CME CREDIT ***EDUCATIONAL OBJECTIVE:*** Readers will be able to explain what some of the new ventilator modes do and their theoretical and actual benefits

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# Alternative modes of mechanical ventilation: A review for the hospitalist

## ABSTRACT

Newer ventilators can be set to modes other than the pressure-control and volume-control modes of older machines. In this paper, the authors review several of these alternative modes (adaptive pressure control, adaptive support ventilation, proportional assist ventilation, airway pressure-release ventilation, biphasic positive airway pressure, and high-frequency oscillatory ventilation), explaining how they work and contrasting their theoretical benefits and the actual evidence of benefit.

## KEY POINTS

The alternative modes of ventilation were developed to prevent lung injury and asynchrony, promote better oxygenation and faster weaning, and be easier to use. However, evidence of their benefit is scant.

Until now, we have lacked a standard nomenclature for mechanical ventilation, leading to confusion.

Regardless of the mode used, the goals are to avoid lung injury, keep the patient comfortable, and wean the patient from mechanical ventilation as soon as possible.

**Abbreviations used in this article**

APC—adaptive pressure control
APRV—airway pressure-release ventilation
ASV—adaptive support ventilation
CPAP—continuous positive airway pressure
$FIO_2$—fraction of inspired oxygen
HFOV—high-frequency oscillatory ventilation
PAV—proportional assist ventilation
PEEP—positive end-expiratory pressure
PSV—pressure support ventilation

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Technologic advances and computerized control of mechanical ventilators have made it possible to deliver ventilatory assistance in new modes. Driving these innovations is the desire to prevent ventilator-induced lung injury, improve patient comfort, and liberate the patient from mechanical ventilation as soon as possible.

We call these innovations "alternative" modes to differentiate them from the plain volume-control and pressure-control modes. Some clinicians rarely use these new modes, but in some medical centers they have become the most common ones used, or are being used unknowingly (the operator misunderstands the mode name). The information we provide on these modes of ventilation is by no means an endorsement of their use, but rather a tool to help the clinician understand their physiologic, theoretical, and clinical effects.

We focused on two goals:

- Explain what the mode does
- Briefly review the theoretical benefits and the actual evidence supporting these alternative modes of ventilation.

## STANDARD NOMENCLATURE NEEDED

Since its invention, mechanical ventilation has been plagued by multiple names being used to describe the same things. For example, volume-control ventilation is also called volume-cycled ventilation, assist-control ventilation, volume-limited ventilation, and controlled mechanical ventilation. Similarly, multiple abbreviations are used, each depending on the brand of ventilator, and new acronyms have been added in recent years as new modes have been developed. The vast number of names

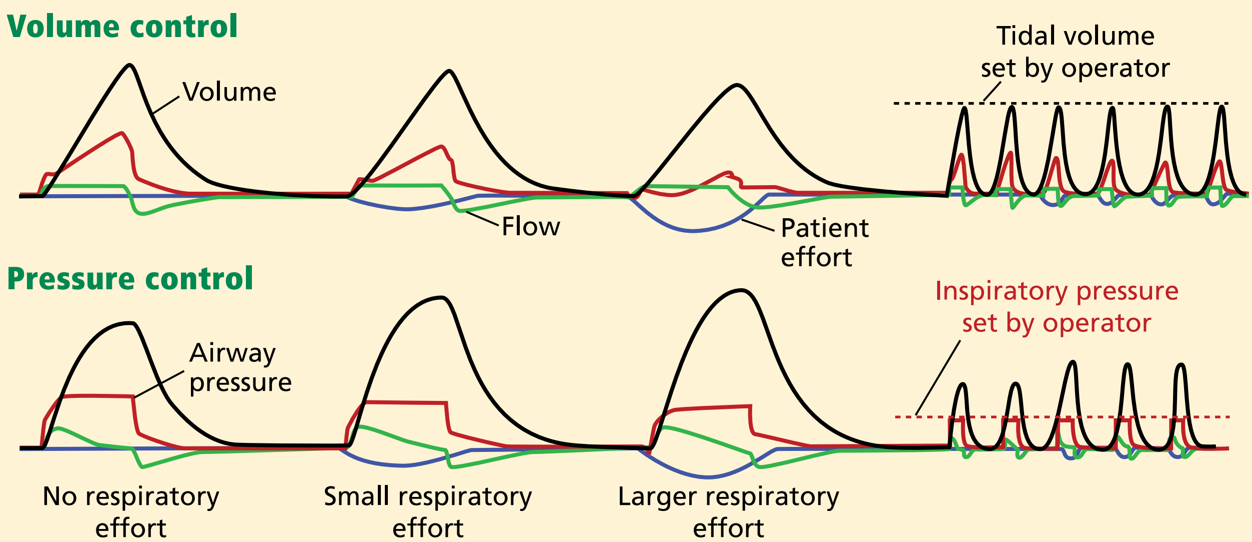


**FIGURE 1.** Volume control (top) and pressure control (bottom) are modes of continuous mandatory ventilation. Each mode is depicted as patient effort increases. Notice that the mode's control variable (volume or pressure) remains constant as patient effort increases. Contrast these findings with those in FIGURE 2.

**The mode name can be misleading**

and modes can confuse even the most seasoned critical care physician.

Efforts to establish a common nomenclature are under way.[1]

## WHAT IS A MODE?

A mode of mechanical ventilation has three essential components:

- The control variable
- The breath sequence
- The targeting scheme.

Similar modes may require more detailed descriptions to distinguish them, but the basic function can be explained by these three components.

### The control variable

In general, inspiration is an active process, driven by the patient's effort, the ventilator, or both, while expiration is passive. For simplicity, in this article a mechanical breath means the inspiratory phase of the breath.

The machine can only control the volume (and flow) or the pressure given. The breaths can be further described on the basis of what triggers the breath, what limits it (the maximum value of a control variable), and what ends (cycles) it.

Therefore, a volume-controlled breath is triggered by the patient or by the machine, limited by flow, and cycled by volume (FIGURE 1). A pressure-controlled breath is triggered by the patient or the machine, limited by pressure, and cycled by time or flow (FIGURE 1).

### The breath sequence

There are three possible breath sequences:

- Continuous mandatory ventilation, in which all breaths are controlled by the machine (but can be triggered by the patient)
- Intermittent mandatory ventilation, in which the patient can take spontaneous breaths between mandatory breaths
- Continuous spontaneous ventilation, in which all breaths are spontaneous (TABLE 1).

### The targeting scheme

The targeting or feedback scheme refers to the ventilator settings and programming that dictate its response to the patient's lung compliance, lung resistance, and respiratory effort. The regulation can be as simple as controlling the pressure in pressure-control mode, or it can be based on a complicated algorithm.

**TABLE 1**

## Mechanical breath terminology

**Mechanical breath description**

Control variable—the mechanical breath goal, ie, a set pressure or a set volume

Trigger variable—that which starts inspiration, ie, the patient (generating changes in pressure or flow) or a set rate (time between breaths)

Limit variable—the maximum value during inspiration

Cycle variable—that which ends inspiration

**Breath sequence**

Continuous mandatory ventilation—all breaths are controlled by the ventilator, so usually they have the same characteristics regardless of the trigger (patient or set rate); no spontaneous breaths are allowed

Intermittent mandatory ventilation—a set number of mechanical breaths is delivered regardless of the trigger (patient initiation or set rate); spontaneous breaths are allowed between or during mandatory breaths

Continuous spontaneous ventilation—all breaths are spontaneous with or without assistance

**Type of control or targeting scheme**[a]

Set point—the ventilator delivers and maintains a set goal, and this goal is constant (eg, in pressure control, the set point is pressure, which will remain constant throughout the breath); to a degree, all modes have some set-point control scheme

Servo—the ventilator adjusts its output to a given patient variable (ie, in proportional assist ventilation, the inspiratory flow follows and amplifies the patient's own flow pattern)

Adaptive—the ventilator adjusts a set point to maintain a different operator-selected set point (ie, in pressure-regulated volume control, the inspiratory pressure is adjusted breath to breath to achieve a target tidal volume)

Optimal—the ventilator uses a mathematical model to calculate the set points to achieve a goal (ie, in adaptive support ventilation, the pressure, respiratory rate, and tidal volume are adjusted to achieve a goal minute ventilation)

[a] Mentioned in this review; for more information, refer to Chatburn[1]

**A mode of ventilation is only as good as the operator who applies it**

In the sections that follow, we describe some of the available alternative modes of mechanical ventilation. We will explain only the targeting schemes in the modes reviewed (TABLE 1, TABLE 2), but more information on other targeting schemes can be found elsewhere.[1,2] We will focus on evidence generated in adult patients receiving invasive mechanical ventilation.

