Update in
Anaesthesia

Humidification

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Summary

Humidity is an important aspect of delivering gases to patients in theatres and intensive care. Every anaesthetist is expected to understand the principles of humidification of gases. The consequences of not humidifying gases can be serious. This article will cover the basics of humidity and techniques of humidification of gases.

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WHAT IS HUMIDITY?

Humidity is a measure of the amount of water vapour in a gas. Absolute humidity is defined as actual mass of water vapour present in a known volume of gas. The absolute humidity of air in the upper airway of humans is about 34g.m^{-3} and it reaches a peak of 43g.m^{-3} as it reaches the alveoli. Relative humidity is defined as the ratio of the mass of water vapour in a given volume of gas to the maximum amount of water vapour that the same gas can hold at the same temperature. Relative humidity is expressed as a percentage.

ROLE OF HUMIDIFICATION OF GAS

The air we breathe becomes fully saturated with water vapour as it passes through nose to finally reach the alveoli. This humidification maintains mucosal integrity, ciliary activity, prevents the drying of secretions and helps in easy expulsion of respiratory secretions when coughing. Lack of humidification (e.g. ventilating a patient with dry gas through a tracheal or tracheostomy tube) can result in cracking of mucosa, drying of secretions, keratinisation of the tracheo-bronchial tree, reduction in ciliary activity, atelectasis and infection. Over-humidification has its own complications. It can result in water intoxication, especially in neonates and infants in intensive care, water clogging and airway burns.[1] Various methods of measuring and providing humidification are described below. The ideal humidifier should be easy to use, efficient, have low resistance to flow of gas, and should be economical and safe. Humidification can be used with any breathing circuit and may be provided for air, oxygen and a mixture of gases including anaesthetic gases.

MEASUREMENT OF HUMIDITY

Humidity is measured using a hygrometer. The following instruments have been used to measure humidity.[2,3] Most measure relative humidity.

Hair hygrometer

This is based on the principle that the length of the hair increases with increasing humidity. It is fairly accurate between 30 and 90%.

Wet and dry bulb hygrometer

Two mercury thermometers, one in ambient temperature and the other in contact with water through a wick are used. The difference in the temperature reading in these two thermometers is a measure of rate of evaporation of water, that in turn depends on humidity.

Regnault's hygrometer

Air is blown through a silver tube containing ether. At *dew point*, condensation occurs on the outer surface of the tube. Ambient air is fully saturated at this temperature. The ratio of saturated vapour pressure (SVP) at *dew point* to SVP at ambient temperature gives relative humidity. This technique is more accurate than the first two.

Mass spectrometer

This instrument uses the principle of reduction in the ultraviolet light transmitted through the medium containing water vapour.[2]

METHODS OF HUMIDIFICATION

Heat and moisture exchanger (HME) filter

HME filters contain materials such as ceramic fibre, paper, cellulose, fine steel or aluminium fibres in a hygroscopic medium such as calcium chloride or silica gel (Figure 1). Warm, humidified, expired gas passes through the HME, water vapour condenses within the medium and is then re-used for humidification of the inspired gas. The HME is warmed by the latent heat of water condensing on it. This heat is also released during subsequent inspiration. Some filters have bacterial (and/or viral) filtering properties with efficiencies more than 99.9977.[4] The microbial filtering property may be due to:

Direct interception

If the particle is more than 1mcm (micrometer), it is physically prevented from passing through the pores.[5]

Inertial impaction

Smaller particles (<0.5mcm) are held by the filtering medium by van der Waals electrostatic forces.[5]

Diffusional interception
Particles less than 0.5mcm move freely and randomly (Brownian movement) and subsequently swell up and get filtered by the pores.[5]

Electrostatic attraction
Charged particles are attracted by oppositely charged fibres.[5]

Figure 1. *Heat and moisture exchanger (HME)*

The main advantages of HME filters are:

- Easy to use in breathing circuits.
- Cheap and disposable.
- 60-70% relative humidity achieved.
- Temperature achieved ranges from 29-34°C.
- Can be incorporated as a microbial filter.

The main disadvantages of HME filters are:

- Need replacing every 24 hours (maximum).
- Secretions can block the filter.
- Resistance to flow of gas can be up to 2cmH_2O.
- Can add to the weight of the circuit – may be significant in neonates/infants.
- Increase circuit dead space.

