CHAPTER FOUR  TRADITIONAL MODES OF MECHANICAL VENTILATION

INTRODUCTION

VOLUME VERSUS PRESSURE CONTROLLED VENTILATION

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OBJECTIVES

1. Contrast pressure and volume controlled modes of ventilation.
2. Compare continuous mandatory ventilation, continuous spontaneous ventilation, and synchronized intermittent mandatory ventilation.
3. Compare continuous positive airway pressure and pressure support ventilation.
4. Compare full and partial ventilatory support.

INTRODUCTION

The relationship between breath types and phase variables is referred to as a mode of ventilation. During mechanical ventilation, the mode is one of the principal ventilator settings. Although many modes are available, the choice of mode is usually based on clinician preference or institutional bias. This chapter describes traditional ventilator modes (Table 4-1), which include continuous mandatory ventilation (CMV), continuous spontaneous ventilation, and synchronized intermittent mandatory ventilation (SMV).

VOLUME VERSUS PRESSURE CONTROLLED VENTILATION

The two general approaches to mechanical ventilatory support are volume control and pressure control. Although the term volume control is usually used, in reality the ventilator controls the inspiratory flow. The important variables for volume-controlled ventilation are shown in Figure 4-1. During pressure-controlled ventilation, the inspiratory flow decreases as the alveolar pressure approaches the pressure applied to the airway. The important variables affecting pressure-controlled ventilation are illustrated in Figure 4-2.

CONTINUOUS MANDATORY VENTILATION

A minimal rate is set by the clinician with this mode (Figure 4-3). The patient can trigger the ventilator at a more rapid rate, but every breath delivered is a mandatory breath type. Note that the mandatory breaths can be either volume-controlled or pressure-controlled. CMV is commonly called assist/control (A/C) ventilation – the terms CMV and A/C are used interchangeably.

Table 4-1 Ventilator modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mandatory breath Control variable</th>
<th>Spontaneous breath Control variable</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous mandatory ventilation (CMV)</td>
<td>Volume</td>
<td>None</td>
<td>Volume-controlled continuous mandatory ventilation (VC CMV)</td>
</tr>
<tr>
<td></td>
<td>Pressure</td>
<td>None</td>
<td>Pressure-controlled continuous mandatory ventilation (PC CMV)</td>
</tr>
<tr>
<td>Continuous spontaneous ventilation (CSV)</td>
<td>None</td>
<td>Pressure</td>
<td>Continuous positive airway pressure (CPAP) or pressure support ventilation (PSV)</td>
</tr>
<tr>
<td>Synchronized intermittent mandatory ventilation (SIMV)</td>
<td>Volume</td>
<td>Pressure</td>
<td>Volume-controlled synchronized intermittent mandatory ventilation (VC SIMV)</td>
</tr>
<tr>
<td></td>
<td>Pressure</td>
<td></td>
<td>Pressure-controlled synchronized intermittent mandatory ventilation (PC SIMV)</td>
</tr>
</tbody>
</table>
CONTINUOUS SPONTANEOUS VENTILATION

With CSV, every breath is a spontaneous type. That is, every breath is triggered and cycled by the patient. The two most common forms of CSV are continuous positive airway pressure (CPAP) and pressure support ventilation (PSV).

Continuous Positive Airway Pressure

This is a spontaneous breathing mode — no mandatory breaths are delivered (Figure 4-4). A clinician-determined level of positive pressure is maintained throughout the ventilatory cycle. However, it is possible to set CPAP = zero, in which the pressure applied to the airway is ambient. The CPAP mode is most commonly used to evaluate extubation readiness. It is interesting to note that the performance of many current generation ventilators is such that a small level of

PSV (1–2 cm H₂O) is applied during CPAP. Ventilator performance during CPAP is better with flow-triggering than with pressure-triggering. For that reason, flow-triggering is recommended when CPAP is used.

Pressure Support Ventilation

With PSV, the patient's inspiratory effort is assisted by the ventilator at a preset level of inspiratory pressure. Inspiration is triggered and cycled by patient effort. During PSV, the patient determines the respiratory rate, inspiratory time, and tidal volume (Figure 4-5). Current generation ventilators provide backup ventilation (volume-controlled or pressure-controlled CMV) should apnea occur during PSV. PSV is normally flow cycled. Secondary cycling mechanisms with PSV are pressure and time. In other words, PSV will cycle to the expiratory phase when the
flow decreases to a ventilator-determined level, when the pressure rises to a ventilator-determined level, or the inspiratory time reaches a ventilator-determined limit. The flow at which the ventilator cycles to the expiratory phase can be either a fixed absolute flow, a flow based on the peak inspiratory flow, or a flow based on peak inspiratory flow and elapsed inspiratory time. Newer generation ventilators allow the clinician to adjust the termination flow at which the ventilator cycles to a level appropriate for the patient. Newer generation ventilators also allow adjustment of rise time at the beginning of the pressure support breath. Rise time refers to the amount of time required to reach the pressure support level at the beginning of inspiration.

