MAXIMIZING HUMIDIFICATION WHILE MINIMIZING CHALLENGES: A guide to delivering optimal humidification without sacrificing clinician efficiency

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ABSTRACT
Providing proper humidification levels to invasively ventilated patients is of key importance. When the upper airway is bypassed during invasive mechanical ventilation, humidification is necessary to prevent hypothermia, disruption of the airway epithelium, bronchospasm, atelectasis, and airway obstruction. Many patients, particularly those for whom a heat and moisture exchanger (HME) is contraindicated or who require long-term ventilatory support, require the use of a heated humidification system to assure that their requirements are met. With heated humidification, however, comes the challenge of managing the condensation of water that occurs in the ventilator tubing between the humidifier and the patient.

Whether using a conventional ventilator circuit, or one with heated wires, condensation will occur when using heated humidification, and the clinician must address the removal of condensate and any consequences that may result. This paper discusses recommendations related to the use of heated humidification with invasively ventilated patients, the challenges posed by condensation removal from the circuit, and a new product option for addressing these challenges.

HUMIDIFICATION DURING MECHANICAL VENTILATION
It is generally agreed that providing heat and humidification during invasive ventilation is mandatory and a prevailing standard of care worldwide. Two options are available for warming and humidifying the gases delivered to the mechanically ventilated patient: active humidification via a heated humidifier; and passive humidification via a heat and moisture exchanger (HME). HMEs cannot be used in all situations, and are specifically contraindicated in some patients and under some circumstances. Active humidification via a heated humidifier is then recommended to assure that adequate humidification is provided.

Heated humidifiers actively increase the heat and water vapor content of inspired gas. These systems heat both a water reservoir and the ventilator gas coming into contact with the water as it moves from the ventilator to the patient. A maximum delivered gas temperature of 37°C and 100% RH (44mg/ H2O/L) at the circuit Y-piece is recommended. If the temperature of the gas cools as it travels through the ventilator circuit, condensation can occur and liquid water will collect in the ventilator tubing. If using conventional, non-heated wire ventilator circuits, the amount of condensation can be significant due to a pronounced temperature drop between the humidifier and the patient. Therefore, heated-wire circuits have increased in popularity, as they maintain the gas temperature throughout the circuit, reducing the amount of condensation build up.

If heated-wire circuits are used, however, condensation will still occur. This can be a result of changing environmental conditions, selected gas temperature and/or heated-wire settings. Therefore, condensation management and an understanding of the clinical consequences of the available options are important considerations when caring for patients receiving active humidification during invasive ventilation.

THE ROLE OF THE VENTILATOR CIRCUIT: CHALLENGES AND CONSEQUENCES
Breathing circuits without heated wires (conventional circuits) have been used with heated-humidifiers for decades, and are still available and used today. When conventional circuits are used, the temperature at the humidifier must often be several degrees higher than the desired patient temperature at the Y-piece to compensate for the gas cooling between the humidifier outlet and patient. As a result, two phenomena occur: the absolute humidity (AH) of the gas leaving the humidifier is higher; and the gas cools significantly between the humidifier and the patient. Both are exacerbated by cold environmental temperatures and lead to large amounts of condensation in the circuit that must be dealt with on an ongoing basis.

Heated wires are frequently used as a means of controlling the amount of condensation in the ventilator circuit. When heated-wire circuits are used, two things occur: 1) the heated humidifier is able to operate at a lower temperature because it does not have to compensate for significant heat loss between the humidifier and the patient; and 2) the amount of cooling that is allowed to occur once the gas leaves the humidifier and traverses to the patient is reduced.
However, when using heated-wire circuits it is important to remember that insufficient heat and humidification can occur, resulting in complications if the heated wires are not used properly. As stated in the AARC Clinical Practice Guideline, *Humidification During Invasive and Non-Invasive Mechanical Ventilation: 2012*, “When using a heated-wire circuit, consideration should be given to the fact that heating the gas between the outlet of the humidifier and the Y-Piece in an effort to control condensation, will decrease the RH of the delivered gas. The magnitude of the decrease will be dependent upon the temperature gradient between the humidifier outlet and the patient, and environmental conditions in the immediate patient care area. Decreased RH may result in drying of secretions inside the endotracheal tube, with potential risk of its occlusion.”

