The Link Between Sedation and ICU Outcomes

Keeping patients comfortable and at ease while they’re in the ICU can be very challenging. Patients often have limited consciousness or ability to communicate.\(^1,2\)

A full 71% of patients show signs of agitation at least once during their stay.\(^1\) Out of compassion, clinicians often turn to sedation to relieve distress.\(^1\)

However, a growing body of research has confirmed a strong link between sedation and poor patient outcomes. When used inappropriately, sedation can lead to failure to wean, prolonged ICU stays and increased cost of care.\(^1\)

The Challenging Reality of Mechanical Ventilation

Although a necessary intervention, conventional modes\(^1\) of mechanical ventilation are limited in their ability to properly manage a patient’s work of breathing.\(^3-5\) In fact, in the ICU, 42% of increases in sedation are in response to patient-ventilator asynchrony.\(^1\)

Without a way to better manage work of breathing, increasing sedation can seem like the best option. But, increased sedation can prolong time on the ventilator.\(^1,2\)

Respiratory muscle atrophy begins in as little as 18 hours.\(^6\) Although there are multiple reasons why atrophy of the diaphragm occurs, it appears that a significant factor is reduced activity, even in PSV and PSV based modes.\(^6\)

\(^1\)VC, VC+, PC, PS and PSV based modes

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1. Patient is mechanically ventilated
2. Sedation is lightened
3. Patient becomes agitated
4. Patient is sedated to alleviate agitation
5. Patient is at increased risk for muscle atrophy

Vicious Cycle Affecting Outcomes

42% of all increases in sedation are in response to asynchrony.\(^1\)
Most patients are extubated in <three
days, but ~20% require prolonged
support.9

ACUTE STAGE
Offload work of breathing and
treat the underlying condition

Controlled Modes
In controlled modes, a patient
doesn’t have to do any work. That’s
often desirable at this stage, but can
cause limitations when trying to get
the patient to breathe on their own.10

WEANING STAGE
Facilitate patients breathing on their own and liberate from the ventilator

Spontaneous Modes
Multiple authors agree respiratory
muscle weakness is an important risk
factor for delayed weaning.7, 11
A study published in the New
England Journal of Medicine found
muscle atrophy occurred in as little as
18 hours of mechanical ventilation.6

Although there are multiple reasons
why atrophy of the diaphragm
occurs, it appears that a significant
factor is reduced activity, even in
spontaneous modes such as pressure
support (PSV).7

FAILURE TO WEAN

In addition, conventional modes of ventilation are rigid in their delivery of a breath. This pattern
can be at odds with the patient’s natural breathing rhythm, facilitating the cycle of asynchrony,
sedation and muscle weakness.3, 4

Volume Controlled
If a patient wakes up and tries to
participate in breathing, work of
breathing (WOB) and/or anxiety can
increase:
  • WOB – Vt limit is not high enough
    or the breath is too short. This
can also cause anxiety.
  • Anxiety – Breath is too long
  • Patient may show signs of
    agitation and is sedated3

Pressure Controlled
Relatively comfortable mode, patient
can receive variable flow, but the
patient does not have to do any work
leading to an increased risk of muscle
atrophy.7, 11

Pressure Support
Spontaneous breathing is allowed, however, it’s still a programmed breath. If the
patient triggers the ventilator he or she receives the programmed breath.
The patient either has to work very hard or not at all if ventilator settings are not aligned.
  • WOB – if the level of support is below patient demand, the WOB will increase
  • Reduced activity – if the level of support exceeds patient demand, the patient
    may have periods of reduced activity leading to an increased risk of muscle
    weakness
  • Ineffective triggers – found to be an independent predictor of longer mechanical
    ventilation duration,4 ineffective triggers can result in an increase in WOB and/
or anxiety
  • Patient may show signs of agitation and is sedated1

To the patient, waiting for that next breath feels like they’re suffocating, causing panic. Being
forced to breathe too quickly, too shallowly, or too deeply is unsatisfying and extremely tiring,
leading to distress.3
Promote Natural Breathing

At Covidien, we believe mechanical ventilation can and should be more natural.

