DM-Seminar

Humidification in ICU

Dr Ajmal Khan

Introduction

- Water - all three states of matter within a relatively small temperature range
- Energy is applied to liquid water - water vapor
- Amount of water vapor present in a gas is commonly referred to as humidity
- Measured & expressed in terms of
  - Absolute humidity
  - Relative humidity

Introduction

- Absolute humidity
  - Amount of water vapor present in a gas mixture
  - Directly proportional to gas temperature
  - At the alveolar level
    - Gas is 37° C
    - 100% relative humidity
    - Contains 43.9 mg H_2O/L

Introduction

- Relative Humidity
  - Gas mixture is saturated if it contains the maximum possible amount of water vapor it is capable of holding at that temperature
  - Amount of humidity in a gas that is less than saturated is relative humidity

  Relative humidity (%) = (Absolute Humidity) / (Maximum Capacity) X 100

Introduction

- The relative humidity of a gas saturated with water vapor at any temperature is 100%
- The temperature at which a gas is 100% saturated is known as the dew point

Airway humidification

- Function of URT – humidification & filtration
- Inspiration – water from airway to inspired gas
- Humidification continues until full saturation
- Expiration
  - Convection – heat from alveolar air to airway
  - Cooling of air reduces capacity to hold vapor so that condensation occurs
  - Releases latent heat of vaporization
  - Rewarms & rehydrates airway mucosa

Airway humidification

- Mucociliary elevator
  - Comprised of cilia & associated fluid
  - Airway lined with film of liquid ~ 10 µm
  - Watery peri-ciliary (sol) & viscid (gel) layer
  - Cilium bathed in fluid layer & allows it move freely within it
  - Fluid layer –moisture for humidification
  - Claws of the cilium extends through fluid layer contacting viscid layer & propel it cephalad

Airway humidification

- Mucociliary clearance
  - Viscosity gradient
    - Evaporation of water from mucus – viscocity increases from sol to gel
  - Large water losses – inhibits movement of cilia
  - Generate encrustation of mucus obstructing airway or trahceal tube
  - Irreversible damage to airway epithelium

Airway humidification

Isothermic saturation boundary- Gases reach alveolar conditions (37°C & 100% relative humidity)

Above ISB- Countercurrent heat & moisture exchanger

Below ISB- Temperature & water content remain constant

Intubation- Shifts ISB down with extra burden of heat & moisture exchange on lower tract.

Mechanical Ventilation - Delivery of cold, anhydrous gases burdens lower tract & pushes the ISB farther down

Combined effect of intubation & MV results in:

- Severe losses of heat and moisture
- Damage to the respiratory epithelium

Devices for humidification

- Physiology & thermodynamics
  - Inspired air is warmed & humidified - URT
  - Air in pulmonary periphery
    - Saturated (moisture content – 44 mg/l)
    - Temperature of 37^0C
    - Relative humidity of 100%

Devices for humidification

- Nasal respiration
  - Ambient air at $22^{0}C$ & moisture content - 10mg/l

Devices for humidification

- Intubation

Devices for humidification

- Requirement for humidification devices
  - Must ensure physiological condition
    - Pulmonary water loss of > 7 mg/L due to ventilation with dry gases should be avoided
    - Ventilation with saturated gases which are warmer than body temperature
  - Methods for providing humidity
    - Heated humidifiers - microprocessor-controlled, heat and humidifying systems
    - Passive humidifiers – heat & moisture exchangers

High-Flow Humidifiers

- Capable of providing a wide range of temperatures and humidities
- It consist of
  - A heating element
  - Water reservoir
  - Temperature control unit
  - Gas/liquid interface – increases surface area for evaporation

High-Flow Humidifiers

- **Pass-over Humidifiers**
  - Simplest form of heated humidifier

High-Flow Humidifiers

- **Wick Humidifiers**
  - Variation of pass-over humidifier
  - Gas enters a cylinder - lined with a wick of blotter paper
  - Wick is surrounded by a heating element & base of the wick is immersed in water
  - Wick absorbs water & gas contacts the moist heated wick, the relative humidity of the gas increase

High-Flow Humidifiers

- **Bubble Humidifiers**
- Gas is directed through a tube submerged in a water reservoir

- Gas bubbles through the water, through a diffuser or grid, and enters the ventilator circuit

High-Flow Humidifiers

- **Cascade Humidifiers**
- Special form of bubble humidifier
- Gas is directed below the surface of the water reservoir and bubbles upward through a grid
- Grid creates a froth of small bubbles that absorb water
- Efficiently delivers water vapor
- May also deliver micro aerosols
- Temperature in the water reservoir inhibits the growth of pathogens

Passive humidifiers

- Generic term - humidification devices that operate without electricity or water sources
- Device that collects patient's expired heat & moisture - returns it during inspiration
- Also known as "artificial noses"
- Several types - differences are related to device design

Passive humidifiers

- **Heat and moist exchangers**
  - Simplest of passive humidifiers
  - Devices that use only physical principles of heat and moisture exchange
  - Consists of a layered aluminum insert with or without an additional fibrous element
  - These devices have nominal moisture output, providing 10–14 mg H_2O/L at tidal volumes of 500–1000 mL

Br J Anaesth 1974;46(10):773–777
Br Med J 1963;1:300–305

Passive humidifiers

- **Heat and moist exchanging filter (HMEF)**
  - Addition of a filter to an HME
  - Fitted with a spun & pleated filter media insert
  - HMEFs have improved performance compared with HMEs
  - Moisture output of 18–28 mg H_2O/L at tidal volume of 500–1000 mL

Respir Care 1996;41(8):736–743
Intensive Care Med 1995;21(2):142–148

Passive humidifiers

- Hygroscopic heat & moisture exchangers
  - These devices are hygroscopically treated to improve moisture exchanging properties by adding a chemical
  - Paper or polypropylene insert treated with a hygroscopic chemical-calcium or lithium chloride
  - Moisture output of 22–34 mg H_2O/L at VT of 500–1000 mL
  - Addition of filter media to HHME creates HHMEF

Passive humidifiers

- Care of passive humidifiers
  - Assessment of sputum characteristics
  - Suzukawa's method:
    - Thin - Suction catheter is clear of secretions following suctioning
    - Moderate - After suctioning, the suction catheter has secretions adhering to the sides that are easily removed by aspirating water
    - Thick - After suctioning, the suction catheter has secretions adhering to the sides that are not removed by aspirating water

Passive humidifiers

- Care of passive humidifiers
  - Assessment of adequacy of humidification
    - Presence of condensate in the elbow or flex tube between the HME and patient
    - Complex techniques
      - Radioactive isotopes
      - Bronchoscopic evaluation

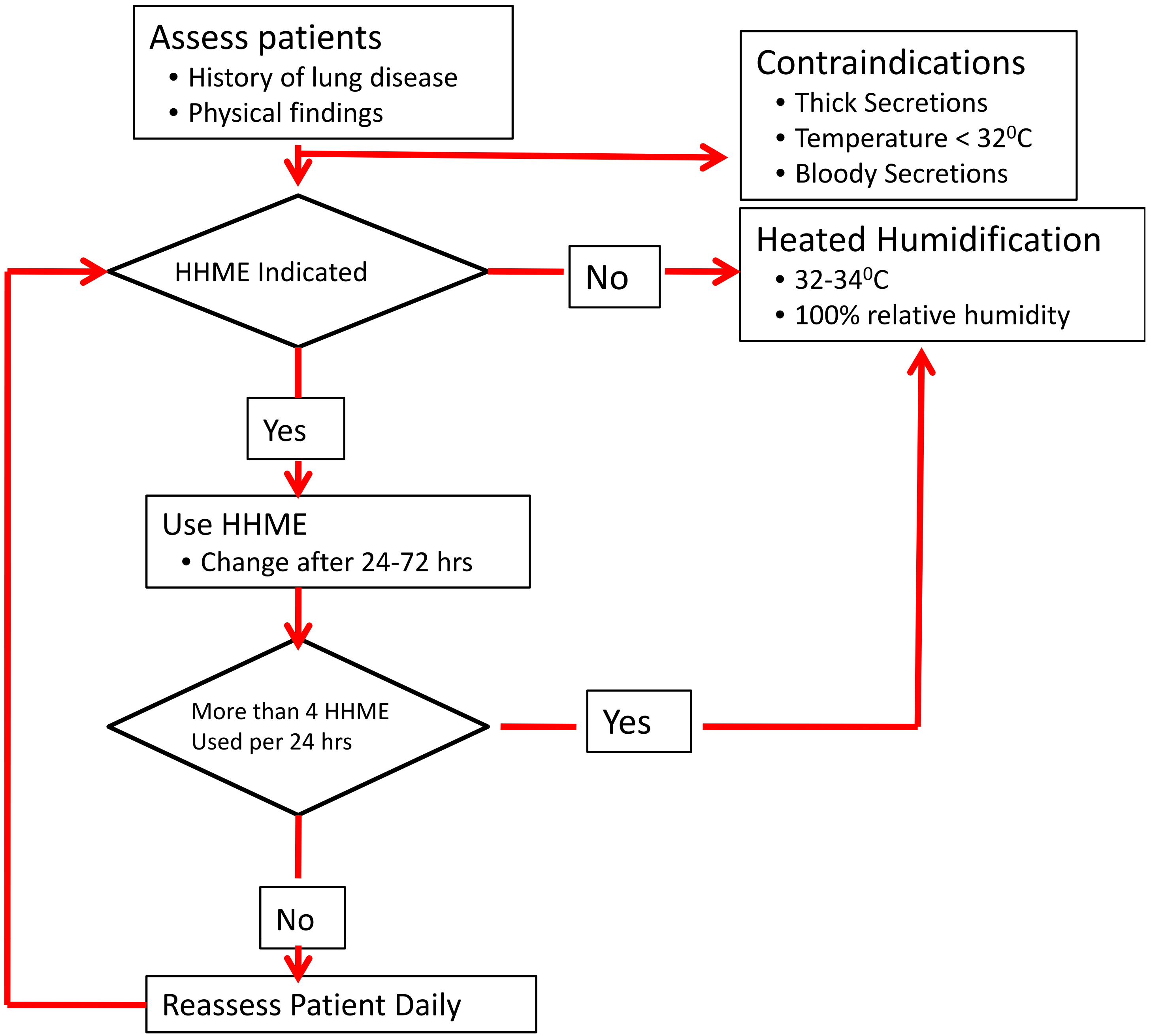
Passive humidifiers

- Duration of passive humidifiers
  - Partial or complete obstruction of endotracheal tubes to occur around 5 days
    Chest 1997
    Crit Care Med 1998
    Intensive Care Med 1992
  - Requiring mechanical ventilation for greater than 5 days – Switch to heated humidifiers
- Frequency of change
  - Changes every 24 hrs
  - Change interval can be increased to every 48 or 72 hours without adverse effect
    Am J Respir Crit Care Med 1995
    Crit Care Med 1999
  - Frequent contamination requiring > 3 changes daily – Switch to heated humidifiers

Comparison of Devices

	Advantages	Disadvantages
Heated Humidifiers	Universal application	Cost
	Wide range of temp. & humidity	Risk of circuit contamination
	Alarms	Condensations
	Temperature monitoring	Water usage
	Reliability	Overheating
		Chance of electric shock
Passive Humidifiers	Cost	
	Passive operation	Increased dead space
	Simple use	Increased resistance
	Elimination of condensate	Potential for occlusion
	Portable	Not applicable in all

