chap. 2, a constant airway pressure during inspiration produces a decelerating ramp flow waveform.

The cycle variable is time. The inspiratory time is selected on the ventilator. Inspiration will end after the set inspiratory time has elapsed. Similar to VCV, inspiratory time cannot be altered by patient respiratory effort or by changes in the respiratory system.

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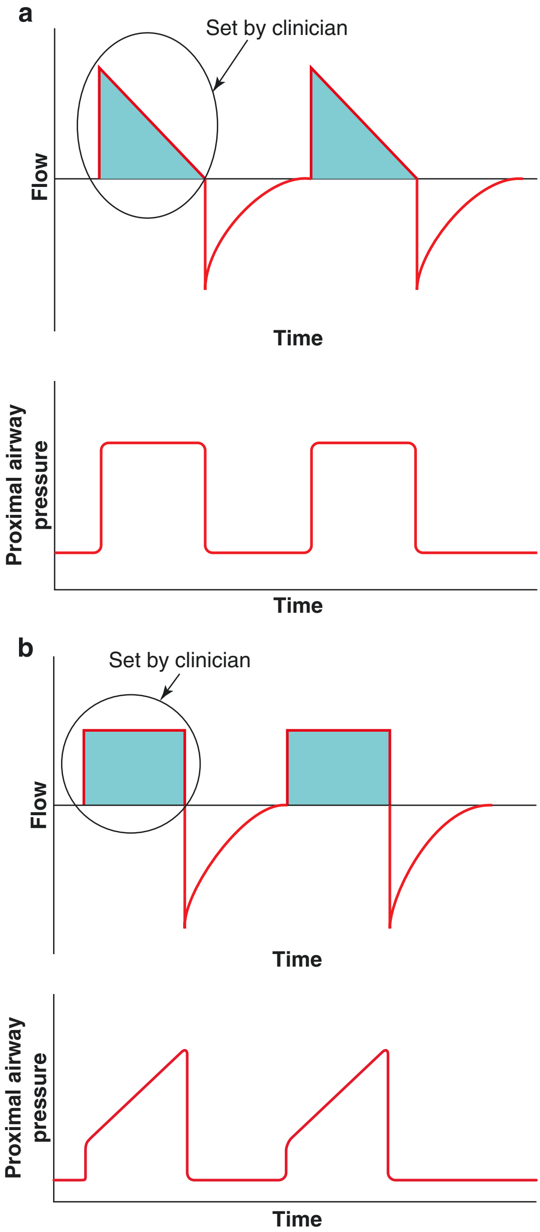
Figure 3.1 Flow and pressure waveforms in VCV. The target variable for VCV is flow. Both decelerating ramp (**a**) and constant flow (**b**) waveforms are demonstrated. The cycle variable for VCV is volume, which equals the area under the flow waveform curve (shaded region). The inspiratory flow waveform is set by the clinician. The pressure waveform is a result of the interaction between the set variables (flow-targeted and volume-cycled) and the respiratory system. *VCV* volume-controlled ventilation


a
Set by clinician
Flow
Time
Proximal airway pressure
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b
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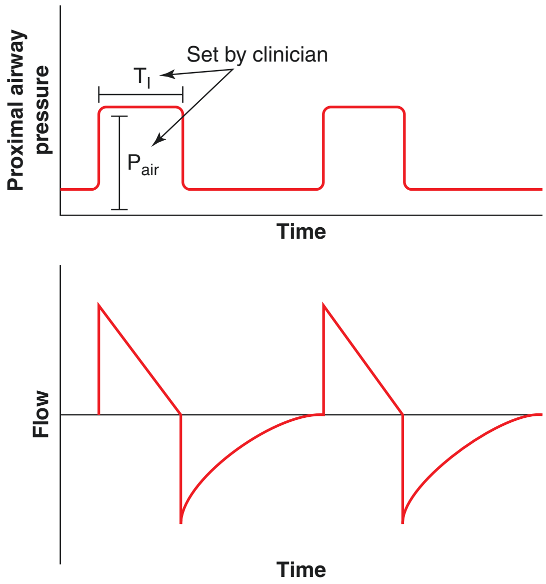

FIGURE 3.2 Flow and pressure waveforms in PCV. The target variable for PCV is pressure. The cycle variable for PCV is time. Proximal airway pressure and inspiratory time are set by the clinician. The flow waveform is a result of the interaction between the set variables (pressure-targeted and time-cycled) and the respiratory system. The resultant flow waveform in PCV is a decelerating ramp. P_{air} proximal airway pressure; *PCV* pressure-controlled ventilation; T_I inspiratory time

In summary, PCV is a pressure-targeted, time-cycled mode of ventilation, in which the ventilator delivers flow to quickly achieve and maintain a set proximal airway pressure for a set amount of time. The flow waveform will vary depending on characteristics of the respiratory system and patient respiratory effort (Fig. 3.2 and Table 3.1).

