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Monitoring and alarm system for the use of VPAP ST as an invasive bi-level ventilator

Advisory on the Use of ResMed VPAP ST

(ResMed, Australia; ResMed USA, San Diego)

Because of an automatic shut-off feature in the ResMed bilevel (S9 VPAP and AirCurve), these devices should NOT be used for invasive ventilation unless no other options exist.

The ResMed VPAP ST is designed to be a *noninvasive* ventilator. Incorporation of supplemental oxygen at > 15 LPM into the circuit anywhere distal to the blower should be undertaken with extreme caution.

At a set CPAP or EPAP > 10 cmH₂O, oxygen flows > 15 LPM in a circuit with a standard exhalation port can result in an unanticipated device shut-off and patient harm. This shut-off does not occur at EPAP ≤ 10 cm H₂O or when O₂ flow < 15 LPM.

At supplemental oxygen flows of 15 LPM, the maximum achievable FiO₂ will be no higher than 60%. If a patient requires FiO₂ > 60% or PEEP > 10 cmH₂O, the use of another brand of bilevel or a conventional invasive ventilator should be considered.

Exercise extreme caution when EPAP requirements exceed 10 cmH₂O and FiO₂ requirements exceed 60%!

This document should be used as a clinical adjunct to the protocol “Repurposing bi-level ventilators for use with intubated patients while minimizing risk to health care works during insufficient supply of conventional ventilation for patients with COVID-19” and is shared with our health care colleagues to increase knowledge about potential solutions to increase the capacity and access to mechanical ventilation during the COVID-19 crisis. Icahn School of Medicine does not warrant the contents or effectiveness of the protocol, and the use and implementation of this protocol should be first reviewed and evaluated with each hospital’s medical staff.

Mount Sinai Health System

Monitoring and alarm system for the use bilevel as an invasive ventilator

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Mount Sinai Health System

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BACKGROUND

Many bilevel devices, including the Resmed VPAP ST, intrinsically lack audible alarms. In addition to standard ECG, SpO₂, and blood pressure monitoring per ICU protocol, intubated patients ventilated with any bilevel device **must** be connected to a dedicated external monitor with an audible alarm system that is capable of continuous pulse oximetry (SpO₂), end-tidal carbon dioxide (EtCO₂), and inspired oxygen concentration (FiO₂) monitoring. This system can provide crucial clinical data about the patient’s physiologic state and alert providers of life-threatening events such as circuit disconnect or blockage, while limiting staff exposure to pathogens by reducing the need to enter the patient’s room. Spirometric data obtained with specialized respiratory modules may provide additional information that can guide clinicians in optimizing ventilator settings.

MONITORING CONFIGURATION

A bilevel device preset has been configured in GE CARESCAPE B450 monitors to allow for ease of standardized monitoring among patients using the bilevel devices, including the Resmed VPAP ST. In the device-specific preset, alarms for SpO₂, EtCO₂, and FiO₂ are “locked in” to prevent alarm inactivation by practitioners. Alarm parameters can be individualized for each patient’s unique ventilatory needs. Alarm max and min thresholds should be set within approximately 15% of the patient’s ventilation parameters. A narrow alarm threshold range allows the monitor to detect not only mechanical insults to the circuit, but also patient-related events such as ventilator dyssynchrony, bronchospasm, or mucus plugging.

Table 1: Example alarm setting for a patient on bilevel S/T ventilation mode:

Parameter	Value	Alarm min-max
SpO ₂	94%	78% - 96%*
EtCO ₂	50 mmHg	42mmHg - 60mmHg
FiO ₂	50%	35% - 75%
Respiratory Rate (CO ₂)	30 breaths/min	25 - 45
Respiratory Rate (Impedance)	30 breaths/min	25 - 45**
Tidal volume (Insp and Exp)	300 ml	255ml - 345ml
Minute Ventilation	9 L/min	7 L/min - 12 L/min
PEEP	10 cmH ₂ O	8 cmH ₂ O - 12 cmH ₂ O
Peak pressure (P _{peak})	25 cmH ₂ O	21 cmH ₂ O - 29 cmH ₂ O***

*Target SpO₂ in patients with COVID-related lung injury should go no higher than 96%.

** Sensitivity for impedance-based respiratory rate should be set based on ECG electrode positioning and adjusted for body habitus and positioning. Sensitivity set to > 50% may lead to inaccurate data from excessive movement or capture of cardiac oscillations leading to miscounting.

