Bench test comparison of absolute humidity delivered by cleared humidification devices and a novel humidification system

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INTRODUCTION

Humidification during mechanical ventilation is important to prevent airway complications such as hypothermia, epithelial damage, and airway obstruction. Traditional devices rely on water sources (water boluses or reservoirs), which introduce infection control challenges and potential risks for aerosolisation of bacteria and viruses. While HMEs reduce reservoir exposure, they may struggle to achieve target absolute humidity across a range of patient needs and ventilation settings, potentially compromising mucosal hydration in some scenarios. There is a clear need for humidification approaches that maintain physiologic humidity without the burdens and risks associated with external water reservoirs. A novel RespirAq™ Active Humidifier (RAH) System introduces rapid-switching fabric technology designed to capture and return moisture, potentially eliminating the need for an external water source while maintaining adequate humidity levels.

OBJECTIVES

The objective of this study was to quantify and compare the absolute humidity (AH) delivered by the RespirAq Active Humidifier (RAH) System against a cleared heated humidifier (HH) (F&P MR850) and a cleared heat and moisture exchanger (HME) (Covidien DAR™) under bench-test conditions that simulate human respiration (see Figure 1).

Bench Test Setup

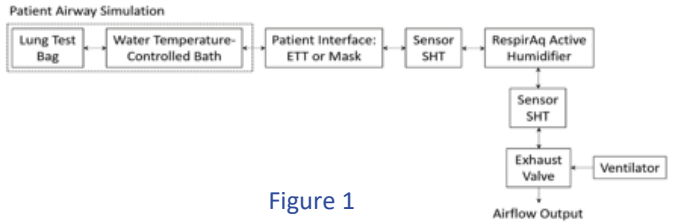

Figure 1

METHODS

A controlled benchtop study was conducted to compare absolute humidity (AH) delivery among three humidification strategies: RespirAq Active Humidifier (RAH) System, a cleared heated humidifier (HH), and a cleared heated moisture exchanger (HME). A closed-circuit adult-size lung simulator was configured to mimic representative ventilation patterns, with tidal volumes of 450–550 mL, respiratory rate 12–18 breaths per minute, inspiratory: expiratory ratio of 1:2, PEEP 5 cmH_2O, and F_iO_2 0.21. An inline hygrometer calibrated for absolute humidity measurement was placed at the airway outlet to capture AH in mg/L. A total of 30 bench experiments were performed, comprising 10 replicated trials per device under identical conditions, with randomised test order to minimise bias. Condensation was controlled by maintaining stable ambient conditions, and the circuit remained closed to avoid external moisture exchange. For each trial, devices were installed in the same circuit and operated under standard manufacturer settings appropriate for clinical humidification. AH was recorded during a defined steady-state interval after warm-up, and the mean AH over this interval served as the primary endpoint.

The primary outcome was mean AH (mg/L) at the airway outlet across devices, with secondary observations on performance stability.

RESULTS

In 30 bench trials (10 per device), the RespirAq Active Humidifier (RAH) System delivered an average absolute humidity (AH) at the airway outlet of 39.1 ± 1.1 mg/L. The cleared HH delivered 39.4 ± 2.4 mg/L, and the cleared HME delivered 32.2 ± 2.1 mg/L. The HME differed significantly from both HH and RAH System ($p < 0.001$ for HME vs HH; $p < 0.001$ for HME vs RAH System). The difference between the RAH System and HH was not statistically significant ($p > 0.05$), indicating comparable humidification performance between the two devices under the tested bench conditions (see Figure 2).

When compared with the clinical benchmark during an invasive ventilation clinical trial (38.8 ± 1.8 mg/L, n = 23), the RAH AH was not significantly different ($p > 0.05$), and the 95% confidence interval for the RAH (38.3–39.9 mg/L) overlapped with the bench test results, supporting the physiological relevance of the bench results (see Figure 2).

RAH System demonstrated low intra-device variability across replicates (SD = 1.1 mg/L) and maintained similar performance to the HH across the matrix of breathing patterns represented in the bench model.

No operational issues were observed during testing: all trials met quality criteria, the circuit remained closed, and no leaks or sensor drifts were recorded during the steady-state measurement interval.

Comparison of humidification devices

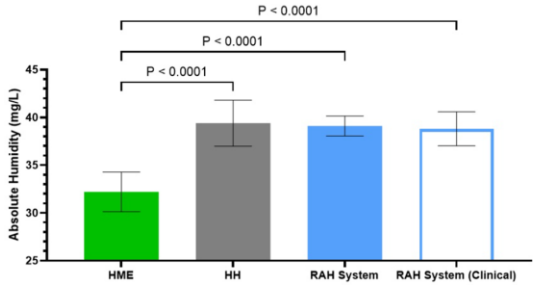

Figure 2

CONCLUSIONS

Bench testing shows that the RespirAq Active Humidifier System delivers physiologic absolute humidity comparable to a cleared HH and significantly higher than a cleared HME, without the need for an external water reservoir. The RAH System maintained consistent humidification across varied simulated breathing patterns and matched the clinical humidity targets observed in invasive ventilation benchmarks. By eliminating reservoir handling, the RAH System offers potential infection-control advantages, reducing reservoir-related contamination and aerosolisation risks while preserving humidification efficacy.