## ADAPTIVE PRESSURE CONTROL

One of the concerns with pressure-control ventilation is that it cannot guarantee a minimum minute ventilation (the volume of air that goes in and out in 1 minute; the tidal volume × breaths per minute) in the face of changing lung mechanics or patient effort, or both. To solve this problem, in 1991 the Siemens Servo 300 ventilator (Siemens, Maquet Critical Care AB, Solna, Sweden) introduced Pressure Regulated Volume Control, a mode that delivers pressure-controlled breaths with a target tidal volume and that is otherwise known as adaptive pressure control (APC) (FIGURE 2).

### Other names for adaptive pressure control

- Pressure Regulated Volume Control (Maquet Servo-i, Rastatt, Germany)

TABLE 2

## Classification of modes of ventilation

| CONTROL VARIABLE | BREATH SEQUENCE | TARGETING SCHEME | EXAMPLES OF COMMERCIALLY AVAILABLE MODES |
|---|---|---|---|
| **Volume** | Continuous mandatory ventilation | Set point | Volume control, VC-A/C, CMV, (S)CMV, Assist/Control |
| | | Dual | CMV + pressure limited |
| | | Adaptive | Adaptive flow |
| | Intermittent mandatory ventilation | Set point | SIMV, VC-SIMV |
| | | Dual | SIMV + pressure limited |
| | | Adaptive | AutoMode (VC-VS), mandatory minute volume |
| **Pressure** | Continuous mandatory ventilation | Set point | Pressure control, PC-A/C, AC PCV, high-pressure oscillatory ventilation [a] |
| | | Adaptive | Pressure-regulated volume control, [a] VC+AC [a], AMV+AutoFlow [a] |
| | Intermittent mandatory ventilation | Set point | Airway pressure-release ventilation, [a] SIMV PCV, BiLevel, [a] PCV+ [a] |
| | | Adaptive | VC+SIMV, V V+SIMV APVSIMV, SIMV+AutoFlow, Automode (PRVC-VS) |
| | | Optimal | Adaptive support ventilation [a] |
| | Continuous spontaneous ventilation | Set point | Continuous positive airway pressure, pressure support |
| | | Dual | Volume assured pressure support, volume augment |
| | | Servo | Proportional assist ventilation, [a] automatic tube compensation |
| | | Adaptive | Volume support |
| | | Intelligent | SmartCare |

Three levels of classification of the modes of mechanical ventilation. As noted in the text, for a given combination of control variable, breath sequence, and targeting scheme, several commercial mode names are described. Each commercial mode name can have subtle differences from others in the same class; however, the main characteristics of the mode can be determined by this classification.

[a] Discussed in this paper

CMV = continuous mandatory ventilation, CSV = continuous spontaneous ventilation, IMV = intermittent mandatory ventilation, SIMV = synchronized intermittent mandatory ventilation

**Mechanical breaths can be delivered only via pressure control or volume control**

- AutoFlow (Dräger Medical AG, Lübeck, Germany)
- Adaptive Pressure Ventilation (Hamilton Galileo, Hamilton Medical AG, Bonaduz, Switzerland)
- Volume Control+ (Puritan Bennett, Tyco Healthcare; Mansfield, MA)
- Volume Targeted Pressure Control, Pressure Controlled Volume Guaranteed (Engström, General Electric, Madison, WI).

### What does adaptive pressure control do?

The APC mode delivers pressure-controlled breaths with an adaptive targeting scheme (TABLE 2).

In pressure-control ventilation, tidal volumes depend on the lung's physiologic mechanics (compliance and resistance) and patient effort (FIGURE 1). Therefore, the tidal volume varies with changes in lung physiology (ie, larger or smaller tidal volumes than targeted).

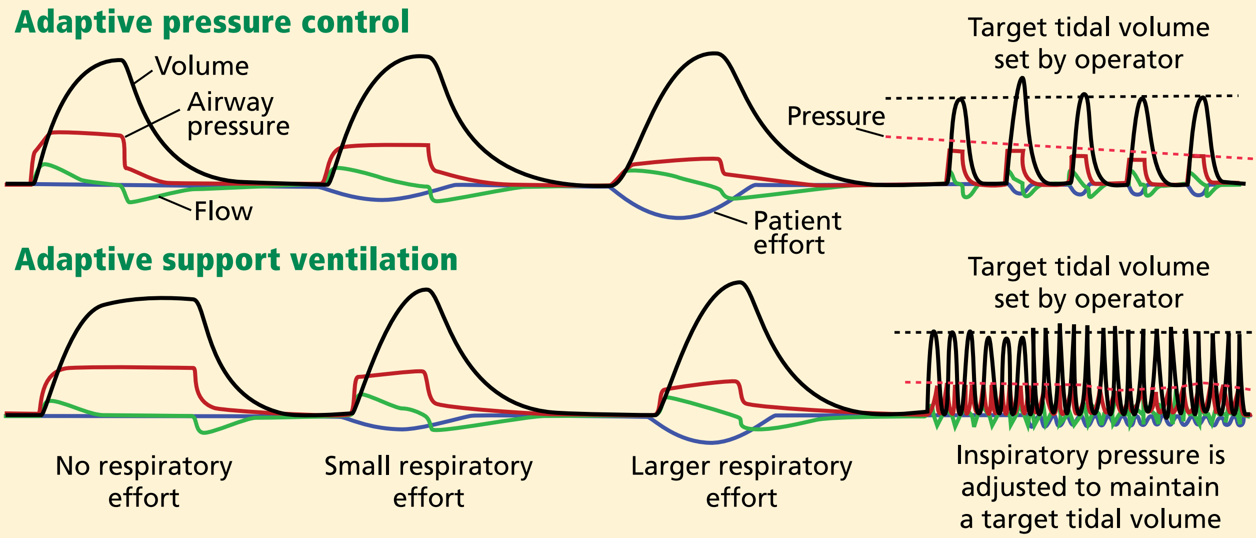


**FIGURE 2.** A machine in adaptive pressure control mode (top) adjusts the inspiratory pressure to maintain a set tidal volume. Adaptive support ventilation (bottom) automatically selects the appropriate tidal volume and frequency for mandatory breaths and the appropriate tidal volume for spontaneous breaths on the basis of the respiratory system mechanics and the target minute ventilation.

To overcome this effect, a machine in APC mode adjusts the inspiratory pressure to deliver the set minimal target tidal volume. If tidal volume increases, the machine decreases the inspiratory pressure, and if tidal volume decreases, the machine increases the inspiratory pressure. However, if the patient effort is large enough, the tidal volume will increase in spite of decreasing the inspiratory pressure (FIGURE 2). The adjustments to the inspiratory pressure occur after the tidal volume is off-target in a number of breaths.

### Common sources of confusion with adaptive pressure control

First, APC is not a volume-control mode. In volume control, the tidal volume does not change; in APC the tidal volume can increase or decrease, and the ventilator will adjust the inflation pressure to achieve the target volume. Thus, APC guarantees an average minimum tidal volume but not a maximum tidal volume.

