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

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BACKGROUND

The VPAP ST intrinsically lacks audible alarms. In addition to standard ECG, SpO_2, and blood pressure monitoring per ICU protocol, intubated patients ventilated with the VPAP ST **must** be connected to a dedicated external monitor with an audible alarm system that is capable of continuous pulse oximetry (SpO_2), end-tidal carbon dioxide ($EtCO_2$), and inspired oxygen concentration (FiO_2) 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 "VPAP ST" preset has been configured in GE CARESCAPE B450 monitors to allow for ease of standardized monitoring among patients using the VPAP ST. In the device-specific preset, alarms for SpO_2, $EtCO_2$, and FiO_2 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 (Impedence)	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 (Ppeak)	25 cmH$_2$O	*21 cmH$_2$O - 29 cmH$_2$O****

*Target SpO_2 in patients with COVID-related lung injury should go no higher than 96%.
** Sensitivity for impedence-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.

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 SpO_2, $EtCO_2$, and FiO_2 should be prioritized. Spirometry monitoring as the *sole* monitoring modality for VPAP ST 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 SpO_2 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**
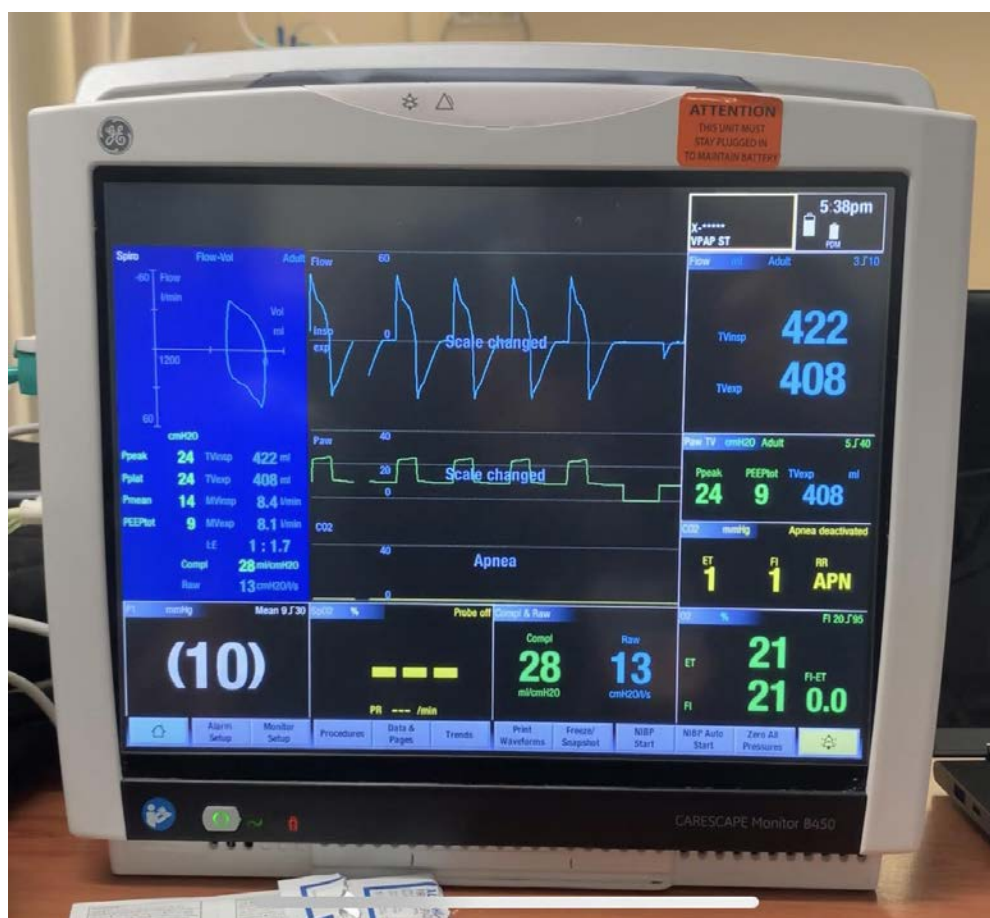
The screen is configured to display multiple spirometric variables, including a flow-volume loop, in real-time with audible alarms. A mean airway pressure, measured via a pressure transducer, is displayed on the bottom left corner. $EtCO_2$ will be displayed on the bottom row when the circuit is connected to a patient.

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