Heated Humidification for Healthcare Professionals Managing COVID-19 Patients

Heated humidification with F&P Evaqua™ 2 circuits promotes a closed system. A closed system reduces the risk of aerosolizing infected particles into the healthcare environment, and this helps reduce the risk of transmission for clinicians.

Summary points

- There is no identified literature (as at May 2020) suggesting that using a heat and moisture exchanger with filter (HMEF) reduces the risk of infectious disease transmission to healthcare workers, compared with heated humidification
- All COVID-19 patients requiring respiratory support have a high viral load, which is of particular concern with aerosolizing or droplet generating procedures. This situation may pose a risk of transmission to clinicians and the healthcare environment when opening the ventilator circuit. Appropriate infection control strategies are vital for the prevention of healthcare worker infections. The use of a heated humidifier reduces the number of circuit breaks required compared to passive humidification with an HME, thereby reducing the risk of aerosols.
- COVID-19 patients, who are critically ill with severe respiratory disease, need high levels of humidity to assist with secretion management, promote efficient ventilation and gas exchange, and to preserve optimal mucociliary function.
- Inadequate humidification increases the risk of an endotracheal tube (ETT) or tracheostomy tube occlusion. HMEs on average, deliver lower levels of humidity than active humidifiers and have been associated with a higher risk of ETT tube obstruction. Obstruction of an endotracheal or tracheostomy tube may require reintubation, an aerosolizing procedure with a risk of infection to clinicians.
- Heated humidification creates water vapor in a closed system. It does not generate aerosolized droplets. Water vapor cannot transport COVID-19 or other viral or bacterial particles.
- Ventilator circuits designed to reduce condensation significantly (i.e. F&P Evaqua 2 circuits) reduce the need for circuit breaks compared to conventional heated circuits. These benefits also reduce the risk of transmitting COVID-19 into the environment and to clinicians.
- Ventilator circuits with the option for use in NIV and NHF (once COVID-19 patients are extubated) simplify equipment requirements and reduce infection risk from the handling multiple circuits. This multipurpose use also saves valuable consumable resources.
- Ventilated patients with COVID-19 require lung-protective ventilation strategies, including maximum reduction of instrumental dead space. HME use is associated with both increased dead space and resistance. Heated humidification is recommended over HMEs because the clinical literature shows heated humidification may support effective lung-protective ventilation:
    - Reducing $PaCO_2$
    - Reducing plateau pressure
    - Reducing tidal volumes
    - Increasing alveolar ventilation

The use of active heated humidification does not increase infection risk to clinicians when compared with passive humidification

1. **There are currently no published clinical studies (as at May 2020) which demonstrate HME use reduces infection risk to clinicians when compared with heated humidification**

2. **Heated humidification reduces the need for circuit breaks and promotes a closed system, which reduces infection risk from cross-contamination**

   The use of a heated humidifier reduces the requirements for circuit breaks. Every circuit break increases the risk of cross-contamination or infection for clinicians treating COVID-19 patients.

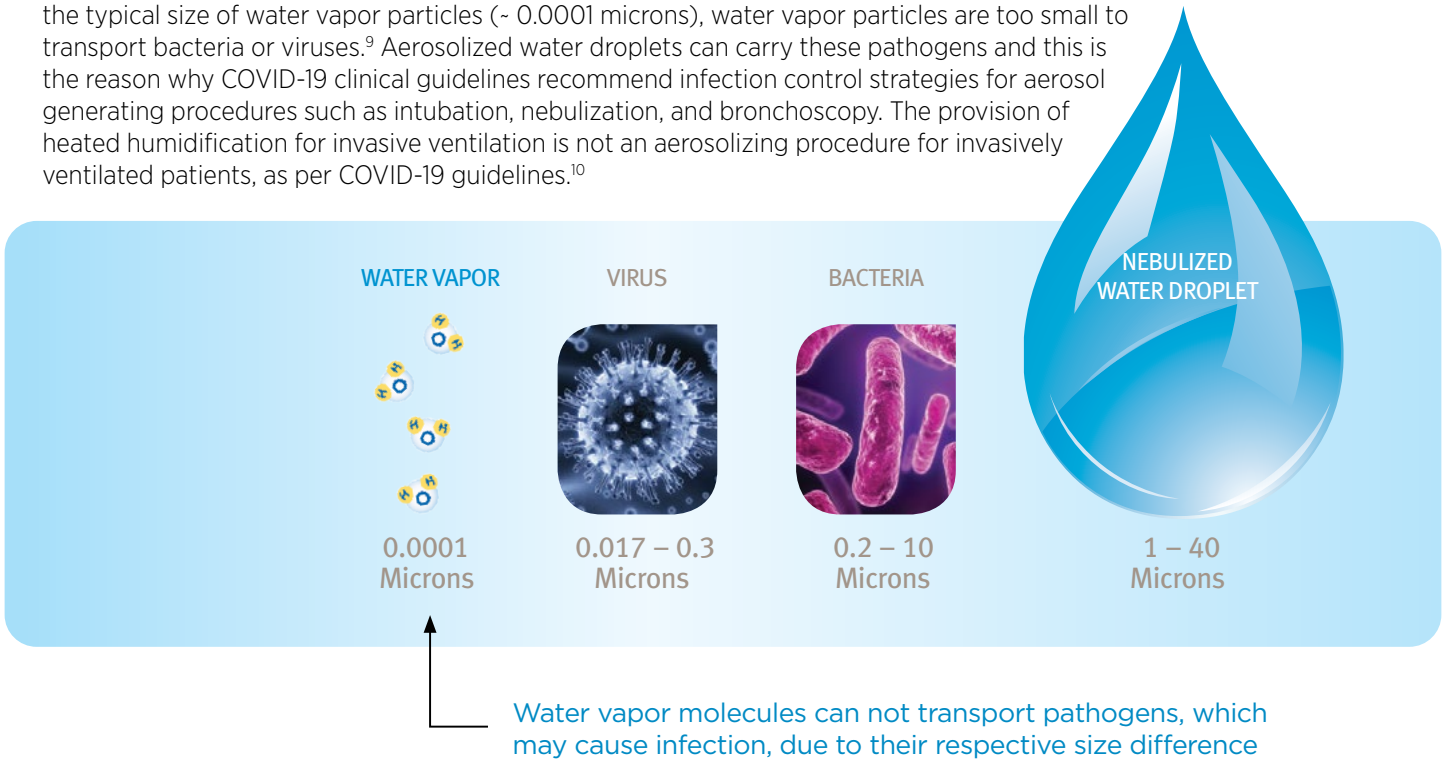
   - Heated humidifiers improve secretion clearance, and reduce the risk of thickened secretions compared to passive humidification. This decreases the number of times a ventilator circuit may need to be opened to manage thick secretions.
   - HMEs with filters may need to be changed frequently due to thickened secretions and filters becoming wet (which reduces filtration efficiency). This requires the circuit to be broken.
   - Heated humidifier circuits that allow water vapor or humidity to diffuse through the material (F&P Evaqua 2 circuits) have been tested to ensure viral and bacterial pathogens cannot permeate or diffuse through the material – only water vapor can, reducing condensation and circuit break frequency.
   - Circuit breaks are inevitable with either active or passive humidification. Active humidification by heated humidifiers can allow clinicians to reduce the number of circuit breaks, promoting a closed system and decreasing cross-contamination risk.