Key Concept #2
PCV = **pressure**-targeted, **time**-cycled

Pressure Support Ventilation

The trigger variable for PSV consists of only the patient (assist) trigger. As with the assist component of the assist-control trigger for both VCV and PCV, the trigger can be set as either a flow or a pressure trigger. There are no time-triggered, control breaths; therefore, this mode of ventilation can only be used if the patient initiates a sufficient number of breaths per minute.

The target variable is pressure. Just like with PCV, proximal airway pressure is selected on the ventilator. Flow is delivered by the ventilator to quickly achieve and maintain the set proximal airway pressure. The constant airway pressure during inspiration produces a decelerating ramp flow waveform, similar to that seen with PCV.

The cycle variable is flow. The ventilator is set to terminate the breath once flow diminishes to a specified percentage of peak inspiratory flow (e.g., 25%). This cycling mechanism utilizes the fact that a constant proximal airway pressure during inspiration produces a decelerating ramp flow waveform, in which flow is highest at the beginning of the breath and then decreases as the inspiratory phase proceeds.

While the inspiratory time in VCV and PCV is predetermined and does not change from breath to breath, the inspiratory time in PSV can vary. Inspiratory time in PSV is not constrained because breath cycling in this mode depends on the depreciation of flow. Flow in pressure-targeted modes, as discussed in Chap. 2, varies with changes in respiratory system resistance and compliance, as well as patient respiratory effort. Thus, patients can regulate inspiratory time with PSV by adjusting their respiratory effort, resulting in greater patient comfort and less patient-ventilator dyssynchrony.

In summary, PSV is a pressure-targeted, flow-cycled mode of ventilation, in which the ventilator delivers flow to quickly achieve and maintain a set airway pressure until the inspiratory flow depreciates to a set percentage of peak inspiratory flow. The flow waveform, tidal volume, and inspiratory time vary depending on characteristics of the respiratory system and patient respiratory effort (Fig. 3.3 and Table 3.1).

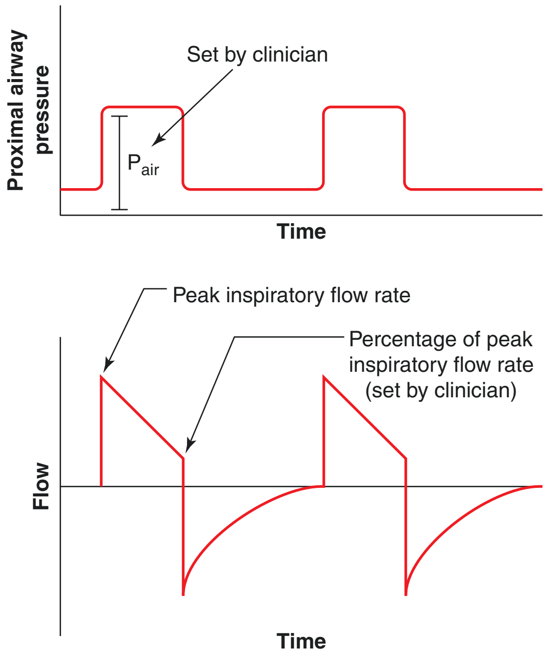

FIGURE 3.3 Flow and pressure waveforms in PSV. The target variable for PSV is pressure. The cycle variable for PSV is flow. Proximal airway pressure and the percentage of peak inspiratory flow for cycling are set by the clinician. The flow waveform is a result of the interaction between the set variables (pressure-targeted and flow-cycled) and the respiratory system. Similar to PCV, the resultant flow waveform in PSV is a decelerating ramp. With flow-cycling, the breath terminates once flow depreciates to a set percentage of the peak flow, in this case 25%.
P_{air} proximal airway pressure; *PSV* pressure support ventilation

Key Concept #3
PSV = **pressure**-targeted, **flow**-cycled

Key Concept #4
- VCV and PCV use **A/C** trigger
- PSV uses only patient **assist** trigger

Table 3.1 Summary of the basic modes of ventilation

Mode of ventilation	Trigger	Target	Cycle
VCV	Assist-control	Flow	Volume
PCV	Assist-control	Pressure	Time
PSV	Assist	Pressure	Flow

Volume-Controlled Ventilation Vs. Pressure-Controlled Ventilation

VCV and PCV are similar in that they both use assist-control as the trigger. Additionally, both modes of ventilation have a predetermined inspiratory time, which cannot be altered by patient effort or by changes in the respiratory system. In PCV, the inspiratory time is directly set, whereas in VCV, inspiratory time is determined by setting flow (target) and tidal volume (cycle).

