Access innovative ergonomics and breath delivery technology with the Puritan Bennett™ 980 ventilator

Accurate delivery of tidal volume (Vt) is essential to lung protection. However, in the presence of airway leaks, errors in the delivery of Vt may increase which raises concerns of ventilator-induced lung injuries. Additionally, ventilators should have intuitive user interfaces that limit user errors that contribute to poor patient outcome.

The studies presented in this guide provide an evaluation of technical performance and usability of ICU ventilators. These articles provide evidence supporting the utility of the Puritan Bennett™ 980 ventilator (PB980) to address the ventilation demands of the critical care population.
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<th>Author(s)</th>
<th>Title</th>
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<td>REFERENCES</td>
<td>List of works cited</td>
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### STUDY INFORMATION

**PURPOSE**
Evaluate the technical performance and usability of six ICU ventilators: (1) Dräger Evita™ Infinity™ V500 ventilator, (2) Puritan Bennett™ 980 (PB980) ventilator (3) Philips Respironics™ V680 ventilator (4) Hamilton S1 ventilator (5) GE Carescapes™ R860 ventilator and (6) Maquet Servo-U™ ventilator

**METHODS**
Six ICU ventilators were evaluated by the following tests:

- Lung model technical performance test of triggering, pressure support, PEEP and tidal volume (VT) accuracy under three respiratory mechanics (normal, restrictive, obstructive), three leak (3.5–4.0 L min⁻¹, 5.0–7.0 L min⁻¹, 9.0–12.5 L min⁻¹), and three inspiratory effort (2, 4 and 8 cmH₂O) scenarios with volume-controlled continuous mandatory ventilation (VC-CMV) and pressure-controlled continuous spontaneous ventilation
- Objective task completion test where physicians completed 11 specific tasks on each ventilator. The performance of each ventilator was compared to a reference ventilator familiar to the physicians.
- Psycho-cognitive evaluation test to evaluate the perceived usability, mental workload, and changes in physiological measurements associated with task completion. The performance of each ventilator was compared to a reference ventilator familiar to the physicians.
- Physiology measurement test evaluated pupil diameter, heart, tidal volume, and respiration rate during the objective task completion test

**RESULTS**

**PEEP, tidal volume, and pressure support error and precision**
- The PB980 ventilator tidal volume error was significantly lower than the Servo-U™, S1, and R860 ventilators
- The V500 ventilator PEEP precision was significantly lower than the R860, PB980, and Servo-U™ ventilators
- The V680 ventilator pressure support precision was significantly different that the S1, PB980, and Servo-U™ ventilators

**Triggering accuracy**
- The PB980 ventilator was the only ventilator where trigger delay did not exceed 200 ms in the obstructive condition
- Triggering pressure was significantly higher for the S1 and R860 ventilators compared to the other ventilators

**Objective task completion**
The PB980 ventilator performed the best in the objective task completion evaluation

**Psycho-cognitive evaluation test**
The V680 and S1 ventilators performed significantly worse than the reference ventilator on one or more of the psycho-cognitive evaluation tests

**Physiology measurement**
- During the objective task completion test, physician pupillary diameter variation was significantly higher for the V500 ventilator than the reference ventilator
- Physician respiratory rate was significantly higher for the Servo-U™ ventilator than the reference
- Physician tidal volume was significantly higher for the V500 and Servo-U™ ventilators than the reference

**CONCLUSION**
The technical performance of the ventilators were similar. The ergonomic performance of the PB980 ventilator was superior to the other tested ventilators for safely completing standardized tasks.
MORITA 2016