Second, a characteristic of pressure control (and hence, APC) is that the flow of gas varies to maintain constant airway pressure (ie, maintain the set inspiratory pressure). This characteristic allows a patient who generates an inspiratory effort to receive flow as demanded, which is likely more comfortable. This is essentially different from volume control, in which flow is set by the operator and hence is fixed. Thus, if the patient effort is strong enough (FIGURE 1), this leads to what is called flow asynchrony, in which the patient does not get the flow asked for in a breath.

**The response of the ventilator to the patient is regulated in a number of ways**

### Ventilator settings in adaptive pressure control

Ventilator settings in APC are:

- Tidal volume
- Time spent in inspiration (inspiratory time)
- Frequency
- Fraction of inspired oxygen ($FiO_2$)
- Positive end-expiratory pressure (PEEP).

Some ventilators also require setting the speed to reach the peak pressure (also known as slope percent or inspiratory rise time).

### Clinical applications of adaptive pressure control

This mode is designed to maintain a consistent tidal volume during pressure-control ventilation and to promote inspiratory flow synchrony. It is a means of automatically reducing ventilatory support (ie, weaning) as the patient's inspiratory effort becomes stronger, as in awakening from anesthesia.

APC may not be ideal for patients who have an inappropriately increased respiratory drive (eg, in severe metabolic acidosis), since the inspiratory pressure will decrease to maintain the targeted average tidal volume, inappropriately shifting the work of breathing onto the patient.

### Theoretical benefits of adaptive pressure control

APC guarantees a minimum average tidal volume (unless the pressure alarm threshold is set too low, so that the target tidal volume is not delivered). Other theoretical benefits are flow synchrony, less ventilator manipulation by the operator, and automatic weaning of ventilator support.

### Evidence of benefit of adaptive pressure control

**Physiologic benefits.** This mode has lower peak inspiratory pressures than does volume-control ventilation,[3,4] which is often reported as a positive finding. However, in volume-control mode (the usual comparator), the peak inspiratory pressure is a manifestation of both resistance and compliance. Hence, peak inspiratory pressure is expected to be higher but does not reflect actual lung-distending pressures. It is the plateau pressure, a manifestation of lung compliance, that is related to lung injury.

**APC adjusts the inspiratory pressure to deliver the set target tidal volume**

**Patient comfort.** APC may increase the work of breathing when using low tidal volume ventilation and when there is increased respiratory effort (drive).[5] Interestingly, APC was less comfortable than pressure support ventilation in a small trial.[6]

**Outcomes** have not been studied.[7]

### Adaptive pressure control: Bottom line

APC is widely available and widely used, sometimes unknowingly (eg, if the operator thinks it is volume control). It is relatively easy to use and to set; however, evidence of its benefit is scant.

## ADAPTIVE SUPPORT VENTILATION

Adaptive support ventilation (ASV) evolved as a form of mandatory minute ventilation implemented with adaptive pressure control. Mandatory minute ventilation is a mode that allows the operator to preset a target minute ventilation, and the ventilator then supplies mandatory breaths, either volume- or pressure-controlled, if the patient's spontaneous breaths generate a lower minute ventilation.

ASV automatically selects the appropriate tidal volume and frequency for mandatory breaths and the appropriate tidal volume for spontaneous breaths on the basis of the respiratory system mechanics and target minute alveolar ventilation.

Described in 1994 by Laubscher et al,[8,9] ASV became commercially available in 1998 in Europe and in 2007 in the United States (Hamilton Galileo ventilator, Hamilton Medical AG). This is the first commercially available ventilator that uses an "optimal" targeting scheme (see below).

### What does adaptive support ventilation do?

ASV delivers pressure-controlled breaths using an adaptive (optimal) scheme (TABLE 2). "Optimal," in this context, means minimizing the mechanical work of breathing: the machine selects a tidal volume and frequency that the patient's brain would presumably select if the patient were not connected to a ventilator. This pattern is assumed to encourage the patient to generate spontaneous breaths.

The ventilator calculates the normal required minute ventilation based on the patient's ideal weight and estimated dead space volume (ie, 2.2 mL/kg). This calculation represents 100% of minute ventilation. The clinician at the bedside sets a target percent of minute ventilation that the ventilator will support—higher than 100% if the patient has increased requirements due, eg, to sepsis or increased dead space, or less than 100% during weaning.

The ventilator initially delivers test breaths, in which it measures the expiratory time constant for the respiratory system and then uses this along with the estimated dead space and normal minute ventilation to calculate an optimal breathing frequency in terms of mechanical work.

The optimal or target tidal volume is calculated as the normal minute ventilation divided by the optimal frequency. The target tidal volume is achieved by the use of APC (see above) (FIGURE 2). This means that the pressure limit is automatically adjusted to achieve an average delivered tidal volume equal to the target. The ventilator continuously monitors the respiratory system mechanics and adjusts its settings accordingly.

The ventilator adjusts its breaths to avoid air trapping by allowing enough time to exhale, to avoid hypoventilation by delivering tidal volume greater than the dead space, and to avoid volutrauma by avoiding large tidal volumes.

### Ventilator settings in adaptive support ventilation

Ventilator settings in ASV are:

- Patient height (to calculate the ideal body weight)
- Sex
- Percent of normal predicted minute ventilation goal
- $FiO_2$
- PEEP.

### Clinical applications of adaptive support ventilation

ASV is intended as a sole mode of ventilation, from initial support to weaning.

### Theoretical benefits of adaptive support ventilation

In theory, ASV offers automatic selection of ventilator settings, automatic adaptation to changing patient lung mechanics, less need for human manipulation of the machine, improved synchrony, and automatic weaning.

### Evidence of benefit of adaptive support ventilation

**Physiologic benefits.** Ventilator settings are adjusted automatically. ASV selects different tidal volume-respiratory rate combinations based on respiratory mechanics in passive and paralyzed patients.[10–12] In actively breathing patients, there was no difference in the ventilator settings chosen by ASV for different clinical scenarios (and lung physiology).[10] Compared with pressure-controlled intermittent mandatory ventilation, with ASV, the inspiratory load is less and patient-ventilator interaction is better.[13]

**Patient-ventilator synchrony and comfort** have not been studied.

**Outcomes.** Two trials suggest that ASV may decrease time on mechanical ventilation.[14,15] However, in another trial,[16] compared with a standard protocol, ASV led to fewer ventilator adjustments but achieved similar postsurgical weaning outcomes. The effect of this mode on the death rate has not been examined.[17,18]

### Adaptive support ventilation: Bottom line

ASV is the first commercially available mode that automatically selects all the ventilator settings except PEEP and $FiO_2$. These seem appropriate for different clinical scenarios in patients with poor respiratory effort or in paralyzed patients. Evidence of the effect in actively breathing patients and on outcomes such as length of stay or death is still lacking.

## PROPORTIONAL ASSIST VENTILATION

Patients who have normal respiratory drive but who have difficulty sustaining adequate spontaneous ventilation are often subjected to pressure support ventilation (PSV), in which the ventilator generates a constant pressure throughout inspiration regardless of the intensity of the patient's effort.

**APC is not a volume-controlled mode**

In 1992, Younes and colleagues[19,20] developed proportional assist ventilation (PAV) as an alternative in which the ventilator generates pressure in proportion to the patient's effort. PAV became commercially available in Europe in 1999 and was approved in the United States in 2006, available on the Puritan Bennett 840 ventilator (Puritan Bennett Co, Boulder, CO). PAV has also been used for noninvasive ventilation, but this is not available in the United States.

### Other names for proportional assist ventilation

Proportional Pressure Support (Dräger Medical; not yet available in the United States).

### What does proportional assist ventilation do?

This mode delivers pressure-controlled breaths with a servo control scheme (TABLE 2).

