ADVANCES IN RESPIRATORY THERAPY

Active Humidification

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Learning Objectives

- List indications and contraindications for active humidification
- Define the operation of heated humidifiers
- Discuss the difference between conventional and heated-wire circuits
- Explain the clinical scenarios that can influence the delivery of humidification
- Understand the impact of ambient room conditions and ventilator outlet temperatures on humidification
- Outline the proper care and maintenance of equipment

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Agenda

- Adequate Humidification
- Active vs. Passive Humidifiers
- Low vs. High Flow Humidifiers
- Optimal Humidification
- Ventilator Circuits and Accessories
- Special Considerations
- Proper Care and Maintenance of Equipment

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States of Water

- Changing states (solid, liquid, gas)
  - Dependent on temperature
  - Increasing temperature increases kinetic energy
    - Faster molecular movement
    - Solid (ice) changes to liquid, then to gas
- Evaporation produces water vapor
  - Increases humidity
- Molecular water vs particulate water
  - Nebulizer output = particulate water
  - Humidifier output = molecular water

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Measures of Humidity

- Absolute humidity
  - Actual water vapor content
  - Often expressed in mg/L
- Relative humidity
  - Ratio of actual content to capacity when saturated

$$RH\% = \frac{content}{capacity} \times 100\%$$

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Dew Point

- The temperature to which air must be cooled for it to be saturated with water vapor at atmospheric pressure
  - Example:

	AH	RH
35°C	34	85%
Dew Point Temp 35°C	34	100%

$$RH\% = \frac{content}{capacity} \times 100\% = \frac{34}{capacity} \times 100\% = 85\%$$

$$capacity = \frac{content}{RH\%} \times 100\% = \frac{34}{85\%} \times 100\% = 40$$

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Water Vapor Pressure

- When water is heated, it evaporates
- When water evaporates, water molecules enter gaseous (vapor) state and exert force
- Force per unit area = pressure
- If water vapor is isolated from liquid water it behaves like an ideal gas

$$\frac{PV}{T} = nR = \text{constant}$$

- If water vapor is in contact with liquid water vapor pressure is primarily a function of temperature
  - At 37°C (98.6° F), water vapor = 46.9 mmHg

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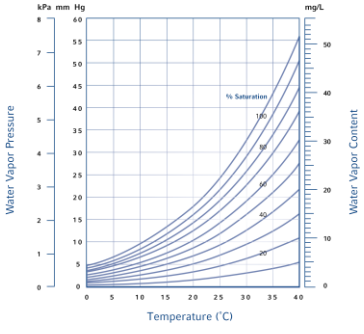
Humidity Relations



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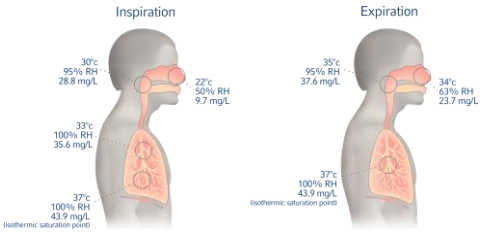
Humidity Conditions in the Body



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Inadequate Humidification

- Inadequate humidification = humidity deficit
  - high minute ventilation
  - breathing cold dry air
- Physiologic effects of humidity deficit
  - destruction of cilia
  - inflammation
  - increased mucus viscosity
- Pulmonary consequences of humidity deficit
  - retained secretions
  - increased resistance, decreased compliance
  - atelectasis

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Delivering Appropriate Humidity

- Active or passive
  - Increase humidity by producing molecular water
- International standards
  - If upper airway bypassed
    - absolute humidity = 33 mg/L
  - If not bypassed
    - absolute humidity = 10 mg/L

PASSIVE

ACTIVE

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Humidification Devices

- Bubble humidifiers
  - Humidity output too low for artificial airways
- Large volume nebulizers
  - Humidity too high and temp hard to control
  - Possible vector for infection
- Heat and moisture exchangers (passive)
  - 19-32 mg/L
  - 22-30°C
- Heated humidifiers (active)
  - 30-51 mg/L
  - 30-40°C

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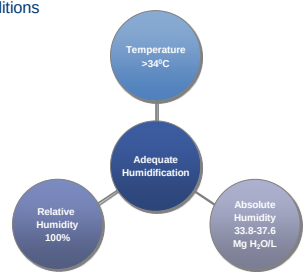
Adequate Humidification

- Heated humidification devices should at least mimic the physiologic conditions



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Modified from: Sottiaux TM. *Respir Care Clinics North Am.* 2006;12(2):233-252.

Active vs. Passive Humidifiers

- Active humidifiers use energy and water external to the body for conditioning inspired gas
- Passive humidifiers rely on temperature and humidity gradient between body and external environment

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Active vs. Passive Humidifiers

- Several advantages of active heated humidifiers
  - Higher absolute humidity
  - No added deadspace
  - Less likely to occlude
  - Decreased resistive load

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Low Flow Active Humidifiers

- Bubble humidifiers, bubble diffuser humidifiers, jet humidifiers, jet diffuser humidifiers
  - ≤10 L/min
  - Unheated, very inefficient
    - Provide only 30%-40% relative humidity
  - Not used with mechanical ventilation

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Dolan GK, et al. *Respir Care*. 1976;21(5):393-403.

