Puritan Bennett™
Bi-Level Software Option for the Puritan Bennett™ 840 Ventilator
Two Ventilating Strategies in One Mode

Healthcare providers and patients throughout the world depend on Covidien for state-of-the-art ventilation therapy. Whether your needs include acute care for critically ill patients with chronic respiratory failure or a solution to transition patients to home care, we have the right system for the task at hand.

Healthcare professionals know all too well the range of issues that impact ventilation outcomes today. At Covidien, our innovations are systematically tackling the issues that truly matter — patient safety, medical efficacy and healthcare efficiency. The Bi-Level Software Option is another example of how we’re helping medical professionals improve ventilation outcomes and quality of life for their patients.

THREE DIMENSIONS OF EXCELLENCE BUILT INTO THE BI-LEVEL SOFTWARE OPTION

- **Patient Safety** – With supported PEEP level transitions and spontaneous breathing, patient comfort and synchrony may be enhanced. Bi-Level mode combines Bi-PAP and PS, both of which can be applied noninvasively via a face mask.

- **Clinician Support** – The Bi-Level mode monitors mandatory and spontaneous tidal volumes and minute volume separately, offering the clinician a clear understanding of what the patient’s spontaneous ventilation contributes to total ventilation.

- **Healthcare Efficiency** – By allowing the principles of APRV to easily transition from controlled ventilation to all levels of augmented ventilation, the Bi-Level mode may be appropriate for the entire course of a patient’s treatment. In addition, sedation due to patient/ventilator asynchrony may be kept at a lower level, allowing patients to become mobile sooner and hospitals to reduce the necessary level of care.

PROMOTING PATIENT/VENTILATOR SYNCHRONY

The control of tidal volume and CO₂ normalization during mechanical ventilation has been a clinical focus over the past few decades. Increasingly, this need to maintain constant volume has come into question. Ventilation strategies that control pressure are commonplace on current-generation ventilators. Recently, researchers have shown an interest in preserving spontaneous breathing during mechanical ventilation to allow patients to contribute to their total ventilation, and to decrease the degree of mechanical ventilation needed.¹ ² ₄ ₁₅ Current modes of ventilation are often limited in their ability to provide for spontaneous breathing. This can increase the use of sedation and muscle relaxants to suppress respiratory drive and adapt the patient to the ventilator. Bi-Level is a form of augmented pressure ventilation that allows for unrestricted spontaneous breathing at any moment of the ventilatory cycle, thereby promoting patient/ventilator synchrony.
**WHAT IS BI-LEVEL?**

Bi-Level is a breath mode in which the patient has the ability to breathe spontaneously at two levels of PEEP. Its pressure waveform resembles Pressure Controlled Ventilation but differs in its ability to allow spontaneous breathing at both the upper and lower pressure levels.

The gas exchanged while switching between the two PEEP levels, and the contribution of spontaneous breathing at either level produce the combined minute volume. Volume monitoring allows all spontaneous breaths to be displayed at either PEEP level as well as the exhaled volumes from PEEP\(_H\) (PEEP at upper pressure level) to PEEP\(_L\) (PEEP at lower pressure level).

**TWO DIFFERENT VENTILATING STRATEGIES IN ONE MODE**

**Conventional I:E ratios**

There are two ventilatory strategies available within Bi-Level Ventilation. They are differentiated by the time allowed at the lower PEEP level. Bi-Level is not restricted to any specific T\(_H\):T\(_L\) (time high to time low) ratio. If the time spent at both the upper and lower PEEP is long enough to allow spontaneous breathing at both levels, it is commonly referred to as BiPhasic (or BiPAP™ in European literature). Spontaneous breaths at both PEEP levels can be pressure supported if desired.