To better understand PAV, we can compare

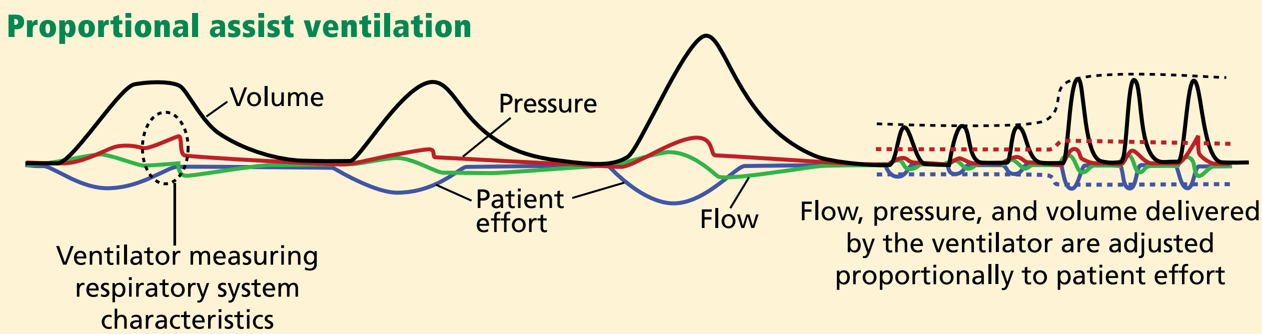


**FIGURE 3.** In proportional assist ventilation, the flow, pressure, and volume delivered are adjusted proportionally to the patient's effort.

it with PSV. With PSV, the pressure applied by the ventilator rises to a preset level that is held constant (a set-point scheme) until a cycling criterion (a percent of the maximum inspiratory flow value) is reached. The inspiratory flow and tidal volume are the result of the patient's inspiratory effort, the level of pressure applied, and the respiratory system mechanics.

In contrast, during PAV, the pressure applied is a function of patient effort: the greater the inspiratory effort, the greater the increase in applied pressure (servo targeting scheme) (FIGURE 3). The operator sets the percentage of support to be delivered by the ventilator. The ventilator intermittently measures the compliance and resistance of the patient's respiratory system and the instantaneous patient-generated flow and volume, and on the basis of these it delivers a proportional amount of inspiratory pressure.

**ASV selects a tidal volume and frequency that the patient's brain would presumably select**

In PAV, as in PSV, all breaths are spontaneous (TABLE 1). The patient controls the timing and size of the breath. There are no preset pressure, flow, or volume goals, but safety limits on the volume and pressure delivered can be set.

### Ventilator settings in proportional assist ventilation

Ventilator settings in PAV are:

- Airway type (endotracheal tube, tracheostomy)
- Airway size (inner diameter)
- Percentage of work supported (assist range 5%–95%)
- Tidal volume limit
- Pressure limit
- Expiratory sensitivity (normally, as inspiration ends, flow should stop; this parameter tells the ventilator at what flow to end inspiration).

**Caution when assessing the literature.** Earlier ventilator versions, ie, Dräger and Manitoba (University of Manitoba, Winnipeg, MB, Canada), which are not available in the United States, required the repeated calculation of the respiratory system mechanics and the manual setting of flow and volume assists (amplification factors) independently. To overcome this limitation, new software automatically adjusts the flow and volume amplification to support the loads imposed by the automatically measured values of resistance and elastance (inverse of compliance) of the respiratory system.[21] This software is included in the model (Puritan Bennett) available in the United States.

### Clinical applications of proportional assist ventilation

The PAV mode is indicated for maximizing ventilator patient synchrony for assisted spontaneous ventilation.

PAV is contraindicated in patients with respiratory depression (bradypnea) or large air leaks (eg, bronchopleural fistulas). It should be used with caution in patients with severe hyperinflation, in which the patient may still be exhaling but the ventilator doesn't recognize it. Another group in which PAV should be used with caution is those with high ventilatory drives, in which the ventilator overestimates respiratory system mechanics. This situation can lead to overassistance due to the "runaway phenomenon," in which the ventilator continues to provide support even if the patient has stopped inspiration.[22]

### Theoretical benefits of proportional assist ventilation

In theory, PAV should reduce the work of breathing, improve synchrony, automatically adapt to changing patient lung mechanics and effort, decrease the need for ventilator intervention and manipulation, decrease the need for sedation, and improve sleep.

### Evidence of benefit of proportional assist ventilation

**Physiologic benefits.** PAV reduces the work of breathing better than PSV,[21] even in the face of changing respiratory mechanics or increased respiratory demand (hypercapnia).[23–25] The hemodynamic profile is similar to that in PSV. Tidal volumes are variable; however, in recent reports the tidal volumes were within the lung-protective range (6–8 mL/kg, plateau pressure < 30 cm $H_2 0$).[26,27]

**Comfort.** PAV entails less patient effort and discomfort that PSV does.[23,25] PAV significantly reduces asynchrony,[27] which in turn may favorably affect sleep in critically ill patients.[28]

**Outcomes.** The probability of spontaneous breathing without assistance was significantly better in critically ill patients ventilated with PAV than with PSV. No trial has reported the effect of PAV on deaths.[27,29]

### Proportional assist ventilation: Bottom line

Extensive basic research has been done with PAV in different forms of respiratory failure, such as obstructive lung disease, acute respiratory distress syndrome (ARDS), and chronic respiratory failure. It fulfills its main goal, which is to improve patient-ventilator synchrony. Clinical experience with PAV in the United States is limited, as it was only recently approved.

## AIRWAY PRESSURE-RELEASE VENTILATION AND BIPHASIC POSITIVE AIRWAY PRESSURE

Airway pressure-release ventilation (APRV) was described in 1987 by Stock et al[30] as a mode for delivering ventilation in acute lung injury while avoiding high airway pressures. APRV combines high constant positive airway pressure (improving oxygenation and promoting alveolar recruitment) with intermittent releases (causing exhalation).

In 1989, Baum et al[31] described biphasic positive airway pressure ventilation as a mode in which spontaneous ventilation could be achieved at any point in the mechanical ventilation cycle—inspiration or exhalation (FIGURE 4). The goal was to allow unrestricted spontaneous breathing to reduce sedation and promote weaning. These modes are conceptually the same, the main difference being that the time spent in low pressure ($T_{low}$; see below) is less than 1.5 seconds for APRV. Otherwise, they have identical characteristics, thus allowing any ventilator with the capability of delivering APRV to deliver biphasic positive airway pressure, and vice versa. Machines with these modes became commercially available in the mid 1990s.

### Other names for biphasic positive airway pressure

Other names for biphasic positive airway pressure are:

- BiLevel (Puritan Bennett)
- BIPAP (Dräger Europe)
- Bi Vent (Siemens)
- BiPhasic (Avea, Cardinal Health, Inc, Dublin, OH)
- PCV+ (Dräger Medical)
- DuoPAP (Hamilton).

**Caution—name confusion.** In North America, BiPAP (Respironics, Murrysville, PA) and BiLevel are used to refer to noninvasive modes of ventilation.

APRV has no other name.

### What do these modes do?

These modes deliver pressure-controlled, time-triggered, and time-cycled breaths using a set-point targeting scheme (TABLE 2). This means that the ventilator maintains a constant pressure (set point) even in the face of spontaneous breaths.

