Humidification Levels during High Frequency Percussive Ventilation Using a Wicking Humidifier and a New Humidifier Technology (Hydrate OMNI™)

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Introduction

High frequency percussive ventilation (HFPV) delivers intrapulmonary percussion to efficiently mobilize secretions while providing a lung protective strategy mode of ventilation. It has been used since the 1980s primarily for ventilation of patients with severe inhalational injury but has been recently used in other applications. However, there is little data on levels of humidification during HFPV despite having been identified by clinicians as a potential concern.

Objective

The purpose of this study was to measure and compare humidification from two humidifier systems during HFPV including a new humidifier technology, the Hydrate OMNI.

Humidifier Technology

The Hydrate OMNI™ (Hydrate, Inc, Midlothian, VA) uses a new technology to create vapor from water. Water is fed by a peristaltic pump from the controller into a small porous ceramic disk. A wafer heater on the top of the disk creates phase transition to vapor which, by volume expansion, is forcefully ejected from the disk into the gas stream. Because temperature and water are controlled separately by the clinician through the controller software the amount of vapor and heat added to the gas can be set independently. The ceramic disk is contained in a clear, disposable plastic housing that is placed immediately proximal to the patient wye to reduce rainout and cooling in the inspiratory limb of the ventilator circuit.

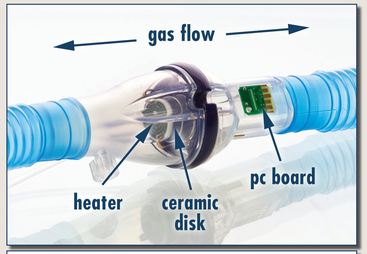

Image One. Close Up of the C-Force™ V unit showing the heater, ceramic disk and pc board.

The ConchaTherm IV Plus (Hudson RCI, Research Triangle Park, NC) uses a wicking material on the sides of a heated tube through which the gas flows. The wicking material allows a near constant surface area for water-gas interface independent of the water level. A heated wire circuit reduces heat loss and condensation in the circuit. The ConchaTherm IV has been used for several years for gas conditioning in mechanical ventilation

Ventilator Technology

The VDR-4® ventilator (Percussionaire Corp., Sandpoint, Idaho) is a time cycled, pressure limited high frequency ventilator which delivers less than physiologic tidal volumes. Two flows provide gas for inspiration: main bias flow and a lower nebulizer flow, both of which are adjustable.

Method

The VDR-4was set at PIP = 30 cm H2O, PEEP = 5 cm H2O, phase = 12 bpm; percussion rate = 600 bpm. Total flow was 20 L/min; nebulizer flow was set to 12 L/min as measured by electronic flowmeter (4040, TSI Incorporated, Shoreview, MN).

Gas temperature and relative humidity were measured using an electronic high-precision capacitive hygrometer/thermometer (SHT75, Sensirion, Westlake Village, CA) which is accurate to 1.8% RH and 0.4°C temperature and placed between the patient wye and test lung. Data collection of relative humidity (RH) and temperature was made over at least 5 minutes of stable readings at a sampling rate of 40 per minute by commercial software designed for the hygrometer (HumiViewer 3.0; Sensirion). Absolute humidity was calculated for each measurement using the following standard equation:

$$AH = ((0.00031243 * T3) + (0.0081847 * T2) + (0.32321 * T) + 5.018) X RH$$

where T is temperature of the gas and RH is relative humidity.

The Hydrate OMNI was set at 37°C, with a water pump speed of 1.2 mg/min and inserted into the inspiratory limb of the circuit immediately proximal to the patient wye. The ConchaTherm was set at 37°C and "+2" for increased humidity and used a dedicated heated wire circuit. For the dual ConchaTherm humidifier setup the second humidifier was placed in the nebulizer flow line proximal to the moving valve and set as above.

Relative humidity of the source gas was <3%. Ambient temperature was 24.8°C + 0.5°C and ambient RH was 47% + 2%. All testing was performed on the same day.

Results did not meet the criteria for parametric analysis using a homogeneity of variance test. Therefore, a Kruskal-Wallis one way ANOVA with a Newman-Keuls Multiple Comparison test for post hoc differences was used. Statistical significance was set at the p< 0.01 level. Statistical analysis was performed using commercial software package (MDAS 2.0, Eskay Software)

Results

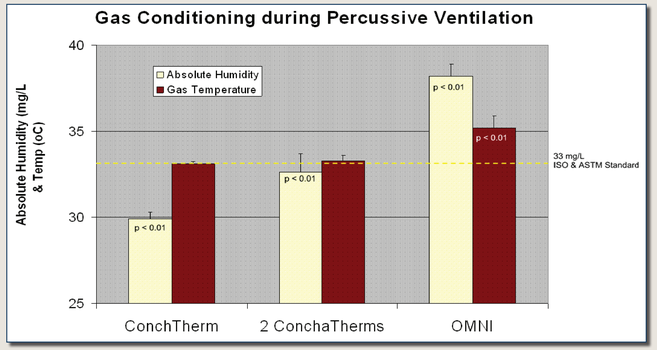

Figure One. Temperature and absolute humidity at the patient wye using a single ConchaTherm humidifier (blue), two ConchTherms (red) and one OMNI (yellow). Note y axis is expanded to show greater resolution.

Both absolute humidity (p<0.01) and gas temperature (p<0.01) at the patient wye were significantly higher using the OMNI. There was no statistically significant differences in either variable between single or dual ConchaTherm humidifier. See results in Figure One.

Conclusions

- The Teleflex ConchaTherm IV Plus water-gas interface humidifier does not provide clinically adequate humidity during high frequency percussive ventilation using the Percussionaire VDR-4.
- Two ConchaTherm IV Plus nebulizers placed in parallel meet AARC absolute humidity guidelines[1] of 30 mg/L but not international recommendations[2],[3] of 33 mg/L.
- The Hydrate OMNI humidifier overcomes the limitation of water-gas interface humidifiers and provides acceptable recommended absolute humidity during HFPV
- The Hydrate OMNI provide closer to set gas temperature at the patient wye than the Teleflex ConchaTherm IV Plus.

References 1. AARC Clinical Practice Guideline: Humidification during Mechanical Ventilation. Respir Care 1992;37:887-890 2. ASTM F 1690-96 (Reapproved 2004) Standard Specification for Humidifiers for Medical Use. 3. ISO/DIS 8185:2004 Respiratory tract humidifiers for medical use — Particular requirements for respiratory humidification systems.