**Airway Pressure Release Ventilation**

Airway Pressure Release Ventilation (APRV) is a different strategy. APRV always implies a short T\(_L\) time, where all spontaneous breathing takes place at the upper PEEP level. The pressure is then “released” to a lower PEEP level just long enough for the lung volume to decrease, and is immediately returned to the upper PEEP level. The principle of releasing rather than increasing volume to augment ventilation distinguishes APRV from other types of support.\(^1\,1^3\)

More than 30 published case reports and animal and human studies have demonstrated the advantages of APRV in patients with low compliance. APRV augments alveolar ventilation of patients who require ventilatory support, despite improved pulmonary mechanics and oxygenation with CPAP alone.\(^9\,10\,12\,13\) When compared with conventional ventilation, APRV has been shown to maintain oxygenation and cardiovascular performance while decreasing physiologic deadspace ventilation.\(^7\,11\)
What improvement does Bi-Level add to pressure-based breaths?

Pressure Control on the Puritan Bennett™ 840 Ventilator allows unrestricted spontaneous breathing during the set inspiratory time at the target pressure level. The Bi-Level mode offers the following distinct enhancements over pressure support and pressure control, particularly in spontaneously breathing patients:

- Synchronized transitions between PEEP levels with patient breathing.
- Augmentation of all spontaneous breathing at both PEEP levels with at least 1.5 cmH₂O of support.
- Monitoring of spirometry for all spontaneous breaths at both PEEP levels.

Additionally, Bi-Level mode offers expanded Pressure Support (PS) capabilities. When the time at lower PEEP is set long enough to allow spontaneous breathing, PS can be used. If the PS level is set high enough, the breaths at the upper PEEP can also be pressure supported, as shown here.
WHAT ARE THE CLINICAL ADVANTAGES OF SPONTANEOUS BREATHING AT TWO PEEP LEVELS?

Increased patient comfort and synchrony
Since PEEP level transitions and spontaneous breathing are supported, patient comfort and synchrony may be enhanced. Synchronization of inspiration and exhalation to the patient’s spontaneous efforts may further reduce work of breathing.4,20-25

A decrease in sedation
If the patient is allowed to breathe spontaneously during all phases of support, and transition between pressure levels is synchronized, sedation due to patient/ventilator dysynchrony may be kept at a lower level.1,4,5,15,17

A decrease in sedation could result in:
- Less interaction with other organ functions.
- Enhanced ability to identify complications that can be masked by sedation.
- Patients becoming mobile sooner.
- The preservation of an active cough, which may improve secretion removal.15

Improved patient monitoring
The BiLevel mode provides enhanced monitoring information that can assist with clinical decisions. It monitors mandatory and spontaneous tidal volumes and minute volume separately, which offers the clinician a clear understanding of what the patient’s spontaneous ventilation contributes to total ventilation.

Simplicity and ease of use
Bi-Level combines two strategies in one mode. By allowing the principles of APRV to easily transition from controlled ventilation to all levels of augmented ventilation, the Bi-Level mode may be appropriate for the entire course of a patient’s disease process.3,4 Additionally, Bi-Level mode combines the concepts of BiPAP and PS, both of which can be applied noninvasively via face mask.17

WHAT ARE THE BENEFITS OF APRV?

Enhanced ability to ventilate between upper and lower inflection points
In patients with low compliance (such as ARDS), strategies to increase mean airway pressures while limiting peak alveolar pressure, and preventing alveolar collapse by ventilating above the lower inflection point, have been reported.4 A minimal variation from an optimal lung volume maintains higher mean airway pressure at lower peak pressures, which may reduce the risk of overdistension.15 APRV results in nearly constant airway pressures, helping to keep alveoli stable. Ventilation is enhanced in the fast compartments due to the short expiratory time.15 Studies have shown that the release of airway pressure during APRV does not cause significant deterioration in oxygenation or lung mechanics.12
Similar gas exchange at lower peak inspiratory pressure
The ideal ventilation system would allow unrestricted spontaneous ventilation so that only the minimally necessary degree of ventilatory augmentation would be used.\textsuperscript{1,15} Even small amounts of spontaneous ventilation may reduce intrapulmonary pressures, which may enhance venous return and pulmonary circulation. Thus, oxygenation may improve as a result of increased cardiac output.\textsuperscript{15} Studies have shown similar gas exchange and mean airway pressures with lower peak airway pressure.\textsuperscript{5}