Therefore, as clinicians strive to ensure adequate absolute and relative humidity levels to patients being invasively ventilated in a variety of environmental settings, some condensation will naturally occur even with heated-wire circuits and must be drained and discarded.

**CATEGORIZATION AND HANDLING OF CIRCUIT CONDENSATION**

Condensation that collects in the ventilator circuit is considered to be contaminated, and care should be taken to avoid cross-contamination of other patients. In addition, because circuit condensation is considered to be infectious waste, it is recommended that strict universal precautions be used when handling it, that it is never drained back into the humidifier reservoir, and that care is taken to avoid accidental drainage of condensate into the patient’s airway. For infection control purposes for those patients being transported, the Centers for Disease Control and Prevention recommend control of exposure to tuberculosis and droplet nuclei are to be implemented when the patient is known, or suspected, to be immunosuppressed or have tuberculosis.

The same concerns apply for the caregiver as well, in light of the above. The collection and disposal of circuit condensation is a matter for concern and an issue that clinicians must address daily in the care of invasively ventilated patients that require heated humidification.

**CONDENSATION CONTROL OPTIONS AND RELATED CONCERNS**

When condensation collects in the ventilator circuit the clinician has two primary options: opening (breaking) the circuit and/or water trap to drain the condensate; or using a “closed-system” approach that does not require breaking the circuit to remove the accumulated condensation.

If the first option is chosen, the following consequences must be dealt with due to opening/breaking the circuit:

- Potential for contamination of the interior of the circuit
- Potential for caregiver exposure to condensate during ventilator/water trap disconnection or disposal
- Potential for cross-contamination of other patients
- Loss of PEEP and/or de-recruitment of the lung

Because of these potential consequences, it is recommended that opening the circuit to drain condensate is to be avoided if possible. The SHEA/IDSA Practice Recommendation *Strategies to Prevent Ventilator Associated Pneumonia in Acute Care Hospitals* indicates that one strategy to minimize contamination of equipment used to care for patients receiving mechanical ventilation is to remove condensate from ventilator circuits, and to keep the ventilator circuit closed while doing so. The AARC Clinical Practice Guideline *Care of the Ventilator Circuit and Its Relation to Ventilator-Associated Pneumonia* states that it makes sense that care should be taken to avoid breaking the ventilator circuit, which could contaminate the interior of the circuit.

It is also recognized that opening the circuit to drain accumulated condensate increases the potential for caregivers to be contaminated during ventilator disconnection. As the AARC Clinical Practice Guideline, *Humidification During Invasive and Noninvasive Ventilation: 2012* states, “When disconnected from the patient, some ventilators generate a high flow through the patient circuit that may aerosolize contaminated condensate, putting both the patient and the clinician at risk for nosocomial infection.” This can occur if the ventilator cycles while the circuit is open, essentially blowing aerosolized condensate out of the tubing and/or open water trap into the atmosphere or onto surfaces, caregivers or others in the immediate care area.

While caregiver exposure to aerosolized condensation when opening the circuit to drain and dispose of condensate is of concern; care must also be taken to avoid cross contamination of other patients.