3. **Heated humidification can reduce the occurrence of ETT obstructions from thickened secretions, which may reduce requirements for clinical intervention and aerosol exposure**

   Heated humidifiers can deliver higher levels of absolute humidity than HMEs.[1,2] Delivery of inspired gas closer to core temperature and saturated (37 °C, 44 mg/L H_2O) aids the optimal function of the mucociliary transport system. It reduces the risk of thickening or retention of secretions, which can lead to increased resistance to flow through ETTs, or ETT obstruction. The use of heated humidifiers has been associated with a better quality of airway secretions[1] and a lower incidence of endotracheal tube obstruction when compared to HMEs.[1,3–6] These effects may reduce the requirement for reintubation, and subsequently, the aerosol exposure of clinicians to infectious particles that are associated with performing intubation procedures.

4. Heated humidification generates water vapor (not aerosols) that cannot transport viruses or bacteria

Heated humidifiers represent an active form of humidification that warms respiratory gas within the humidification chamber and delivers water vapor particles to the patient.[7,8] The process of vaporization generates a molecular distribution of water in the air that exerts a gaseous pressure. Due to the molecular nature of water distribution and the typical size of water vapor particles (~ 0.0001 microns), water vapor particles are too small to transport bacteria or viruses.[9] Aerosolized water droplets can carry these pathogens and this is the reason why COVID-19 clinical guidelines recommend infection control strategies for aerosol generating procedures such as intubation, nebulization, and bronchoscopy. The provision of heated humidification for invasive ventilation is not an aerosolizing procedure for invasively ventilated patients, as per COVID-19 guidelines.[10]



5. Newer technology circuits can significantly reduce condensation compared to conventional heated humidifier circuits. Circuit breaks can be reduced, transmission risk decreased, and a closed system promoted

Newer technology circuits can significantly reduce condensation because the material allows water vapor to diffuse through the circuit wall. This material in F&P Evaqua 2 has been designed and tested to ensure that viruses and bacteria cannot permeate or diffuse through the material; only water vapor. F&P Evaqua 2 circuits have insulating material in the inspiratory limb to prevent gas from cooling and condensing in the circuit. The inspiratory insulation and expiratory water vapor diffusion lead to significantly less condensation compared with conventional heated humidifier circuits and reduce the need to break the circuit to empty condensate.

6. Clinicians can use the same invasive ventilation circuit for NIV and NHF on extubated patients; reducing the amount of contaminated waste to be handled

Using a heated humidifier allows the use of a single circuit for invasive ventilation, noninvasive ventilation (NIV), and nasal high flow (NHF). Reuse in different applications simplifies the equipment required and saves individual patients requiring numerous circuits. For example, dual-limb NIV can be performed using the same circuit, or the expiratory limb can be detached to leave the inspiratory limb for single-limb NIV and NHF.

Benefits of heated humidification for ventilated COVID-19 patients

7. COVID-19 patients, who are critically ill with severe respiratory disease, need high levels of humidity to assist with secretion management, promote efficient ventilation and gas exchange, and to ensure optimal mucociliary function

The upper airway naturally heats and humidifies inhaled air to 37 °C and 100% Relative Humidity (44 mg/L Absolute Humidity).[11,12] Invasively ventilating a patient with lower levels of heat and humidity can have the following adverse effects:

- Mucociliary transport system dysfunction[11,13,14]
- Airway drying[15]
- ETT blockages[3,16]
- Thick, difficult to suction secretions[17,18]
- Increased rates of Ventilator Acquired Pneumonia (VAP)[19]

Heated humidifiers aim to deliver optimum levels of heat and humidity to patients (37 °C, 44 mg/L). HMEs achieve a maximum humidity level of 32–33 mg/L, with many producing less than 30 mg/L.[20] Using an HME provides patients with significantly lower levels of humidity than a heated humidifier, and studies show that delivering just 10% less humidity for 15 minutes can have a significant impact on mucociliary function.[21]

8. Heated humidifiers provide humidification without increasing instrumental dead space, an essential requirement for effective lung-protective ventilation

COVID-19 patients require lung-protective ventilation strategies. When compared to HMEs, heated humidification may enable patients to be ventilated with reduced tidal volume (V_T), reducing the partial pressure of carbon dioxide ($PaCO_2$) and plateau pressures (P_{plat}), resulting in increased alveolar ventilation and gas exchange. Heated humidifiers are recommended for lung-protective ventilation,[22] as reduced tidal volume delivery requires minimal instrumental dead space, which cannot be achieved with HMEs.

Lung-protective ventilation is a combination of ventilation settings and associated procedures which can have a direct impact on mortality.[23–27] A key aspect of lung-protective ventilation is minimizing instrumental dead space, which can have a substantial impact on work of breathing, gas exchange, and alveolar ventilation.[24,28–33] Several clinical guidelines recommend lung-protective ventilation for invasively ventilated COVID-19 patients, or those meeting the criteria for ARDS.[10,34]

- The use of a heated humidifier does not add any instrumental dead space, whereas an HME can add up to 100 mL of dead space. Several studies have demonstrated that dead space reduction using a heated humidifier can have a significant impact on gas exchange along with a decrease in $PaCO_2$ which is proportional to the reduction in dead space.[29–33] Prat et al.[31] showed that using a heated humidifier compared to an HME resulted in a $PaCO_2$ decrease (80 to 63 mmHg) without changing any other settings.
- Moran et al.[30] showed that using a heated humidifier compared to an HME resulted in the ability to decrease tidal volume (V_T) by 81 mL, peak pressure (P_{peak}) by 7 cmH_2O and plateau pressure (P_{plat}) by 4 cmH_2O.

9. Heated humidifiers can support more effective weaning in difficult-to-wean patients compared to HMEs

COVID-19 patients will likely be difficult to wean off mechanical ventilation due to the nature of the disease and likely development of Acute Respiratory Distress Syndrome (ARDS). Heated humidification reduces dead space and resistance to flow for optimized weaning when compared to HMEs.[28]

Girault et al.[28] compared the use of HMEs and heated humidifiers in difficult-to-wean patients. They found that using HMEs required pressure support to be increased by 8 cmH_2O in the HME group compared to the heated humidifier group. The study recommended not using HMEs in this patient group.

10. Heated humidification has no contraindications, but it is important to understand the contraindications to HME use that may present in some COVID-19 patients

There are no contraindications to the physiological conditioning of inspired gas during mechanical ventilation. However, clinicians should consider the device used to heat and humidify respiratory gases. While there are no documented contraindications for heated humidifiers, HMEs are contraindicated in some circumstances. These include, but are not limited to:

- Patients with thick, copious secretions[16,22,35] or those requiring long term ventilation, as humidification of inspired gas may be insufficient to prevent airway dysfunction and subsequent HME occlusion.
- Patients with large mask leaks, as the exhaled volume is insufficient to replenish heat and moisture for subsequent inspiration.
- Patients with body temperature <32 °C or with expired tidal volume <70% of the delivered volume, as reductions to exhaled heat and moisture impair HME efficiency.[16,22]
- Patients with low tidal volumes, acute respiratory failure[36,37], chronic respiratory failure[28], ARDS[31] or high minute volumes (>10 L/min)[5,38], as HMEs add dead space to the circuit[22,29–31,36] which reduces alveolar ventilation and can substantially elevate $PaCO_2$,[30,37] resistance to flow, work of breathing, and thus ventilatory requirements.[29,35,39,40]

The American Association for Respiratory Care also recommends the use of heated humidifiers over HMEs in noninvasive ventilation, as this may improve patient comfort and tolerance.[22] The additional dead space and resistance added by the HME system may negate the effects of noninvasive positive pressure, elevating work of breathing and ventilatory requirements.[37]

Note: The simultaneous use of heated humidification and an HME should not be used as per a patient safety alert (PSA) notification issued in 2015 by the NHS and MHRA[41]. For further information please refer to the PSA: *Risk of using different airway humidification devices simultaneously*

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