Humidification

Sampath Shenoy
Correspondence Email: sampathshenoy99@yahoo.com

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 34 g.m$^{-3}$ and it reaches a peak of 43 g.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. 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. Most measure relative humidity.

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.

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. 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. The microbial filtering property may be due to:

Direct interception
If the particle is more than 1 micrometer, it is physically prevented from passing through the pores.

Inertial impaction
Smaller particles (<0.5 micrometer) are held by the filtering medium by van der Waals electrostatic forces.
**Diffusional interception**
Particles less than 0.5mcm move freely and randomly (Brownian movement) and subsequently swell up and get filtered by the pores.¹

**Electrostatic attraction**
Charged particles are attracted by oppositely charged fibres.²

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**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 2cmH₂O.
- 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 tracheobronchial 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.

**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.⁴
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 44 g.m^{-3})**

<table>
<thead>
<tr>
<th>Type of humidifier</th>
<th>Absolute humidity produced (approximate) g.m^{-3}</th>
</tr>
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<tbody>
<tr>
<td>Cold water bath</td>
<td>10</td>
</tr>
<tr>
<td>Heat and moisture exchanger</td>
<td>25</td>
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<tr>
<td>Hot water bath</td>
<td>40</td>
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<tr>
<td>Gas driven nebuliser</td>
<td>60</td>
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<tr>
<td>Ultrasonic nebuliser</td>
<td>90</td>
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</tbody>
</table>

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**REFERENCES**