**Caution—source of confusion.** The term continuous positive airway pressure (CPAP) is often used to describe this mode. However, CPAP is pressure that is applied continuously at the same level; the patient generates all the work to maintain ventilation ("pressure-

**In PAV, the greater the inspiratory effort, the greater the increase in applied pressure**

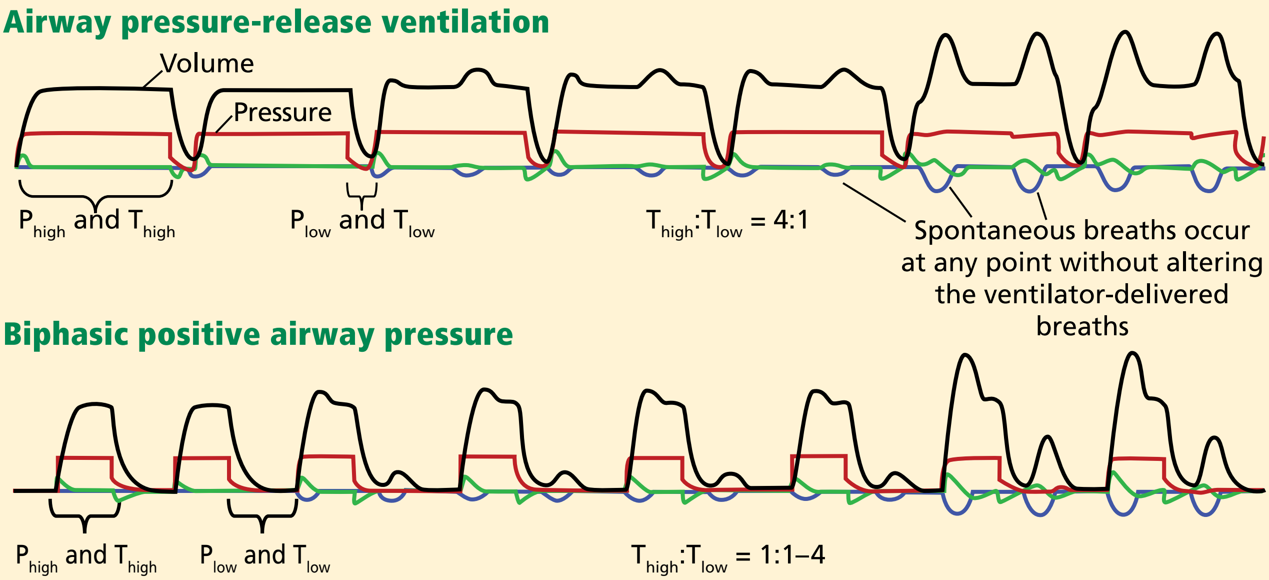


**FIGURE 4.** Airway pressure-release ventilation (top) and biphasic positive airway pressure (bottom) are forms of pressure-controlled intermittent mandatory ventilation in which spontaneous breaths can occur at any point without altering the ventilator-delivered breaths. The difference is that the time spent in high pressure is greater in airway pressure-release ventilation.

**APRV allows spontaneous breaths at any point in the cycle**

controlled continuous spontaneous ventilation" in the current nomenclature). In APRV, the airway pressure is intermittently released and reapplied, generating a tidal volume that supports ventilation. In other words, this is a pressure-controlled breath with a very prolonged inspiratory time and a short expiratory time in which spontaneous ventilation is possible at any point ("pressure-controlled intermittent mandatory ventilation" in the current nomenclature).

How these modes are set in the ventilator may also be a source of confusion. To describe the time spent in high and low airway pressures, we use the terms $T_{high}$ and $T_{low}$, respectively. By convention, the difference between APRV and biphasic mode is the duration of $T_{low}$ (< 1.5 sec for APRV).

Similarly, $P_{high}$ and $P_{low}$ are used to describe the high and low airway pressure. To better understand this concept, you can create the same mode in conventional pressure-control ventilation by thinking of the $T_{high}$ as the inspiratory time, the $T_{low}$ as the expiratory time, the $P_{high}$ as inspiratory pressure, and the $P_{low}$ as PEEP.

Hence, APRV is an extreme form of inverse ratio ventilation, with an inspiration-to-expiration ratio of 4:1. This means a patient spends most of the time in $P_{high}$ and $T_{high}$, and exhalations are short ($T_{low}$ and $P_{low}$). In contrast, the biphasic mode uses conventional inspiration-expiration ratios (FIGURE 4).

As with any form of pressure control, the tidal volume is generated by airway pressure rising above baseline (ie, the end-expiratory value). Hence, to ensure an increase in minute ventilation, the mandatory breath rate must be increased (ie, decreasing $T_{high}$, $T_{low}$, or both) or the tidal volume must be increased (ie, increasing the difference between $P_{high}$ and $P_{low}$). This means that in APRV the $T_{low}$ has to happen more often (by increasing the number of breaths) or be more prolonged (allowing more air to exhale). Because unrestricted spontaneous breaths are permitted at any point of the cycle, the patient contributes to the total minute ventilation (usually 10%–40%).

In APRV and biphasic mode, the operator's set time and pressure in inspiration and expiration will be delivered regardless of the patient's breathing efforts—the patient's spontaneous breath does not trigger a mechanical breath. Some ventilators have automatic adjustments to improve the trigger synchrony.

### Ventilator settings in APRV and biphasic mode

These modes require the setting of two pressure levels ($P_{high}$ and $P_{low}$) and two time durations ($T_{high}$ and $T_{low}$). One can add pressure support or automatic tube compensation to assist spontaneous breaths. The difference in $T_{low}$ generates differences in the $T_{high}$:$T_{low}$ ratio: APRV has a short $T_{low}$ (an inspiration-expiration ratio of 4:1). Biphasic mode has a conventional inspiration-expiration ratio of 1:1 to 1:4.

### Clinical applications

**APRV** is used in acute lung injury and ARDS. This mode should be used with caution or not at all in patients with obstructive lung disease or inappropriately increased respiratory drive.[32–35]

**Biphasic mode** is intended for both ventilation and weaning. In a patient who has poor respiratory effort or who is paralyzed, biphasic is identical to pressure-control/continuous mandatory ventilation.

### Theoretical benefits of APRV and biphasic mode

Multiple benefits have been ascribed to these modes. In theory, APRV will maximize and maintain alveolar recruitment, improve oxygenation, lower inflation pressures, and decrease overinflation. Both APRV and biphasic, by preserving spontaneous breathing, will improve ventilation-perfusion matching and gas diffusion, improve the hemodynamic profile (less need for vasopressors, higher cardiac output, reduced ventricular workload, improved organ perfusion), and improve synchrony (decrease the work of breathing and the need for sedation).

### Evidence of benefit of APRV and biphasic mode

APRV and biphasic are different modes. However studies evaluating their effects are combined. This is in part the result of the nomenclature confusion and different practice in different countries.[36]

**Physiologic benefits.** In studies, spontaneous breaths contributed to 10% to 40% of minute ventilation,[37,38] improved ventilation of dependent areas of the lung, improved ventilation-perfusion match and recruitment,[39] and improved hemodynamic profile.[40]

**Patient comfort.** These modes are thought to decrease the need for analgesia and sedation,[38] but a recent trial showed no difference with pressure-controlled intermittent mandatory ventilation.[41] Patient ventilator synchrony and comfort have not been studied.[32,42]

**Outcomes.** In small trials, these modes made no difference in terms of deaths, but they may decrease the length of mechanical ventilation.[38,41,43,44]

### APRV and biphasic mode: Bottom line

Maintaining spontaneous breathing while on mechanical ventilation has hemodynamic and ventilatory benefits.

APRV and biphasic mode are not the same thing. APRV's main goal is to maximize mean airway pressure and, hence, lung recruitment, whereas the main goal of the biphasic mode is synchrony.

There is a plethora of ventilator settings and questions related to physiologic effects.[33,34,36]

Although these modes are widely used in some centers, there is no evidence yet that they are superior to conventional volume- or pressure-control ventilation with low tidal volume for ARDS and acute lung injury. There is no conclusive evidence that these modes improve synchrony, time to weaning, or patient comfort.

**Maintaining spontaneous breathing while on mechanical ventilation has benefits**

## HIGH-FREQUENCY OSCILLATORY VENTILATION

High-frequency oscillatory ventilation (HFOV) was first described and patented in 1952 by Emerson and was clinically developed in the early 1970s by Lunkenheimer.[45]

The goal of HFOV is to minimize lung injury; its characteristics (discussed below) make it useful in patients with severe ARDS. The US Food and Drug Administration approved it for infants in 1991 and for children in 1995. The adult model has been available since 1993, but it was not approved until 2001 (SensorMedics 3100B, Cardinal Health, Inc).