A final concern when breaking the circuit to drain condensate is the loss of PEEP to the patient, which can result in hypoxemia, shock and/or de-recruitment of the lung. The benefits of using PEEP in the treatment of acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) and in the prevention of ventilator induced lung injury (VILI) has been reported in the literature. It has long been known that an injured lung is at a greater risk for superimposed infection; and the presence of underlying lung injury, especially acute lung injury, imposes a several-fold increase in the incidence of VAP. Ventilator Induced Lung Injury (VILI) is a form of acute lung injury that can occur from repeated opening and closing of atelectatic alveoli in an injured lung, causing a shearing injury. The use of expiratory pressure to prevent alveolar derecruitment can help ameliorate this injury. During positive pressure ventilation cyclical atelectasis may occur due to the repeated application of inspiratory pressure that initially opens (recruits) lung unit, followed by collapse during expiration (derecruitment). An approach to reducing cyclical
atelectasis is to maintain alveolar recruitment with PEEP. Ideally, the lung should be recruited with pressure high enough to open recruitable lung and sustained with adequate PEEP after lung recruitment so as to avoid derecruitment. If the benefit is sustained, no additional recruitment maneuvers are needed. However, if PEEP is not maintained after recruitment, as would occur if the ventilator circuit is disconnected to drain condensate, the recruited lung is almost immediately derecruited.

Clearly there are the recognized risks associated with opening the ventilator circuit to drain condensation. However, not draining the circuit frequently in order to reduce these potential risks also has significant consequences. Excessive accumulation of condensate in the circuit can lead to accidental drainage of condensate into the patient’s airway and unintentional tracheal lavage. This can happen when the patient is turned or repositioned in the bed. Accumulated condensation, which is considered to be infectious waste, may also accidentally drain back into the humidifier.

The challenge and a solution

Since the provision of heat and humidity during mechanical ventilation is the recognized standard of care for patients with artificial airways; and since many patients require the humidity levels provided by an active heated humidification system; condensation management will continue to be a critical factor in the care of these patients. Breaking the circuit to drain condensate is accompanied by a host of potential risks to the patient and the caregiver as discussed above. Not draining the circuit when needed to avoid those risks is also fraught with consequences. Finding a solution that will aid the clinician in efficient condensation management without breaking the circuit will help improve the quality of care and help increase patient and caregiver safety.

The Hudson RCI® ISO-Gard® Closed Circuit Condensation Management System, when used with the ConchaTherm® Neptune® Heated Humidifier, allows the clinician to meet the unique humidification needs of every patient, while helping to avoid the risks associated with breaking the circuit to drain condensate.

The ConchaTherm® Neptune® adjustable Patient Airway Temperature and Gradient Control allow the clinician the ability to adjust absolute and relative humidity based on unique patient, ventilation and environmental conditions. This is in keeping with the AARC Clinical Practice Guideline *Humidification During Invasive and Noninvasive Mechanical Ventilation: 2012*, which states that in order to avoid insufficient heat and humidification resulting in complications, the temperature selection should be based on clinical assessment of the patient, rather than pre-set and nonadjustable.

The ISO-Gard Closed Circuit Condensation Management System allows for the collection of condensate in its reservoir, and is offered in an 80 cc capacity for adult applications and a 40 cc capacity for pediatric and infant applications. Measurement markers on the transparent reservoir allow for the monitoring of condensate volumes and humidification trends. The color-coded suction port on the reservoir and suction wand allow for the timely and efficient removal of condensate in the inspiratory and expiratory limb of the circuit without breaking the circuit or disrupting ventilation due to its closed circuit design. The ISO-Gard Closed Circuit Condensation Management System, when used in conjunction with the ConchaTherm® Neptune® Heated Humidifier, enables the clinician to customize therapy based on ventilator type, humidification needs and environment factors.

Conclusion

Providing heated humidification to patients requiring invasive ventilator support is the acknowledged standard of care. When doing so with an active heated humidification system, condensation is an expected consequence of providing optimal humidity to the patient, regardless of the type of ventilator circuit being used. Condensation collection and disposal, therefore, is required and should be done in a manner that avoids the acknowledged risks associated with breaking the ventilator circuit. The Hudson RCI® ISO-Gard® Closed Circuit Condensation Management System and ConchaTherm® Neptune® Heated Humidifier provide just such a solution.
REFERENCES:


