Humidity

Air that is totally saturated with water vapour at a given temp is said to be fully saturated or to have a relative humidity of 100%
The absolute humidity is the number of grams of water per cubic metre of air.
Fully saturated air at 37% has an absolute humidity of 44mg/l.
The associated gas laws show this to have an SVP of 47mmHg (should sound familiar)
Relative Humidity of 50% implies half of this mass of water vapour and also a partial pressure of water vapour at this temp of half of the SVP
Thus, relative humidity can be described as the ratio of the vapour pressure of the sample to the SVP at THAT TEMPERATURE!
As air cools, SVP falls, the air contains less water vapour and that water condenses out of the air as its temperature falls. The converse occurs when air is heated and water evaporates again.

Measurement of humidity

Regnault hygrometer, or a wet/dry thermometer.
Wet/dry thermometer - consists of 2 thermometer, one of which has a bulb covered with a water soaked cloth. Evaporation of water results in a fall of temperature at a rate that depends on the surrounding air humidity, being greater at lower humidity. The difference in temperature between the two thermometers is related to the humidity and is read off a table.

Regnault - enclosed thin silver tube containing ether and a thermometer to measure the ether temperature. There is also a tube through which air can be pumped into the ether. As this happens, the ether evaporates and its temperature falls. Cooling continues until the air adjacent to the the outside surface of the tube gets saturated with water vapour - which condenses. This is known as the dew point. Reference tables show the partial pressure of water for full saturation at the lower temperature which is the same as the unsaturated vapour pressure at room temp. The room temp SVP can also be referenced and the ratio of the two vapour pressures is the relative humidity.

HUMIDIFICATION

Natural humidification occurs when the air is heated by the respiratory tract - gives water vapour carrying capacity a boost and at the same time, evaporation of water from the respiratory tract provides this extra humidification with the result that air is 100% saturated rapidly. Note that the specific heat of air is very low, so it RAPIDLY attains body temperature.

Why is humidification important in theatre?
RH of <50% renders antistatic precautions invalid. Within the resp tract it is important to have adequate humidification to avoid drying and inspissation.
There is considerable heat loss from patients who breathe dry cold gas.
Additionally, we remove the ability of the airways to humidify the air by intubation.

What are the effects of inhaling dry gases?

- Damage to the respiratory tract
  - Secretions dry, ciliary function is reduced, surfactant activity is impaired and mucosa becomes susceptible to injury
  - Airway obstruction can result, as can atelectasis
  - Dry gases can cause bronchoconstriction.
  - No agreement on minimum humidity required to prevent these.
- Body heat loss
  - Is an issue. But controlling this loss doesn't adequately prevent temp loss in theatre.
- Absorbent Desiccation
- Tracheal tub obstruction

What are the effects of excessive humidity?

- Increased water load can cause ciliary paralysis, pulmonary oedema, decreased Vc and compliance.

Sources of Humidity

- Co2 Absorbent
  - Reaction of CO_2 with absorbent liberates water and water is also contained in the granules. The exothermic reaction provides warming.
- Exhaled gases
  - There is some rebreathing in the tracheal tube and circuit almost half of the humidity in expired gas is preserved in this manner.
  - If rebreathing of expired gas is allowed, the final inspired humidity depends on the relative portions of fresh and expired gas.
- Low fresh gas flows
- Coaxial breathing circuits.
  - Not very efficient.
- HMEs
  - See Below.

HEAT/MOISTURE EXCHANGERS
Disposable devices.
With exchanging medium enclosed in a plastic housing. Vary in size and shape. They by convention have 15mm portex connectors..
There may be a port to attach a sampling line. Dead space varies and can be significant.
Two main types

HYDROPHOBIC

- Hydrophobic membrane with small pores. This membrane is pleated to increase surface area.
- Provides moderately good inspired humidity.
- Performance may be impaired by high ambient temperatures
- They are efficient bacterial and viral filters.
- They allow passage of water vapour but not liquid water.
- There is an associated increase in resistance.

HYGROSCOPIC

Contain wool, foam or paper-like material coated with moisture retaining chemicals. May be impregnated with a bactericide

Composite hygroscopic HMEs contain a hygroscopic layer and a layer of thin, non-woven fibre membrane subjected to an electrical field in order to increase its polarity

These are more efficient at retaining moisture and temperature conservation than hydrophobic ones. They lose airborne filtration capacity if they get wet and microorganisms held by the filter medium can be washed through the device and resistance will increase greatly when they become wet.

INDICATIONS

Increase heat and inspired humidity during ventilation.

CONTRAINDICATIONS

Thick, copious or bloody secretions and patients with a leak that prevents exhaled gas from traversing the HME.

FACTORS AFFECTING MOISTURE OUTPUT

Type

Composite hygroscopic better than hydrophobic

Initial humidity

Increasing the humidity in the gas entering the HME from the breathing system will increase inspired humidity

Inspiratory and expiratory flows

Faster the gas passes through the HME the less humidification

Leaks

Will obviously decrease

NB is a nebuliser or MDI is used it should be placed between patient and humidifier
Replace if contaminated

ADVANTAGES

Cheap, easy to use, small, lightweight, reliable and silent
Have low resistance when dry
Do not require water, external energy sources monitors or alarms.
No danger of burns, or shock
Act as barrier to large particles
Role in reduction of nosocomial infections remains controversial.

DISADVANTAGES

Limited humidity output
Insignificant contribute to temp conservations
Increased deadspace

HAZARDS

Excessive resistance

Not a major issue

Heavy secretions can markedly increase resistance

- HME should not be used with a heated humidifier as this can lead to a dangerous increase in resistance.
- With a mapleson system, increased resistance may cause diversion of gas down the expiratory lim b
- May provide enough resistance to nullify the low pressure alarm which activates at disconnection

Obstruction
- Fluid, blood, secretions, weight causing kinking of tube

Inefficient filtration
Foreign particle aspiration
Rebreathing
Leaks and disconnection
Hypothermia
Drying of absorbent - less moisture is supplied to the absorbent

HUMIDIFIERS

A humidifier passes a stream of gas over water, across wicks dipped in water (blow by) or through water (bubble or cascade). Can be heated or unheated

Heated
- Most warm the water in the device

Unheated
- The majority. Fairly inefficient, can only give 9mg/l

Description
- Humidification chamber
  - Contains water. May be disposable or reusable
  - Clear chamber to be able to check the water level
  - Some have a remote reservoir to supply liquid.
- Heat source
  - Heated rods or a plate
- Inspiratory tune
  - Conveys gas to patient
  - If it is not heated it will lose some of the humidity
  - The heating wire should extend as close to the patient as possible
- Temp monitors
- Thermostat
  - Servo controlled
    - Automatically regulates power to the heating element in the humidifier in response to the temp sensed by a probe near the patient
  - Non-servo controlled
    - Power is set manually

Action
- Some heat gas to above patient temp to allow for cooling in tube, this will result in condensation in the tube.
- If tube is not heated, temp will drop - d/o flow rate, length, ambient temp
- A water trap will be required to collect the condensed water

STANDARD REQUIREMENTS FOR HUMIDIFIER's

1. Need to produce >10mg/l unless pt is tubed in which case must make >33

2. Average temp at outlet not to fluctuate by more than 2 deg from set temp after equilibrium is achieved
3. Volume of liquid exiting device should not exceed 1 ml/minute
4. If humidifier is heated, gas temp at delivery tube outlet shall not exceed 41 celsius or at least alarm at that level
5. Surface temp of delivery tube is not to exceed 44 celsius
6. 20degree tilt of device shall not cause water to enter delivery system
7. All dials to be within 5% of spec

Advantages

Saturated gas at body temp even with high flow rates

Disadvantages

Bulky, complex, potential for shock, buttons and increased work.

Hazards

Infection
Breathing system problems - sticking valves, leaks disconnections, obstruction
Melting of delivery tubing
Fires
Shock
Water aspiration
Over hydration
Thermal injury
Increased work of breathing
Monitor interference