### Other names for high-frequency oscillatory ventilation

While HFOV has no alternative names, the following acronyms describe similar modes:

## High-frequency oscillatory ventilation

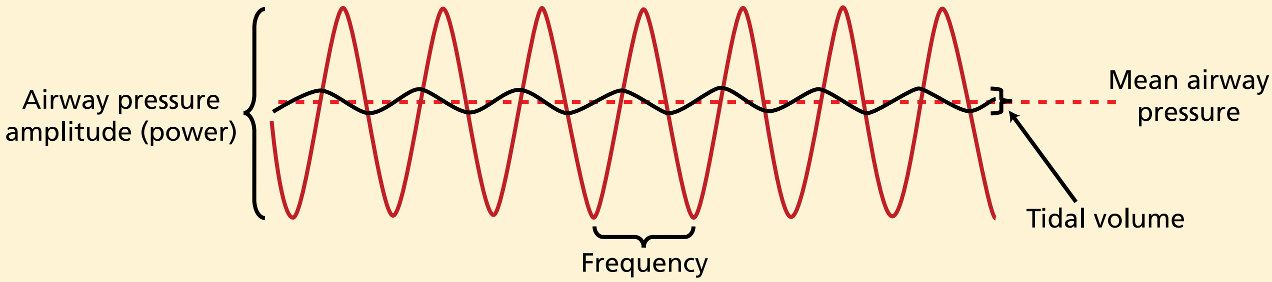


**FIGURE 5.** High-frequency oscillatory ventilation delivers very small mandatory breaths (oscillations) at frequencies of up to 900 breaths per minute.

- HFPPV (high-frequency positive pressure ventilation)
- HFJV (high-frequency jet ventilation)
- HFFI (high-frequency flow interruption)
- HFPV (high-frequency percussive ventilation)
- HFCWO (high-frequency chest wall oscillation).

All of these modes require different specialized ventilators.

**The goal of HFOV is to minimize lung injury, especially in ARDS**

### What does high-frequency oscillatory ventilation do?

Conceptually, HFOV is a form of pressure-controlled intermittent mandatory ventilation with a set-point control scheme. In contrast to conventional pressure-controlled intermittent mandatory ventilation, in which relatively small spontaneous breaths may be superimposed on relatively large mandatory breaths, HFOV superimposes very small mandatory breaths (oscillations) on top of spontaneous breaths.

HFOV can be delivered only with a special ventilator. The ventilator delivers a constant flow (bias flow), while a valve creates resistance to maintain airway pressure, on top of which a piston pump oscillates at frequencies of 3 to 15 Hz (160–900 breaths/minute). This creates a constant airway pressure with small oscillations (FIGURE 5); often, clinicians at the bedside look for the "chest wiggle" to assess the appropriate amplitude settings, although this has not been systematically studied.

Adult patients are usually paralyzed or deeply sedated, since deep spontaneous breathing will trigger alarms and affect ventilator performance.

To manage ventilation ($CO_2$ clearance), one or several of the following maneuvers can be done: decrease the oscillation frequency, increase the amplitude of the oscillations, increase the inspiratory time, or increase bias flow (while allowing an endotracheal tube cuff leak). Oxygenation adjustments are controlled by manipulating the mean airway pressure and the $F_{IO_2}$.

### Ventilator settings in high-frequency oscillatory ventilation

Ventilator settings in HFOV are[46]:

- Airway pressure amplitude (delta P or power)
- Mean airway pressure
- Percent inspiration
- Inspiratory bias flow
- $F_{IO_2}$.

### Clinical applications of high-frequency oscillatory ventilation

This mode is usually reserved for ARDS patients for whom conventional ventilation is failing. A recently published protocol[46] suggests considering HFOV when there is oxygenation failure ($F_{IO_2} \geq 0.7$ and PEEP ≥ 14 cm $H_2O$) or ventilation failure (pH < 7.25 with tidal volume ≥ 6 mL/kg predicted body weight and plateau airway pressure ≥ 30 cm $H_2O$).

This mode is contraindicated when there is known severe airflow obstruction or intracranial hypertension.

### Theoretical benefits of high-frequency oscillatory ventilation

Conceptually, HFOV can provide the highest mean airway pressure paired with the lowest tidal volume of any mode. These benefits might make HFOV the ideal lung-protective ventilation strategy.

### Evidence of benefit of high-frequency oscillatory ventilation

**Physiologic benefits.** Animal models have shown less histologic damage and lung inflammation with HFOV than with high-tidal-volume conventional ventilation[47,48] and low-tidal-volume conventional ventilation.[49]

**Patient comfort** has not been studied. However, current technology does impose undue work of breathing in spontaneously breathing patients.[50]

**Outcomes.** Several retrospective case series have described better oxygenation with HFOV as rescue therapy for severe ARDS than with conventional mechanical ventilation. Two randomized controlled trials have studied HFOV vs high-tidal-volume conventional mechanical ventilation for early severe ARDS; HFOV was safe but made no difference in terms of deaths.[42,51–54]

### High-frequency oscillatory ventilation: Bottom line

In theory, HFOV provides all the benefits of an ideal lung-protective strategy, at least for paralyzed or deeply sedated patients. Animal studies support these concepts. In human adults, HFOV has been shown to be safe and to provide better oxygenation but no improvement in death rates compared with conventional mechanical ventilation. Currently, HFOV is better reserved for patients with severe ARDS for whom conventional mechanical ventilation is failing. ■