High Flow Active Humidifiers

- Operate at >10 L/minute
- At ≈37˚C, capable of providing near 100% relative humidity
- Can be used during mechanical ventilation
- Very efficient
- Several different types

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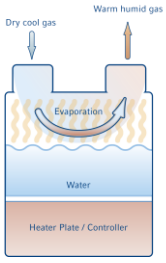
Gilmour IJ, et al. *Am J Infect Control*. 1995;23(2):65-72.

Passover Humidifier

- Gas passes over surface of the heated water
  - Humidity of gas increases
  - Temperature of gas increases
- Humidity control accomplished by manipulating temperature of the water in the reservoir



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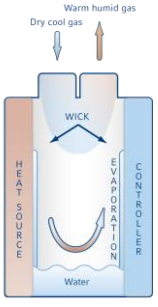
Wick Humidifier

- Modified passover design
- Paper wick increases surface area



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Vapor-Phase Humidifier

- Incorporates a hydrophobic filter
  - Filter separates water reservoir from gas
  - Water heated beneath the filter
  - Water vapor passes through the filter where it is picked up by the gas

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Capillary Force Vaporizer (CFV)

- Integrated into the inspiratory limb of the ventilator circuit
  - Absorbs water through a disk by capillary action
  - Disk heated to create vapor
  - Vapor jets out an orifice (due to the increased pressure from expansion of water from solid into gas)
  - Monitors and controls temperature and humidity
  - Incorporates pump to ensure exact water delivery to the CFV

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Excessive Humidification

- Low risk of over-humidification
  - Most active humidifiers are set to near-body temperatures
  - May affect fluid balance as normal breathing can account for ≈250 mL of insensible water loss per day

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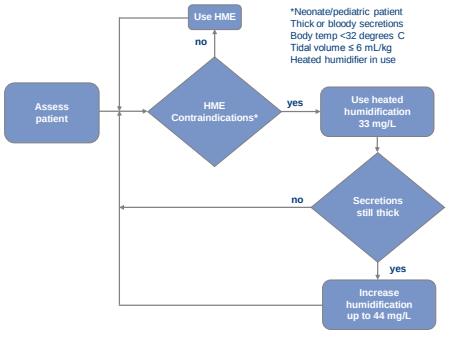
Hess D. *Essentials of Mechanical Ventilation*. New York, NY: McGraw-Hill; 2002: 71.

Humidification Device Selection



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Humidification for Mask Ventilation

- Humidification optional for noninvasive ventilation
- May increase patient comfort and adherence to treatment
- Temperature setting of 30°-34°C may be used with NIV because upper airway is not bypassed

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Ventilator Circuits and Accessories

- Heated wires available for inspiratory limb or both limbs of ventilator circuit
- Higher circuit temperature ensures decreased likelihood of excessive rainout but increased likelihood of inadequate humidification (low relative humidity)
  - Some commercially available humidifiers make circuit/ chamber temperature adjustment automatically; others allow clinician to do so
  - Understand the precise function of the humidifier you are using

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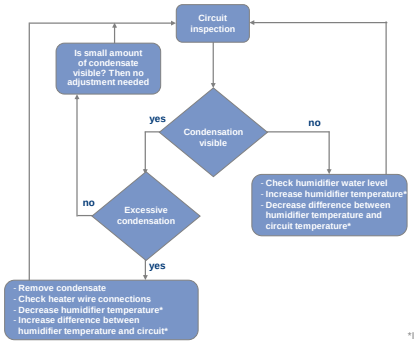
Circuit Management



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*If applicable

Special Conditions Affecting Humidity

- Factors that may affect humidity and circuit temperature include
  - Room temperature
  - Minute ventilation
  - Peak inspiratory flows
  - Ventilator gas outlet temperature
    - Ventilator outlet as well as ambient air temperature could reduce absolute humidity to as low as 20 mg H_20/L

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Lellouche F, et al. *Am J Respir Crit Care Med.* 2004;170(10):1073-1079.

Proper Care and Maintenance of Equipment

- Understand operation and ensure proper function
- Infection control
  - Ventilator associated pneumonia (VAP): nosocomial infection associated with mechanical ventilation
    - Significant cause of patient morbidity and mortality, increased utilization of healthcare resources and excessive cost
    - Strategies to reduce the risk of VAP include
      - Remove condensate from ventilatory circuit
      - Keep ventilatory circuit closed during condensate removal

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Equipment Maintenance

- Circuit change frequency
  - Warm and moist nature of the humidifier and circuit may seem to be prone to infection
  - However, bacteria levels are low in heated humidifiers[1]
    - Nosocomial pathogens survive poorly in the conditions within an active humidifier

The American Association for Respiratory Care (AARC) evidence-based guideline[2]
"No need for routine circuit changes"

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1. Goularte TA, et al. *Infect Control* 1987;8(5):200-203.
2. Hess DR, et al. *Respir Care.* 2003;48(9):869-879.

Equipment Maintenance

- Although routine circuit changes are unnecessary,* routine circuit inspection important
- Be vigilant for:
  - Visible soiling (sputum, blood, etc.)
  - Condensate
  - Other foreign bodies

*Unless indicated by manufacturer's labeling

Conclusion

- Wide range of increasingly complex active humidifiers available
- Clinical scenarios can influence delivery of humidification, adequate level of heat and humidification required
- Know parameters of individual devices
- Individualize treatment based upon patient need
- Employ vigilance to ensure optimal outcomes

Thank you for your attention!

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