Water bath humidifier

A simple **cold water bath humidifier** allows gas to flow through water and carries water vapour as it bubbles out. This type is less efficient as bubbles are large and the loss of heat from the latent heat of vaporization reduces humidity. The vapour output can be increased by warming the water using electricity (**hot water bath humidifier**) but must incorporate a thermostat to maintain an operating temperature at about 40°C (Figure 2). At 37°C, near full saturation can be achieved. A water trap is placed between the humidifier and the patient and is placed below the level of the patient. In a typical hot water bath humidifier, gas flows over the water to become saturated with water vapour. In the **cascade humidifier**, gas bubbles through perforations at the bottom of the water reservoir. Vapour output depends on temperature of the water, gas flow and surface area of contact.[3]

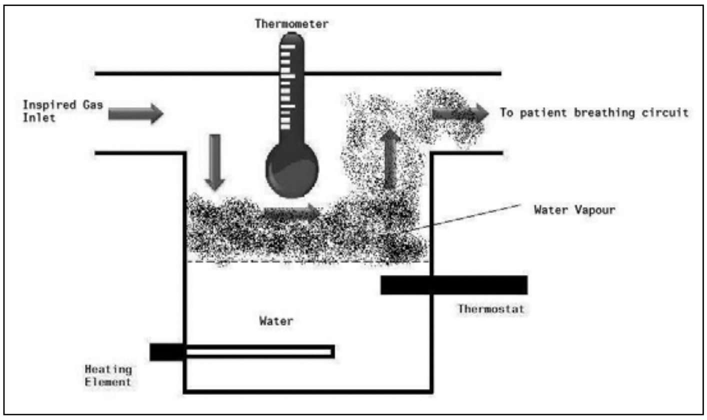

Figure 2. *Hot water bath humidifier*

The main problems of hot water humidifier are:

- Water spillage into the breathing circuit and even into tracheo-bronchial tree. A water trap will help reduce this problem.
- Airway burns due to thermostat failure and overheating.
- Colonization of water with harmful bacteria can occur. This may be reduced by heating the water to 60°C.

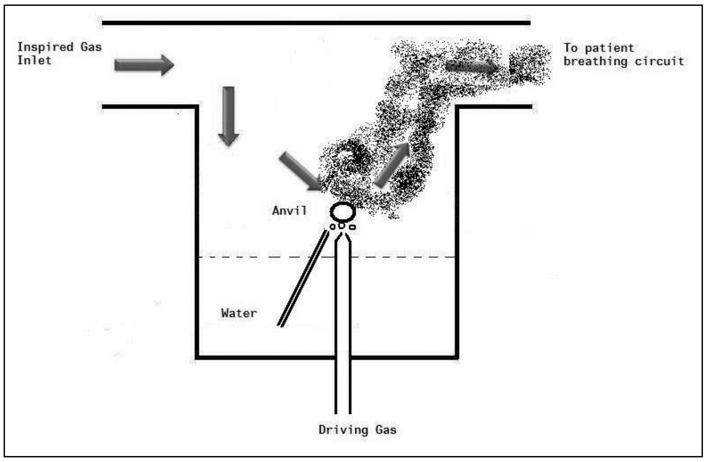

Figure 3. *A nebuliser*

Nebulisers

Nebulisers produce water vapour in the form of microdroplets (1-20mcm) There are three types of nebulisers. In a **gas driven nebuliser** (Figure 3), gas is passed through a narrow orifice that produces a pressure gradient. This results in water being drawn up through the tube and broken into a fine spray as it comes in contact with the high-speed gas jet. Even smaller droplets can be produced if this spray of gas hits an anvil or a baffle. Most of the droplets are in the range of 2-4mcm and deposit in the upper airway with a very small amount reaching the smaller bronchioles. In a **spinning disc nebuliser,** the rotating disc produces microdroplets when water is drawn onto the disc. The **ultrasonic nebuliser** has a transducer head immersed in water vibrating at ultrasonic frequency (3MHz). Ultrasonic nebulizers produce microdroplets less than 2mcm which are capable of reaching alveoli and are therefore a very efficient form of humidification.[5]

A comparison of the various humidifiers is given in Table 1.

Table 1. *Comparison of various humidifiers (fully saturated gas at 37 °C has an absolute humidity of 44g.m^{-3})*

Type of humidifier	Absolute humidity produced (approximate) g.m^{-3}
Cold water bath	10
Heat and moisture exchanger	25
Hot water bath	40
Gas driven nebuliser	60
Ultrasonic nebuliser	90

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REFERENCES

1. Shelly MP, GM LLoyd, GR Park. A review of the mechanisms and methods of humidification of inspired gases. *Intensive Care Medicine* 1988; **14**: 1-9.

2. Bricker S. Humidification (of inspired gases). In: The Anaesthesia Science Viva Book (2004). Cambridge University Press, Cambridge. Pages 230 31.

3. Davies PD, GD Parbrook, Kenny GNC, Humidification. In: Basic Physics and Measurement in Anaesthesia (1995). Butterworth Heinmann. Pages 146-57.

4. Bersten AD. Humidification and inhalation therapy. In: Oh's Intensive Care Manual (2003). Butterworth Heinmann. Pages 321-8.

5. Al-Shaikh B, S Stacey. Humidification and filtration. In: Essentials of anaesthetic equipment (2002). Churchill Livingstone. Pages 103-10.