Use of Appropriate Humidification Device



Optimum humidification

- Isothermic saturation boundary remains in its natural position
- Inspired air – Saturated, 30^0C to 33^0C maintains physiological condition
- Inspired air in trachea - minimal level of 32^0C at 75% relative humidity - absolute humidity level of 25 mg/L
- Change in humidification device if absolute humidity level of less than 25 mg/L

Over-humidification

- Defined as ventilation with tracheal gas saturated at or above 32^0C – above BTPS
- Humidity above BTPS
  - Progressive worsening of airway structure & function
    - Water condensation in upper airway
    - Decreased mucus viscosity
    - Reduced mucus transport
    - Hypotonicity of secretions
    - Surfactant dilution
    - Thermal cellular damage
    - Airway obstruction

Over-humidification

- Prolonged water condensation
  - Deposition & accumulation of fluids mimicking a drowning effect
  - Local & systemic water intoxication
  - Weight gain
  - Increased local susceptibility to bacterial invasion leading to pneumonia
  - Dilution inactivation of surfactants

Over-humidification

- Ventilation with saturated gas above $35^{0}C$
  - Mucosal hypermia & necrosis
  - Submucosal acute inflammation
  - Decreased functional residual capacity
  - Copious & thin secretion accumulation exceeding normal ciliary transport capacity
  - Thermo-hydric stress
    - Water condensation
    - Heat retention
    - Tracheobronchial burns

Under-humidification

- Cyto-morphologic airway modification
  - Decrease in sol phase depth of mucociliary apprarus
  - Hyperviscocity of airway secretions
  - Tracheal inflammation
  - Epithelial ulceration
  - Epithelial necrosis

- Functional airway modification
  - Decrease in humidification capabilities
  - Downward shift of the ISB
  - Decrease in mucus transport velocity, secretion retention
  - Decrease in bronchospasm threshold
  - Alteration of the ciliary function – ciliary paralysis
  - Airway obstruction and increased airway resistance

- Pulmonary, mechanical & functional alteration
  - Atelectasis
  - Decrease compliance
  - V/Q mismatching
  - Increased intrapulmonary shunt
  - Hypoxemia
  - Pulmonary infections

Humidification devices & VAP

- Respiratory tubing – risk factor for VAP
- Use of HMEs – Decreases VAP
  - Dreyfuss et al – HMEs (61) vs Heated devices (70)
  - Incidence of VAP similar in two groups AJRCCM 1995;151:986-92
  - HME (6/61) & Heated devices (8/70)
- Other studies confirmed this findings
  - Martin et al – Chest 1990;97:144-9
  - Branson et al – Respir Care 1996;41:809-16

Humidification devices & VAP

- Kirton & coworkers   Chest 1998;112:1055-9
  - Randomly allocated 280 trauma patients to HME vs Heated humidifier
  - VAP – HME (9/140-6.4%) & HH (22/140-15.7%)
  - Pitfall
    - Study population was exclusively trauma patient
    - VAP in this population is low as compared to reported figures in same population (17.5%)
    - VAP – No bacteriological sampling
    - Use of poor performing HME in terms of humidity delivery

Humidification devices & VAP

- Two multicenter RCT – Comparision
  - Memish et al – No difference in the rate of VAP in two groups (11.5% vs 15.8%,p=0.3)
  - Lacherade et al – similar rates of VAP in two groups (25.4% vs 28.8%,p=0.48)
- Previous results & Two RCTs
  - Type of humidification device had no influence on the VAP rate

Humidification devices & VAP

- Current recommendation
  - No recommendation can be made for the preferential use of either HMEs or heated humidifiers to prevent VAP

    MMWR Recomm Rep 2004;53(RR-3):1-36

  - Recommend the use of HMEs in patients with no contraindication

    Ann Inter Med 2004;141:305-13

Conclusions

- Humidification devices used must ensure physiological condition

- Proper care of passive humidification devices with switch over to heated humidification devices if
  - Prolonged ventilation
  - Frequent change in HMEs are required