## REFERENCES

1. **Chatburn RL**. Classification of ventilator modes: update and proposal for implementation. Respir Care 2007; 52:301–323.
2. **Chatburn RL**. Computer control of mechanical ventilation. Respir Care 2004; 49:507–517.
3. **Alvarez A, Subirana M, Benito S**. Decelerating flow ventilation effects in acute respiratory failure. J Crit Care 1998; 13:21–25.
4. **Guldager H, Nielsen SL, Carl P, Soerensen MB**. A comparison of volume control and pressure regulated volume control ventilation in acute respiratory failure. Crit Care 1997; 1:75–77.
5. **Kallet RH, Campbell AR, Dicker RA, Katz JA, Mackersie RC**. Work of breathing during lung protective ventilation in patients with acute lung injury and acute respiratory distress syndrome: a comparison between volume and pressure regulated breathing modes. Respir Care 2005; 50:1623–1631.
6. **Betensley AD, Khalid I, Crawford J, Pensler RA, DiGiovine B**. Patient comfort during pressure support and volume controlled continuous mandatory ventilation. Respir Care 2008; 53:897–902.
7. **Branson RD, Chatburn RL**. Controversies in the critical care setting. Should adaptive pressure control modes be utilized for virtually all patients receiving mechanical ventilation? Respir Care 2007; 52:478–485.
8. **Laubscher TP, Frutiger A, Fanconi S, Jutzi H, Brunner JX**. Automatic selection of tidal volume, respiratory frequency and minute ventilation in intubated ICU patients as start up procedure for closed-loop controlled ventilation. Int J Clin Monit Comput 1994; 11:19–30.
9. **Laubscher TP, Heinrichs W, Weiler N, Hartmann G, Brunner JX**. An adaptive lung ventilation controller. IEEE Trans Biomed Eng 1994; 41:51–59.
10. **Arnal JM, Wysocki M, Nafati C, et al**. Automatic selection of breathing pattern using adaptive support ventilation. Intensive Care Med 2008; 34:75–81.
11. **Campbell RS, Sinamban RP, Johannigman JA, et al**. Clinical evaluation of a new closed loop ventilation mode: adaptive supportive ventilation (ASV). Crit Care 1999; 3(suppl 1):083.
12. **Belliato M, Palo A, Pasero D, Iotti GA, Mojoli F, Braschi A**. Evaluation of adaptive support ventilation in paralysed patients and in a physical lung model. Int J Artif Organs 2004; 27:709–716.
13. **Tassaux D, Dalmas E, Gratadour P, Jolliet P**. Patient ventilator interactions during partial ventilatory support: a preliminary study comparing the effects of adaptive support ventilation with synchronized intermittent mandatory ventilation plus inspiratory pressure support. Crit Care Med 2002; 30:801–807.
14. **Gruber PC, Gomersall CD, Leung P, et al**. Randomized controlled trial comparing adaptive-support ventilation with pressure-regulated volume-controlled ventilation with automode in weaning patients after cardiac surgery. Anesthesiology 2008; 109:81–87.
15. **Sulzer CF, Chiolero R, Chassot PG, et al**. Adaptive support ventilation for fast tracheal extubation after cardiac surgery: a randomized controlled study. Anesthesiology 2001; 95:1339–1345.
16. **Petter AH, Chiolèro RL, Cassina T, Chassot PG, Müller XM, Revelly JP**. Automatic “respirator/weaning” with adaptive support ventilation: the effect on duration of endotracheal intubation and patient management. Anesth Analg 2003; 97:1743–1750.
17. **Brunner JX, Iotti GA**. Adaptive support ventilation (ASV). Minerva Anestesiol 2002; 68:365–368.
18. **Campbell RS, Branson RD, Johannigman JA**. Adaptive support ventilation. Respir Care Clin North Am 2001; 7:425–440.
19. **Younes M**. Proportional assist ventilation, a new approach to ventilatory support. Theory. Am Rev Respir Dis 1992; 145:114–120.
20. **Younes M, Puddy A, Roberts D, et al**. Proportional assist ventilation. Results of an initial clinical trial. Am Rev Respir Dis 1992; 145:121–129.
21. **Kondili E, Prinianakis G, Alexopoulou C, Vakouti E, Klimathianaki M, Georgopoulos D**. Respiratory load compensation during mechanical ventilatio—proportional assist ventilation with load-adjustable gain factors versus pressure support. Intensive Care Med 2006; 32:692–699.
22. **Kondili E, Prinianakis G, Alexopoulou C, Vakouti E, Klimathianaki M, Georgopoulos D**. Effect of different levels of pressure support and proportional assist ventilation on breathing pattern, work of breathing and gas exchange in mechanically ventilated hypercapnic COPD patients with acute respiratory failure. Respiration 2003; 70:355–361.
23. **Grasso S, Puntillo F, Mascia L, et al**. Compensation for increase in respiratory workload during mechanical ventilation. Pressure support versus proportional assist ventilation. Am J Respir Crit Care Med 2000; 161:819–826.
24. **Wrigge H, Golisch W, Zinserling J, Sydow M, Almeling G, Burchardi**

**H**. Proportional assist versus pressure support ventilation: effects on breathing pattern and respiratory work of patients with chronic obstructive pulmonary disease. Intensive Care Med 1999; 25:790–798.
25. **Ranieri VM, Giuliani R, Mascia L, et al**. Patient ventilator interaction during acute hypercapnia: pressure support vs. proportional assist ventilation. J Appl Physiol 1996; 81:426–436.
26. **Kondili E, Xirouchaki N, Vaporidi K, Klimathianaki M, Georgopoulos D**. Short-term cardiorespiratory effects of proportional assist and pressure support ventilation in patients with acute lung injury/acute respiratory distress syndrome. Anesthesiology 2006; 105:703–708.
27. **Xirouchaki N, Kondili E, Vaporidi K, et al**. Proportional assist ventilation with load-adjustable gain factors in critically ill patients: comparison with pressure support. Intensive Care Med 2008; 34:2026–2034.
28. **Bosma K, Ferreyra G, Ambrogio C, et al**. Patient ventilator interaction and sleep in mechanically ventilated patients: pressure support versus proportional assist ventilation. Crit Care Med 2007; 35:1048–1054.
29. **Sinderby C, Beck J**. Proportional assist ventilation and neurally adjusted ventilatory assist—better approaches to patient ventilator synchrony? Clin Chest Med 2008; 29:329–342.
30. **Stock MC, Downs JB, Frolicher DA**. Airway pressure release ventilation. Crit Care Med 1987; 15:462–466.
31. **Baum M, Benzer H, Putensen C, Koller W, Putz G**. [Biphasic positive airway pressure (BIPAP)—a new form of augmented ventilation]. Anaesthesist 1989; 38:452–458.
32. **Seymour CW, Frazer M, Reilly PM, Fuchs BD**. Airway pressure release and biphasic intermittent positive airway pressure ventilation: are they ready for prime time? J Trauma 2007; 62:1298–1308.
33. **Myers TR, MacIntyre NR**. Respiratory controversies in the critical care setting. Does airway pressure release ventilation offer important new advantages in mechanical ventilator support? Respir Care 2007; 52:452–458.
34. **Neumann P, Golisch W, Strohmeyer A, Buscher H, Burchardi H, Sydow M**. Influence of different release times on spontaneous breathing pattern during airway pressure release ventilation. Intensive Care Med 2002; 28:1742–1749.
35. **Calzia E, Lindner KH, Witt S, et al**. Pressure-time product and work of breathing during biphasic continuous positive airway pressure and assisted spontaneous breathing. Am J Respir Crit Care Med 1994; 150:904–910.
36. **Rose L, Hawkins M**. Airway pressure release ventilation and biphasic positive airway pressure: a systematic review of definitional criteria. Intensive Care Med 2008; 34:1766–1773.
37. **Sydow M, Burchardi H, Ephraim E, Zielmann S, Crozier TA**. Long-term effects of two different ventilatory modes on oxygenation in acute lung injury. Comparison of airway pressure release ventilation and volume-controlled inverse ratio ventilation. Am J Respir Crit Care Med 1994; 149:1550–1556.
38. **Putensen C, Zech S, Wrigge H, et al**. Long-term effects of spontaneous breathing during ventilatory support in patients with acute lung injury. Am J Respir Crit Care Med 2001; 164:43–49.
39. **Davis K Jr, Johnson DJ, Branson RD, Campbell RS, Johannigman JA, Porembka D**. Airway pressure release ventilation. Arch Surg 1993; 128:1348–1352.
40. **Kaplan LJ, Bailey H, Formosa V**. Airway pressure release ventilation increases cardiac performance in patients with acute lung injury/adult respiratory distress syndrome. Crit Care 2001; 5:221–226.
41. **Varpula T, Valta P, Niemi R, Takkunen O, Hynynen M, Pettilä VV**. Airway pressure release ventilation as a primary ventilatory mode in acute respiratory distress syndrome. Acta Anaesthesiol Scand 2004; 48:722–731.
42. **Siau C, Stewart TE**. Current role of high frequency oscillatory ventilation and airway pressure release ventilation in acute lung injury and acute respiratory distress syndrome. Clin Chest Med 2008; 29:265–275.
43. **Rathgeber J, Schorn B, Falk V, Kazmaier S, Spiegel T, Burchardi H**. The influence of controlled mandatory ventilation (CMV), intermittent mandatory ventilation (IMV) and biphasic intermittent positive airway pressure (BIPAP) on duration of intubation and consumption of analgesics and sedatives. A prospective analysis in 596 patients following adult cardiac surgery. Eur J Anaesthesiol 1997; 14:576–582.
44. **Habashi NM**. Other approaches to open lung ventilation: airway pressure release ventilation. Crit Care Med 2005; 33(suppl 3):S228–S240.
45. **Hess D, Mason S, Branson R**. High-frequency ventilation design and equipment issues. Respir Care Clin North Am 2001; 7:577–598.
46. **Fessler HE, Derdak S, Ferguson ND, et al**. A protocol for high frequency oscillatory ventilation in adults: results from a roundtable discussion. Crit Care Med 2007; 35:1649–1654.
47. **Hamilton PP, Onayemi A, Smyth JA, et al**. Comparison of conventional and high-frequency ventilation: oxygenation and lung pathology. J Appl Physiol 1983; 55:131–138.
48. **Sedeek KA, Takeuchi M, Suchodolski K, et al**. Open-lung protective ventilation with pressure control ventilation, high-frequency oscillation, and intratracheal pulmonary ventilation results in similar gas exchange, hemodynamics, and lung mechanics. Anesthesiology 2003; 99:1102–1111.
49. **Imai Y, Nakagawa S, Ito Y, Kawano T, Slutsky AS, Miyasaka K**. Comparison of lung protection strategies using conventional and high-frequency oscillatory ventilation. J Appl Physiol 2001; 91:1836–1844.
50. **van Heerde M, Roubik K, Kopelent V, Plötz FB, Markhorst DG**. Unloading work of breathing during high-frequency oscillatory ventilation: a bench study. Crit Care 2006; 10:R103.
51. **Derdak S, Mehta S, Stewart TE, et al; Multicenter Oscillatory Ventilation For Acute Respiratory Distress Syndrome Trial (MOAT) Study Investigators**. High-frequency oscillatory ventilation for acute respiratory distress syndrome in adults: a randomized, controlled trial. Am J Respir Crit Care Med 2002; 166:801–808.
52. **Bollen CW, van Well GT, Sherry T, et al**. High-frequency oscillatory ventilation compared with conventional mechanical ventilation in adult respiratory distress syndrome: a randomized controlled trial [ISRCTN24242669]. Crit Care 2005; 9:R430–R439.
53. **Mehta S, Granton J, MacDonald RJ, et al**. High frequency oscillatory ventilation in adults: the Toronto experience. Chest 2004; 126:518–527.
54. **Chan KP, Stewart TE, Mehta S**. High-frequency oscillatory ventilation for adult patients with ARDS. Chest 2007; 131:1907–1916.