Our PAV™+ software for the Puritan Bennett™ 840 ventilator is a breath type that better manages the patient’s work of breathing and promotes natural breathing compared to conventional mechanical ventilation.8

PAV™+ software manages the patient’s work of breathing differently than other current modes of mechanical ventilation in the following ways.12

With PAV™+ mode the patient defines rate, depth and timing.

- Flow is an indicator of demand. It tells us when the patient wants to begin inspiration, how deep the breath should be, when to end the breath and how often to breathe.
- PAV™+ mode continuously measures patient demand by measuring flow and volume every 5 milliseconds.
- As patient demand changes, PAV™+ mode changes support within the same breath.

Enabling the patient to define rate, depth and timing helps reduce excessive workload or patient agitation, potentially reducing the need for unnecessary sedation.13-17

PAV™+ mode provides better synchrony with a patient’s breathing than pressure support ventilation modes (PSV)

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Costa et al13</td>
<td>“PAV+ improves patient-ventilator interaction, significantly reducing the incidence of end-expiratory asynchrony and increasing the time of synchrony.”</td>
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<tr>
<td>2009</td>
<td>Xirouchaki et al14</td>
<td>“Compared to PS, PAV+ is associated with fewer interventions in terms of ventilator settings and sedative dose changes.”</td>
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<tr>
<td>2008</td>
<td>Xirouchaki et al15</td>
<td>“Compared to PS, PAV+ increases the probability of remaining on spontaneous breathing, while it considerably reduces the incidence of patient-ventilator asynchronies.”</td>
</tr>
<tr>
<td>2007</td>
<td>Bosma et al16</td>
<td>“PAV+ resulted in better quality of sleep compared to PS.”</td>
</tr>
</tbody>
</table>
When the %Support is set, the patient and the ventilator are sharing the work of breathing as defined by the clinician.

- Work of breathing can be calculated using the equation of motion.18
- When R and E are known, it's possible to calculate patient-generated pressure (Pmusc) and work of breathing in real time using the equation of motion.16, 18-21
  \[ P_{\text{MUSC}} + P_{\text{VENT}} = (\text{flow} \times \text{resistance}) + (\text{volume} \times \text{elastance}) \]
- PAV™+ mode measures resistance and compliance every 4-10 breaths.
- Once %Support is set, clinicians can use the work of breathing (WOB) bar for real-time feedback on how much work the patient is doing.
- The work of breathing bar displays both total work of breathing (WOBTot) and the patient work of breathing (WOBpt).
- Associated fatigue values for work of breathing are shown as being outside the green zone.

The work of breathing bar, when coupled with good clinical assessment, can help take the guesswork out of determining the appropriate level of mechanical ventilation support.

Providing real-time feedback on work of breathing enables the clinician to keep the patient at a sustainable level of work—reducing the risk for respiratory muscle atrophy, but off-loading enough work to avoid fatigue.7, 9, 11
A Good Fit for Your Institution

In addition to PAV™ software, the Puritan Bennett™ 840 ventilator features a full suite of software options, safety features and accessories to fit a variety of patients, from infant to adult.

Software Options

Leak Compensation: To help ensure patients are receiving the flow and volume they need, Leak Compensation software immediately detects and rapidly adjusts to changes caused by patient or airway interface movement, leaks and other barriers to targeted breath delivery. This helps prevent auto-triggering and as a result can help minimize patient-ventilator asynchrony.

In studies, the Puritan Bennett™ 840 ventilator with Leak Compensation software was shown to:\textsuperscript{5,12}

- Synchronize to increasing and decreasing leaks in both obstructive and restrictive lung models and with PEEP 5 cm H\textsubscript{2}O and 10 cm H\textsubscript{2}O
- Require fewer breaths to synchronize, under all test conditions
- Perform equally in both invasive and noninvasive ventilation settings
NeoMode 2.0 Software: This software enables the clinician to adjust ideal body weight (IBW) without disconnecting the patient, thereby avoiding the additional risks associated with patient disconnection. The ventilator is also able to detect and compensate for patient leaks, reducing the number of nuisance alarms and improving patient safety.