**SYNCHRONIZED INTERMITTENT MANDATORY VENTILATION**

SIMV is a ventilator mode in which mandatory breaths are delivered at a set rate with volume-control or pressure-control. Between the mandatory breaths, the patient is allowed to breathe spontaneously. Although older SIMV systems have been associated with a high imposed work-of-breathing, this has improved in the current generation of ventilators. The ventilator delivers the mandatory breaths in synchrony with the patient's inspiratory effort (Figure 4-6). If no inspiratory effort is detected, the ventilator delivers a mandatory breath at the scheduled time. This is usually achieved by use of an assist window (Figure 4-7). This window opens at intervals determined by the set SIMV rate, and remains open for a manufacturer-specific period of time. If a patient-generated breathing effort is detected while this window is open, a mandatory breath is delivered. If no patient effort is detected in the time that the window is open, the ventilator delivers a mandatory breath. With SIMV, the spontaneous breaths can be pressure-supported (Figure 4-8).

**FULL VERSUS PARTIAL VENTILATORY SUPPORT**

Mechanical ventilation can be referred to as full or partial ventilatory support. With full ventilatory support, the ventilator does all of the ventilation for the patient; the patient does not trigger the ventilator or breathe spontaneously. This can be achieved as the result of the patient’s primary disease process (e.g., quadriplegia), pharmacologic therapy (e.g., paralysis), or use of a minute ventilation high enough to suppress the patient's spontaneous breathing efforts (e.g., hyperventilation). Full ventilatory support can be achieved using CMV or SIMV. Full ventilatory support
is often preferred for patients who are critically ill to decrease the oxygen cost of breathing and achieve control of the patient’s ventilatory pattern.

With partial ventilator support, some of the work-of-breathing is provided by the ventilator and the remainder is provided by the patient. Partial ventilatory support is commonly used during weaning from mechanical ventilation. Partial ventilatory support is also preferred by clinicians who believe that this form of ventilation maintains respiratory muscle tone, allows the patient to maintain some control of the ventilatory pattern, and improves patient comfort. Partial ventilatory support can be achieved with CMV, SIMV, and PSV. With CMV, most of the work-of-breathing is usually provided by the ventilator. With SIMV and PSV, the balance between the work-of-breathing provided by the patient and that provided by the ventilator can be set by the clinician.

### POINTS TO REMEMBER

- With CMV, all breaths are mandatory.
- All breaths are spontaneous with continuous positive airway pressure.
- The patient’s inspiratory effort is assisted by a preset level of inspiratory pressure during pressure support ventilation.
- With synchronized intermittent mandatory ventilation, both spontaneous and mandatory breaths can be delivered and the ventilator breaths are synchronized to patient effort.
- With full ventilatory support, the ventilator does all of the breathing for the patient.
NEW MODES OF MECHANICAL VENTILATION

INTRODUCTION

DUAL CONTROL MODES
- Dual Control Within a Breath
- Dual Control Breath-to-Breath: Pressure-Limited Flow-Cycled Ventilation
- Dual Control Breath-to-Breath: Pressure-Limited Time-Cycled Ventilation
- Adaptive Support Ventilation

AUTOMODE

PROPORTIONAL ASSIST VENTILATION

AUTOMATIC TUBE COMPENSATION

AIRWAY PRESSURE-RELEASE VENTILATION

MANDATORY MINUTE VENTILATION

POINTS TO REMEMBER

ADDITIONAL READING


CAMPBELL RS, BRANSON RD. Ventilatory support for the 90s: Pressure support ventilation. Respir Care 1993; 38:526–537.


OBJECTIVES

1. Compare approaches to dual control modes.
2. Describe Automode.
3. Describe the control of airway pressure during proportional assist ventilation.
4. Describe automatic tube compensation.
5. Compare approaches to airway pressure release ventilation.
6. Discuss the rationale for mandatory minute ventilation.