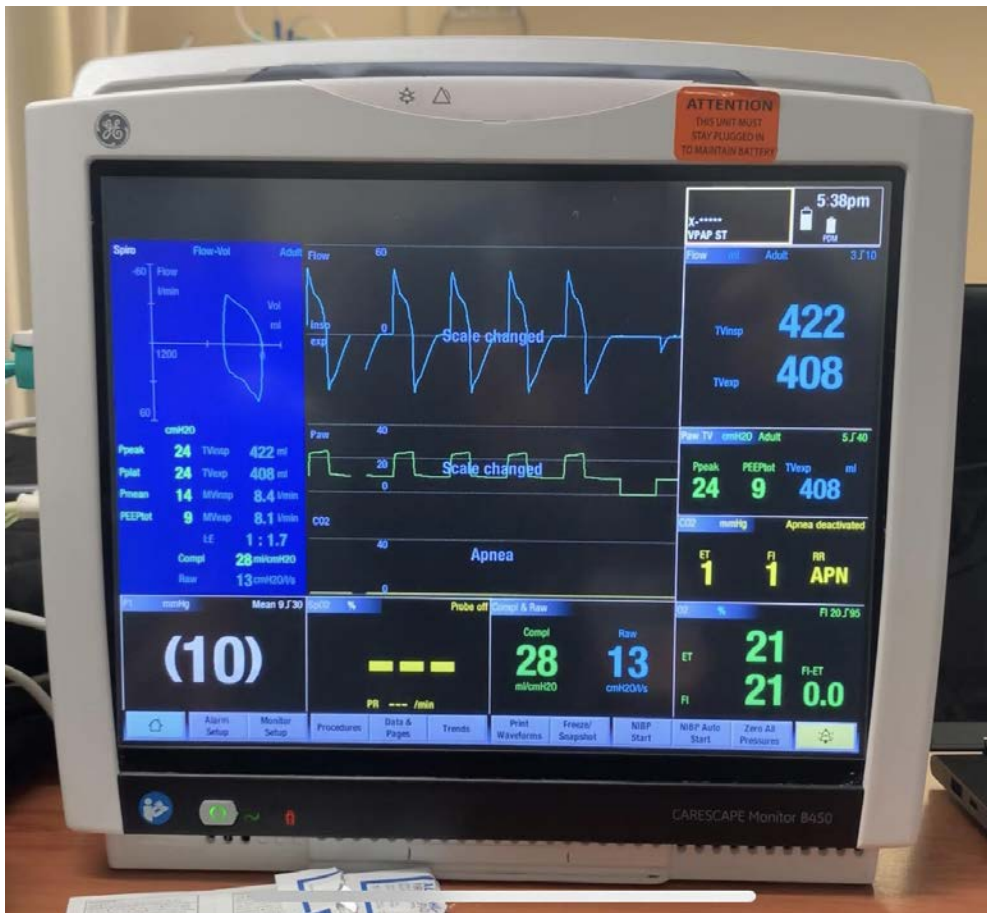
*** This is unlikely to alarm because the IPAP is preset on the VPAP ST.

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While this monitor setup closely approximates that of a typical invasive ventilator, it is not perfect. Although the monitor can detect abrupt changes in tidal volume, minute ventilation, PEEP, and peak pressure; GE’s current firmware for the CARESCAPE B450 limits user configuration of priority and escalation times to hasten audible alarming, which can lead to adverse patient outcomes. Therefore, monitoring variables with **zero-second alarm delays**, such as SpO₂, EtCO₂, and FiO₂ should be prioritized. Spirometry monitoring as the *sole* monitoring modality for bilevel patients is **not recommended**.

Of note, redundant monitoring may provide an additional margin of safety in the event of equipment failure. For example, poor peripheral perfusion in critically ill patients can affect SpO₂ readings, in which case, a second sampling source may be preferred. In the event of respiratory module failure, a secondary source of airway pressure monitoring via a separate pressure transducer can serve as a backup alarm.

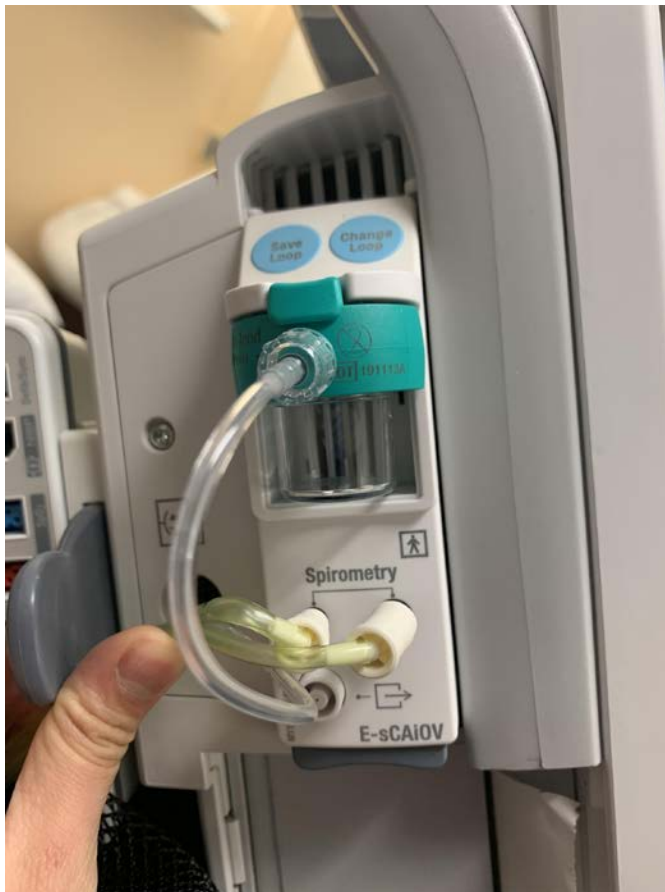
Figure 1: Ventilator monitoring with a GE CARESCAPE B450 monitor fitted with the E-SCAiOV respiratory module and back up invasive airway pressure monitoring



The screen is configured to display multiple spirometric variables, including a flow-volume loop, in real-time with audible alarms. A mean airway pressure, measured via a pressure transducer, is displayed on the bottom left corner. EtCO₂ will be displayed on the bottom row when the circuit is connected to a patient.

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Figure 2: GE E-SCAiOV respiratory module with a D-Fend Pro+ side-stream gas sampling and spirometry



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