### STUDY INFORMATION

<table>
<thead>
<tr>
<th>PURPOSE</th>
<th>To assess four ventilators for use errors and user experience.</th>
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</table>
| METHODS | **Participants:** Forty-eight respiratory therapists familiar with the Maquet Servo-U™ ventilator recruited from three North Carolina hospital networks  
**Training:** A self-led, exploration-based training session (max 1.5-hour duration)  
**Methods:** Participants completed 16 ventilation tasks. Use errors and close calls were recorded through observation during each task. Then, system usability and workload were assessed by questionnaires after all 16 tasks were completed. This evaluation was repeated for each of the ventilators.  
• Use error: An action (or failure to act) that directly compromises the safety or effectiveness of a device or that results in an undesirable or unintended treatment  
• Close call: Successful recovery of a use error prior to compromising the task  
**Ventilators:** Maquet Servo-U™ ventilator, HAMILTON-G5 ventilator, Dräger Evita™ Infinity V500 ventilator, and Puritan Bennett™ 980 (PB980) ventilator. |
| RESULTS | • The PB980 ventilator was not found to have statistically significant higher rates of use errors or close calls when compared to the three other ventilators.  
• The G5 and V500 ventilators were found to have statistically higher rates of use errors and close calls when compared to the SERVO-U™ ventilator. |
| CONCLUSION | Even without extensive experience or training with the Puritan Bennett™ 980 ventilator, users were able to safely complete standardized tasks. |
**ITAGAKI 2017**


**STUDY INFORMATION**

| PURPOSE | To evaluate the ability of leak compensation algorithms in all-age ICU ventilators to support synchronous breathing in the presence of leaks during premature/neonatal patient-triggered invasive ventilation and NIV |
| STUDY DESIGN | Bench study using an ASL 5000 Lung Simulator to create four scenarios with differing patient sizes and respiratory mechanics (0.5, 1, 2, and 4 kg). |

**METHODS**

- **End Points:** Asynchrony Index; breathing frequency, resistance, compliance, occlusion pressure, inspiratory time
- **Methods:** Stopcocks were used to create three intentional leak levels in a dry circuit attached to a lung simulator. Spontaneous and Controlled modes were evaluated during invasive and non-invasive ventilation if available on each ventilator for neonatal ventilation.
- **Ventilators:** Medtronic PB840, Medtronic PB980, Maquet Servo-i™*, Evita™” Infinity™” V500, Carefusion Avea™*

**RESULTS**

<table>
<thead>
<tr>
<th>Overall Asynchrony Index (Median)</th>
<th>Medtronic PB980</th>
<th>Medtronic PB840</th>
<th>Dräger Evita™” Infinity™” V500</th>
<th>Maquet Servo-i™*</th>
<th>Carefusion Avea™*</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMV* 1%</td>
<td>33%</td>
<td>3%</td>
<td>50%</td>
<td>62%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>NIV* 2%</td>
<td>75%</td>
<td>NA</td>
<td>100%</td>
<td>NA</td>
<td>&lt;0.05</td>
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*IMV – Invasive Mechanical Ventilation, NIV – Non-Invasive Ventilation*

- During IMV, the Medtronic PB980 ventilator showed similar triggering delays to the Dräger Evita™” Infinity™” V500 ventilator in all scenarios and leak levels.
  - Trigger delay data could not be recorded for the Maquet Servo-i™” and Carefusion Avea™” ventilators with most leak levels as 5 consecutive synchronous breaths were not observed.
- During NIV, only the Medtronic PB980 ventilator was triggered in the presence of a baseline leak in the 0.5 kg simulation.
- During IMV, the Carefusion Avea™” ventilator (without flow sensor) was not triggered by inspiratory efforts in the presence of a baseline leak in the 0.5 kg simulation.
- The Medtronic PB980 ventilator showed significantly lower asynchrony index levels than the Maquet Servo-i™” in non-invasive modes when the smallest two simulated patient sizes (0.5, 1 kg) were assessed (Avea™” and Evita™” Infinity™” V500 ventilators do not support neonatal patient triggered NIV).
- During spontaneous ventilation, a sudden decrease in leak caused ineffective efforts with the Medtronic PB980 and Evita™” Infinity™” V500 ventilators, but backup ventilation with continued spontaneous triggering was activated with the PB980 ventilator and not the Evita™” Infinity™” V500 ventilator.

**CONCLUSION**

The PB980 ventilator was the only ventilator that could trigger and maintain low asynchrony rates across all leak scenarios during both invasive and non-invasive ventilation.

**STUDY INFORMATION**

**PURPOSE**
To confirm previous data that indicated that all-age ventilators performed as well on neonatal patients as neonatal ventilators.