Bi-Level Software: Permits spontaneous breathing at all times, reducing patient-ventilator asynchrony. This software supports biphasic or airway pressure release ventilation for extra flexibility. An active exhalation valve improves patient comfort and reduces ICU costs associated with continuous sedation.

Volume Control Plus: This controlled breath type enables the patient to take spontaneous breaths, and pressure is automatically adjusted to encourage the patient to pull the targeted tidal volume.

Trending Software: Shows time-stamped displays of ventilator settings up to 53 parameters of monitored patient data and specific events for intervals up to 72 hours.


Tube Compensation Software: Accurately overcomes the work of breathing imposed by the artificial airway. Helps clinicians better recognize when a patient is ready to extubate.
Features Designed for Safety

- **Circuit disconnect detection**: Monitors circuit pressure and effective patient volume to promptly detect circuit disconnection.

- **Automatic patient detection**: Helps prevent inadvertent changes from existing ventilator settings to standby modes that do not provide ventilation.

- **Ongoing background checks**: Assesses the proper function of the ventilator’s electronics and pneumatics hardware continuously during ventilation.

- **Heated expiratory filters**: Traps 99.97% of pathogens to shield patients, clinicians and visitors from exposure to viruses and bacteria from exhaled gases.¹⁸, ¹⁹

- **Puritan Bennett™ 803 extended backup power source (BPS)**: Minimizes risks during power outages by providing up to four hours of continuous battery backup power.²⁰
Accessories

- **Puritan Bennett™ 840 ventilator pole cart**: Enables the ventilator to fit into confined spaces when a compressor is not required. Features dual-wheel castors and an ergonomic 360-degree handle system to improve maneuverability.

- **Puritan Bennett™ 840 compressor mount cart**: Offers a sturdy compressor mount plus either a one-hour or four-hour backup power supply.

- **Puritan Bennett™ 806 compressor**: Fits the compressor mount cart to provide a safe alternative air source if bottled or wall air are not available.

- **Puritan Bennett™ 840 ventilator cart**: Offers lightweight, easy maneuverability in a cost-effective package.
## Standard Accessories

<table>
<thead>
<tr>
<th>Item</th>
<th>Catalog Number</th>
</tr>
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<tbody>
<tr>
<td>Flex arm</td>
<td>4-032006-00</td>
</tr>
<tr>
<td>Inspiratory bacteria filter</td>
<td></td>
</tr>
<tr>
<td>Disposable filter (D/Flex, carton of 12)</td>
<td>4-074601-00</td>
</tr>
<tr>
<td>Expiratory bacteria filter and collector vial</td>
<td></td>
</tr>
<tr>
<td>Disposable filter (D/X800, carton of 12)</td>
<td>4-076887-00</td>
</tr>
<tr>
<td>Test hose</td>
<td>4-018506-00</td>
</tr>
<tr>
<td>Oxygen hose assembly, DIS (U.S.)</td>
<td>4-001474-00</td>
</tr>
<tr>
<td>Air hose assembly, DIS (U.S.)</td>
<td>4-006541-00</td>
</tr>
<tr>
<td>Power cord (North America)</td>
<td>4-071420-00</td>
</tr>
</tbody>
</table>

## Operator’s and technical reference manual

- English: 4-075609-00
- Spanish: 4-070147-00

## Software Options

<table>
<thead>
<tr>
<th>Software Option</th>
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<tbody>
<tr>
<td>NeoMode 2.0 Software Option</td>
<td>10051492</td>
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<tr>
<td>Leak Compensation Software Option</td>
<td>10035870</td>
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<tr>
<td>Tube Compensation Software Option</td>
<td>4-076371-00</td>
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<tr>
<td>Bi-Level Software Option</td>
<td>4-076064-00</td>
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<tr>
<td>Volume Ventilation Plus Software Option</td>
<td>4-078126-00</td>
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<tr>
<td>PAV™”+ Option Kit</td>
<td>4-078203-00</td>
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<tr>
<td>Respiratory Mechanics Option Kit</td>
<td>10019218</td>
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<tr>
<td>Trending Software Option</td>
<td>10020408</td>
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## Optional Accessories