**GUIDELINES FOR ADJUSTING BI-LEVEL VENTILATION AT CONVENTIONAL T\textsubscript{hi}:T\textsubscript{li} RATIOS**

The following recommendations are from a five-year study involving 1,500 patients:\textsuperscript{3}

The initial setting of upper and lower PEEP pressures for Bi-Level ventilation can be based on the set PEEP and plateau pressure derived during volume ventilation. Times spent at the upper and lower PEEP settings are often adjusted to a T\textsubscript{hi}:T\textsubscript{li} ratio of 1:1 or to a ratio similar to volume ventilation. The lower PEEP level is adjusted to obtain adequate oxygenation, and the upper PEEP level is usually selected 12 to 16 cmH\textsubscript{2}O above the lower PEEP level, depending on the compliance of the patient, to obtain adequate V\textsubscript{T}. PS can be set to assist spontaneous breathing at either PEEP level.

**GUIDELINES FOR ADJUSTING APRV**

Multiple studies have published similar guidelines for setting up APRV.\textsuperscript{1,2,4,10-13,15,16,18,19} An initial frequency (release) setting can be determined in much the same way as the rate in conventional ventilation (the frequency that achieves acceptable alveolar ventilation). The upper PEEP level (usually 10 to 30 cmH\textsubscript{2}O) is determined by compliance and adjusted to achieve the desired mean airway pressure (MAP) (and its effect on oxygen delivery) and minute volume, keeping in mind that spontaneous ventilation may augment these values.\textsuperscript{2,15}
The lower PEEP level is initially set at 3 to 15 cmH₂O with higher or lower values adjusted to achieve desired release volume. The period of release in most studies has been short (approximately 0.8 to 1.2 seconds for adults). As release time exceeds two seconds, gas exchange appears to deteriorate. Although the exact expiratory time desired is debated, many researchers favor expiratory times that result in minimal levels of auto-PEEP to prevent alveolar collapse of lower compliance lung units. If slight auto-PEEP is desired, it can be detected on the expiratory flow waveform, close to but not yet reaching zero flow. Rapidly changing compliance can cause significant changes in the level of auto-PEEP and resultant FRC. Auto-PEEP should be evaluated frequently and T̄_l adjusted if conditions warrant. Respiratory frequency and the upper pressure level can then be adjusted to maintain desired levels of PaCO₂ and pH. Oxygenation can be increased by any adjustment resulting in an increase in MAP, such as increasing the upper or lower pressure level, or lengthening T̄_p, or by increasing FiO₂.

### WHICH PATIENTS MAY BE POOR CANDIDATES FOR APRV?

Patients with increased airway resistance who are unable to empty their lungs within two seconds will, in all probability, be poor candidates for APRV. Some physicians have excluded people with increased airway resistance as demonstrated by an audible expiratory wheeze or prolonged expiratory time. Examining the expiratory flow pattern to determine increased resistance may be a reliable indicator.

### SUMMARY

The preservation of spontaneous breathing offers challenges to mechanical ventilation. Some newer-generation ventilators incorporate technologies that facilitate synchrony while maintaining a variety of support options and patient monitoring. Bi-Level mode offers two new styles of ventilatory support:

- APRV helps support the current goals for the ARDS patient while optimizing spontaneous breathing.
- Bi-Level ventilation in conventional T₁:T₄ ratio simplifies the transition from controlled to spontaneous breathing, without requiring any change of mode.

Together, they offer new tools to enhance an easy and more physiological means of incorporating today’s ventilation goals.
REFERENCES

1. Lefebvre DL, Stock C. Airway pressure release ventilation. The Department of Anesthesiology, Emory University School of Medicine, Atlanta, Georgia.
6. Cane RD, Peruzzi WT, Shapiro BA. Airway pressure release ventilation in severe acute respiratory failure. The Department of Anesthesia, Div. of Respiratory and Critical Care, Northwestern University Medical School, Chicago.

Ordering Information

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