**STUDY DESIGN**
Bench study using an ASL 5000 Lung Simulator to create four scenarios with different patient sizes and respiratory mechanics (0.5, 1, 2, and 4 kg).

**METHODS**
- **End Points:** difference in tidal volume, asynchronous events, breathing frequency, resistance, compliance, occlusion pressure, inspiratory time
- **Methods:** Stopcocks were used to create two intentional leak levels in a dry circuit attached to a lung simulator. Invasive spontaneous and mandatory ventilation settings were used with the tidal volume set at 6 mL/kg and PEEP set at 5 cm H2O.
- **Ventilators:** Medtronic PB980, Maquet Servo-i™*, Dräger Evita™* Infinity™* V500, Carefusion Avea™* ventilators

**RESULTS**

<table>
<thead>
<tr>
<th>End Mode</th>
<th>Medtronic PB980 Ventilator</th>
<th>Dräger Evita™* Infinity™* V500 Ventilator</th>
<th>Maquet Servo-i™* Ventilator</th>
<th>Carefusion Avea™* Ventilator</th>
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<tbody>
<tr>
<td>ΔV, (%)</td>
<td>PC* 3.1</td>
<td>1.5</td>
<td>*</td>
<td>33.8‡</td>
</tr>
<tr>
<td></td>
<td>PSV* 2.8</td>
<td>9.3</td>
<td>*</td>
<td>Not Available</td>
</tr>
<tr>
<td>Asynchrony Occurrence</td>
<td>PC ND* 0.3%</td>
<td>22.1%</td>
<td>21.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PSV 0%</td>
<td>0.3%</td>
<td>26.8%</td>
<td>Not Available</td>
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- PC* Pressure Control - Continuous Mandatory Ventilation (PC); Pressure Control - Continuous Spontaneous Ventilation (PSV); No Data (ND)
- ‡ p<0.05 when comparing VT before and after leaks were added
- * Could not be calculated as 5 consecutive synchronous breaths were not observed

- **Leaks caused persistent volume overshooting in the Carefusion Avea™* ventilator.**
- The Maquet Servo-i™* ventilator was the only ventilator with unacceptable baseline tidal volume outside +/- 10% of target setting and was markedly affected by leaks.

**CONCLUSION**
The Medtronic PB980 and Evita™* Infinity™* V500 ventilators were the only ventilators, out of the four assessed in the study, to achieve the targeted tidal volume in the presence of all leak scenarios during invasive ventilation. The Medtronic PB980 and Evita™* Infinity™* V500 ventilators showed significantly lower asynchrony index when compared to the Maquet Servo-i™* ventilator.

**STUDY INFORMATION**

**PURPOSE**
To compare the performances of six mechanical ventilators in maintaining appropriate tidal volume (VT) delivery in the presence of airway leaks during non-invasive ventilation (NIV).

**STUDY DESIGN**
Bench study using a lung simulator of a 3 kg patient to create 18 scenarios with different combinations of leak levels, PEEP settings, and respiratory mechanics in NIV mode.

**METHODS**
Methods: Compared the actual delivered VT to the value displayed on the ventilators and calculated the mean errors at various levels of airway leaks (0, 1.0, and 1.5 L/min).
Ventilators: Dräger Babylog™* VN500, Puritan Bennett™ 980 (PB980), Puritan Bennett™ 840 (PB840), Maquet SERVO-i™*, and Hamilton-C3 and Hamilton-G5 ventilators.

**RESULTS**
- Of the six ventilators, both Medtronic PB980 and SERVO-i*Maquet ventilators showed less than 10% VT variance in all leak scenarios.
- In the absence of airway leak, all ventilators (except Hamilton C3 ventilator) exhibited minor variance in reported VT.
- The Hamilton C3 and G5 and Dräger VN500 ventilators showed marked increase in error of reported VT, as leak levels increased.

**CONCLUSION**
Not all ventilators during neonatal NIV performed the same: different VT accuracy among different leak conditions. The Medtronic PB980 and Maquet SERVO-i™ ventilators were the only ventilators, out of the six assessed in the study, to have less than 10% error in the presences of all leak scenarios during neonatal NIV.
REFERENCES