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<tr>
<th>Accessory</th>
<th>Catalog Number</th>
</tr>
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<tbody>
<tr>
<td>Service manual, English</td>
<td>4-070089-00</td>
</tr>
</tbody>
</table>

## Puritan Bennett™ 840 Ventilator Cart and Accessories

- Puritan Bennett™ 840 Ventilator Cart with 1 Hr BPS | 10000193       |
- Puritan Bennett™ 840 Ventilator Cart with 4 Hr BPS | 10000194       |
- Wall-Air Water Trap Kit                          | 4-075315-00    |
- Fisher & Paykel Humidifier Mounting Kit for Black Carts | 4-075313-00   |
- Puritan Bennett™ 803 Backup Power Supply (BPS)   | 10030274       |
- Battery Replacement Kit                          | 4-070523-SP    |

## Puritan Bennett™ 840 Ventilator Compressor Mount Cart and Accessories

- Puritan Bennett™ 840 Ventilator Compressor Mount Cart with 1 Hr BPS | 10046822       |
- Puritan Bennett™ 840 Ventilator Compressor Mount Cart with 4 Hr BPS | 10046823       |
- Cylinder Mount Bracket Kit                       | 10045586       |
- Wall-Air Water Trap Kit                          | 10045588       |
- Universal Humidifier Mounting Bracket for White Carts | 10045589       |

## Humidifiers and Breathing Circuits

- Reusable, adult, with heated wire, for Fisher & Paykel | G-061235-00   |
- Reusable, adult, without heated wire                | G-061208-SP    |
- Reusable, pediatric, with heated wire, for Fisher & Paykel | G-061237-00  |
- Reusable, pediatric, without heated wire            | G-061223-00    |

## Humidifiers and Breathing Circuits (continued)

- Humidifier Base                                    | 4-MR850-00     |
- Puritan Bennett™ MR 850 Starter Kit                | 4-070773-00    |
- Fisher & Paykel Mount Kit for Universal Bracket    | 10081874       |
- Hudson Mount Kit for Universal Bracket             | 10081875       |
- Kendall A2000 Mount for Universal Bracket          | 10081876       |
- Fisher & Paykel Shroud Kit                        | 10081877       |
- Mounting Plate - Fisher & Paykel Shroud            | 10081785       |

## Inspiratory bacteria filter

- Reusable filter (Re/Flex, each)                    | 4-074600-00    |

## Neo filter and adapter

- Neo disposable filter (carton of 12)               | 4-076408-00    |
- Neo filter adapter                                  | 4-076405-00    |

## Expiratory bacteria filter and collector vial

- Reusable filter (Re/X800, each)                    | 4-070305-00    |
- Reusable collector vial (Re/X800, each)            | 4-074647-00    |

## Drain Bag and Drain Bag Accessories

- Drain bag, disposable (package of 25)              | 4-048491-00    |
- Drain bag tubing, disposable (package of 10)       | 4-048493-00    |
- Clamp, reusable (package of 5)                     | 4-048492-00    |
- Drain cap                                         | 4-074613-00    |

## Filters and Sensors

- Seal, expiratory filter                            | 4-070311-00    |
- Filter, foam, compressor inlet                     | 4-074374-00    |
- Oxygen sensor††                                     | 4-072214-00    |

## Nebulizer

- Aeroneb® Pro Nebulizer                             | 4-AP6000-US     |

## Preventive Maintenance Kits

- 10,000-hour preventive maintenance kit, BDU/GUI    | 4-078179-00    |
- 15,000-hour preventive maintenance kit, compressor | 4-076805-00    |

†† Oxygen sensor to be replaced every two years or as necessary by a qualified service technician. Preventive maintenance kits must be installed by a qualified service technician.
References

12. Puritan Bennett™ B40 ventilator operations manual