Key Concept #5
- VCV and PCV: inspiratory time cannot vary from breath to breath
- PSV: inspiratory time can vary from breath to breath

It is important to note that in both modes of ventilation, a flow waveform is delivered, resulting in a pressure waveform, and culminating in a delivered tidal volume. In VCV, flow and volume are set, producing a resultant proximal airway pressure. In PCV, proximal airway pressure and inspiratory time are set, producing a resultant flow and volume. If the respiratory system (resistance and compliance) remains unchanged, switching between these modes of ventilation would not result in changes to the ventilator output.

Imagine a patient receiving PCV with proximal airway pressure (target) set to 20 cm H_2O and inspiratory time (cycle) set to 1 second. Now imagine that the respiratory system is such that these PCV settings result in a decelerating ramp flow waveform with peak flow of 60 L/minute and tidal volume of 500 mL. If this same patient were switched from PCV to VCV with a decelerating ramp flow waveform (target), peak flow set to 60 L/minute (target), and tidal volume set to 500 mL (cycle), the resultant proximal airway pressure would be 20 cm H_2O, and the resultant inspiratory time would be 1 second, which were the previous PCV settings. Given that the characteristics of the respiratory system have remained unchanged, flow, tidal volume, proximal airway pressure, and inspiratory time are the same in both cases (Fig. 3.4).

What distinguishes these two modes of ventilation is the response to changes in the respiratory system, either because of a change in resistance or compliance, or as a result of patient respiratory efforts. As explained in Chap. 2, the target and cycle variables remain unchanged, while the other variables change. If a patient is receiving VCV and bites the endotracheal tube, causing an increase in airway resistance, flow (target) and volume (cycle) remain unchanged, while airway pressure increases. Alternatively, if a patient is receiving PCV and bites the endotracheal tube, proximal airway pressure (target) and inspiratory time (cycle) remain unchanged, while flow, and consequently volume, decrease. If a patient is receiving VCV and makes a sustained inspiratory effort during inspiration, flow (target) and volume (cycle) remain unchanged, while proximal airway pressure decreases. Alternatively, if a patient is receiving PCV and makes a sustained inspiratory effort during inspiration, proximal airway pressure (target) and inspiratory time (cycle) remain unchanged, while flow, and consequently volume, increase.

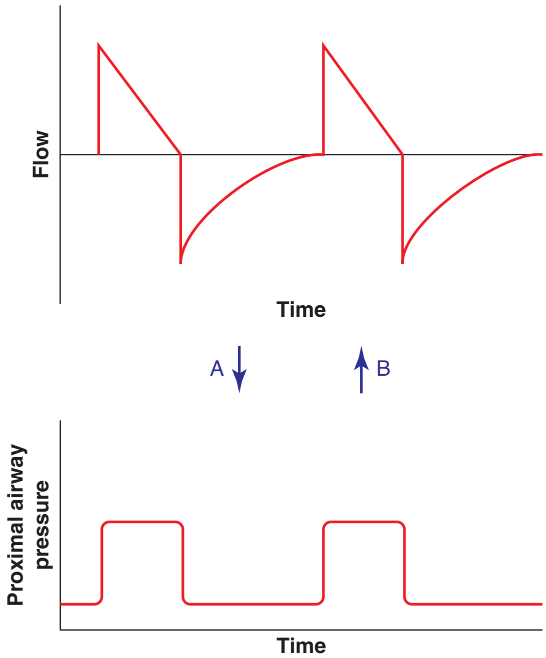

FIGURE 3.4 Flow and pressure waveforms. For a given resistance and compliance of the respiratory system, setting a flow waveform (as occurs with volume-controlled ventilation) will result in a distinct pressure waveform (**A**). If the respiratory system does not change, setting that same pressure waveform (as occurs with pressure-controlled ventilation) will result in the original flow waveform (**B**).

Pressure-Controlled Ventilation Vs. Pressure Support Ventilation

PCV and PSV are both pressure-targeted modes. That is, during the inspiratory phase for each mode, flow is delivered to achieve and maintain a set pressure. The only differences between the two modes of ventilation are during the trigger and cycle phases.

The trigger for PCV is assist-control, a hybrid of a patient trigger (assist) and a ventilator trigger (control). The trigger for PSV, on the other hand, consists only of a patient trigger and lacks the ventilator trigger. The patient trigger for both PCV and PSV are the same and can be set by either using a pressure or a flow trigger. Therefore, a patient receiving PCV who is triggering the ventilator at a rate faster than the set control rate, such that all of the breaths are "assist," will have absolutely no change in the triggering mechanism if the mode were switched to PSV.

The cycle for PCV is time, which does not vary from breath to breath and cannot be altered by patient effort or by changes in the respiratory system. The cycle for PSV is flow, specifically a percentage of the peak inspiratory flow rate. In contrast to PCV, inspiratory time in PSV can vary with changes in respiratory system resistance and compliance, as well as with patient respiratory effort.

Suggested Readings

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