CLINICAL BULLETIN

January 24, 2005

To: **Newport International e500 Ventilator Users**

SUBJECT: **Understanding e500 Ventilator Volume Delivery and Monitoring**

The following information is provided to help you understand that it is normal to see variations between the monitored V_TE (exhaled tidal volume) and the set and/or delivered V_T. These variations may be the result of the difference between the assumed gas condition and the actual gas condition, the result of initial ventilator warm-up period or the result of F_IO_2 changes.

Assumed Gas Condition versus Actual Gas Condition

Ventilators deliver gas that is at Ambient Temperature Pressure Dry condition (ATPD condition: ~25 °C and dry (ambient temperature, ambient PB, P_{H2O}= 0 mm Hg). When this cool dry gas enters the lung, it is warmed and humidified to Body Temperature Pressure Saturated condition (BTPS condition: 37 °C and 100% relative humidity). If a ventilator delivers 100 mL gas, it will expand by 11% when it is inhaled to the patient lung because of the added heat (adding ~ 4^+%) and the added humidity (adding ~ 6^+%). Thus, the 100 mL dry and cool gas becomes ~111 mL in the patient lung.

The e500 is designed from the patient's perspective so the tidal volume you set is the tidal volume in the lung. All gas delivery is referenced to BTPS. The e500 delivers a tidal volume that is 11% lower than set tidal volume so that when it expands by 11% in the lung, it will be equal to the user set volume. Physiologically, it makes sense to do it this way.

If the volume stays at BTPS condition when it reaches the exhaled volume monitor, exhaled volumes will be very close to set volumes (minus leak). If the gas cools down and/or loses water content, or never entered the lung to become BTPS, the monitored exhaled volumes will be lower than the volume that actually left the lung.

Example Using High Output Humidifier with e500 Ventilator to Ventilate a Patient:
If you set 500 mL tidal volume the ventilator delivers 500 – (500 x 11%), i.e., 445 mL, and expects the gas to be expanded with heat (adding ~ 4^+%) and humidity (adding ~ 6^+%), to become 500 mL in the patient lung and continue to hold the same heat and humidity when it exits the circuit into the exhalation flow sensor.

Example Using No Heated Humidifier or Heated Wire Circuit to Ventilate a Test Lung:
If you are not ventilating a patient but instead, ventilating a test lung without a heated humidifier or heated wire circuit, the 445 mL that leaves the e500 (when V_T 500 mL is set) will still be 445 mL when it passes the exhalation flow sensor. So even though set V_T is 500 mL and there are no leaks the V_TE will read ~445 mL. When you put the ventilator with heated humidifier and heated wire circuit on the patient, V_TE will become 500 mL.

Example when Switching a Patient from a Ventilator Referenced to ATPD to the e500 Ventilator:
If you switch a patient from a ventilator referenced to ATPD to the e500 Ventilator that is referenced to BTPS, you will probably notice a decrease in the patient's peak airway pressure (in Volume Control). This is because the e500 ventilator that is referenced to BTPS is delivering 11% lower tidal volume than the one referenced to ATPD.

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Warm Up Time after Powering on the e500

Even though the gas that is exiting the patient lung is in BTPS (37 °C and 100% relative humidity), condition, it cools down to a certain degree as it passes through the cold expiratory limb of the breathing circuit. When the cooled gas enters into the heated exhalation system of the e500, it will be heated to about 37 °C. The e500 calculates the exhaled tidal volume with an assumption that the exhaled gas is 37 °C. But for the first 30-45 min after e500 is powered on, the heater is not fully warmed up, therefore it is not able to heat the exhaled gas to 37 °C. This will result in a monitored V_TE that is lower than the actual value. The error during the initial 30-45 min is no more than 10%, which is within the international standard requirements for ventilators.

The Impact of F_IO_2 Setting Changes

The e500 exhalation flow sensor is a differential pressure flow sensor, which is affected by gas density. Air has a different density than O_2 so the ventilator is programmed to modify its calculation for volume based on the F_IO_2 setting. When you set F_IO_2 at 0.21, the exhalation flow sensor assumes that the exhaled gas O_2 concentration to be 0.21. If you change the F_IO_2 to 1.00, the ventilator's exhalation flow sensor will immediately assume that the exhaled gas O_2 concentration is 100%. However, in reality, although the inspired O_2 concentration will immediately become 1.00 in this case, the exhaled O_2 concentration will not become 1.00 immediately. Instead, the exhaled O_2 concentration will gradually increase from 0.21 to 0.30, to 0.40, ... to 1.00 as the residual gas in the lung is washed out to the new concentration level. The bigger the volume of the lung capacity, the longer it will take before the exhaled O_2 concentration becomes 1.00. This means that in an adult patient, it will take probably 10-15 breaths, and in the case of a typical test lung, it will take 3-4 breaths.

If you increase the F_IO_2 from 0.21 to 1.00, you will see the displayed V_TE drop by up to 10% in the first breath and then gradually return to the normal value. If you decrease the F_IO_2 from 1.00 to 0.21, the displayed V_TE will jump up by up to 10% in the first breath and then gradually return to the normal value. Again, the speed at which the value returns to the normal value depends on the size of the lung.

Keeping the laws of physics in mind can help eliminate confusion about variations in volume delivery and monitoring.

If you have any questions about this information please contact Newport Clinical Education: 1.714.427.5811 ext 218 or email: clinical@newportnmi.com.

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