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10. **Thompson IM, Pauler DK, Goodman PJ, et al**. Prevalence of prostate cancer among men with a prostate-specific antigen level < or = 4.0 ng per milliliter. N Engl J Med 2004; 350:2239–2246.
11. **Hamilton RJ, Goldberg KC, Platz EA, Freedland SJ**. The influence of statin medications on prostate-specific antigen levels. N Natl Cancer Inst 2008; 100:1487–1488.
12. **Vickers AJ, Savage C, O'Brien MF, Lilja H**. Systematic review of pretreatment prostate-specific antigen velocity and doubling time as predictors for prostate cancer. J Clin Oncol 2009; 27:398–403.
13. **Lilja H, Ulmert D, Vickers AJ**. Prostate-specific antigen and prostate cancer: prediction, detection and monitoring. Nat Rev Cancer 2008; 8:268–278.
14. **Marks LS, Fradet Y, Deras IL, et al**. PCA molecular urine assay for prostate cancer in men undergoing repeat biopsy. Urology 2007; 69:532–535.
15. **Sreekumar A, Poisson LM, Thekkelnaycke M, et al**. Metabolomic profile delineates potential role for sarcosine in prostate cancer progression. Nature 2009; 457:910–914.
16. **Zheng SL, Sun J, Wiklund F, et al**. Cumulative association of five genetic variants with prostate cancer. N Engl J Med 2008; 358:910–919.
17. **Witte JS**. Prostate cancer genomics: toward a new understanding. Nat Rev Genet 2009; 10:77–82.
18. **Gaziano JM, Glynn RJ, Christen WG, et al**. Vitamins E and C in the prevention of prostate and total cancer in men: the Physicians' Health Study II randomized controlled trial. JAMA 2009; 301:52–62.
19. **Thompson IM, Goodman PJ, Tangen CM, et al**. The influence of finasteride on the development of prostate cancer. N Engl J Med 2003; 349:215–224.
20. **Lucia MS, Darke AK, Goodman PJ, et al**. Pathologic characteristics of cancers detected in the Prostate Cancer Prevention Trial: implications for prostate cancer detection and chemoprevention. Cancer Prev Res (Phila PA) 2008; 1:167–173.
21. **Andriole G, Bostwick D, Brawley O, et al**. Further analyses from the REDUCE prostate cancer risk reduction trial [abstract]. J Urol 2009; 181:(suppl):555.
22. **Kramer BS, Hagerty KL, Justman S, et al; American Society of Clinical Oncology/American Urological Association**. Use of 5-alpha-reductase inhibitors for prostate cancer chemoprevention: American Society of Clinical Oncology/American Urological Association 2008 Clinical Practice Guideline. J Urol 2009; 181:1642–1657.


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## CORRECTION

# Newer modes of mechanical ventilation

(JULY 2009)

A mistake appeared in **FIGURE 2** on page 418 in the July issue of the *Cleveland Clinic Journal of Medicine* (Mireles-Cabodevila E, Diaz-Guzman E, Heresi GA, Chatburn RL. Alternative modes of mechanical ventilation: A review for the hospitalist. Cleve Clin J Med 2009; 76:417–430). The graph of the parameters in adaptive support ventilation incorrectly states, "Target tidal volume set by operator." It should say, "Target tidal volume set by the ventilator." The corrected figure is shown below.

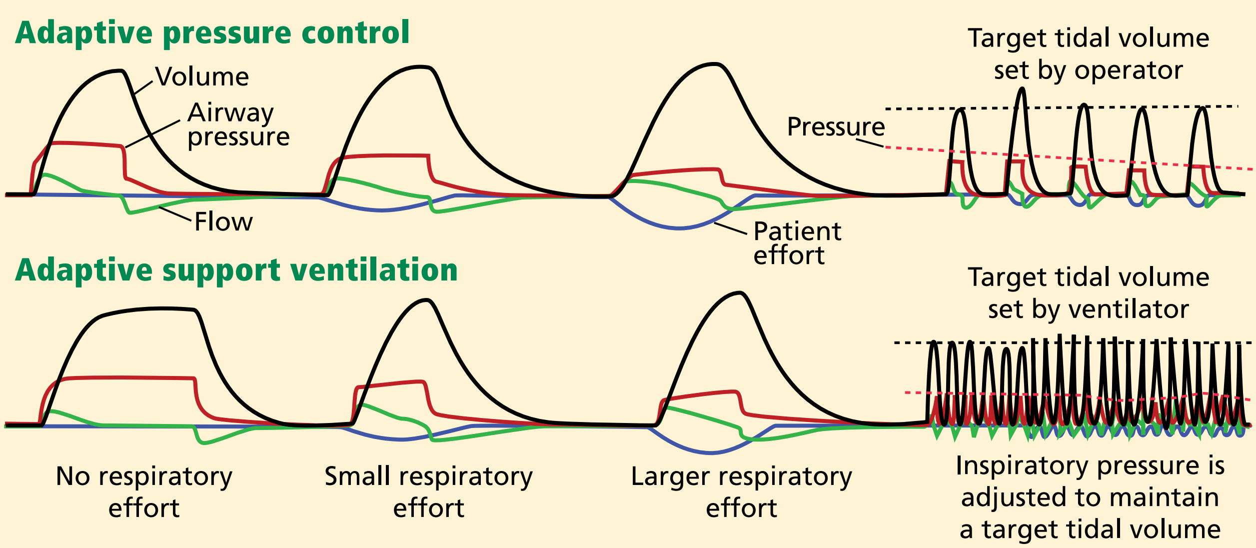


**FIGURE 2.** A machine in adaptive pressure control mode (top) adjusts the inspiratory pressure to maintain a set tidal volume. Adaptive support ventilation (bottom) automatically selects the appropriate tidal volume and frequency for mandatory breaths and the appropriate tidal volume for spontaneous breaths on the basis of the respiratory system mechanics and the target minute ventilation.