CHAPTER

9

Humidification

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Humidification is a natural process of the naso/oropharynx and the upper airway during natural/spontaneous breathing. During normal environmental conditions, when one inhales, the atmospheric air enters the nares at a temperature of 24 to 26°C and at a relative humidity of nearly 50%. In the upper airway this gas is warmed to a temperature of 37°C and added with moisture (water vapor) to obtain a relative humidity of 100% by the time it reaches the bronchi and the respiratory bronchioles. Optimal warming and humidification of the inspired gases maintains the mucus clearing, ciliary function, and the cellular integrity of the respiratory tract.

Bypassing the upper airway as in intubated infants, high flows and use of medical gases as in CPAP or ventilation compromise the humidification process. Suboptimal humidification results in mucus thickening, slowing of the mucociliary function, death of the epithelial cells and growth of bacteria. Greater the time of suboptimal humidification, worse are the effects on the respiratory passage. Every effort should be made to deliver the respiratory gases at body temperature and a relative humidity of 100%.

Absolute humidity, relative humidity, dew point and isothermic saturation boundary are the terms one need to understand to deliver gases at optimal humidity.

Absolute Humidity

It is the actual amount of water vapor in a liter of gas (mg/L)

Relative Humidity (RH)

- It is the ratio of actual amount of water vapor in a liter of gas to the maximum amount it can hold at that temperature. Suppose air at 37 C is holding 22 mg/L of water while maximum it can hold is 44 mg/L. The relative humidity would be 22/44 x100 =50% at 37 C.

- As the gas temperature increases the ability to hold water vapor increases
- Dry heating of gases decreases the relative humidity (maximum ability to hold water vapor increase but absolute humidity remains the same)
- When a gas is fully saturated (100%RH), decreasing the gas temperature leads to water condensation (maximum ability to hold water vapor decreases) but the gas would still be at 100%RH
- Normally a gas is fully saturated with 30mg/L of vapor at 30°C and with 44mg/L of vapor at 37°C
- Heating of the gases with a water bath increases the RH to 100% if adequate time is allowed between the gas and the water bath

When one inhales room air (26°C), the temperature of the gases increases due to body heat but the relative humidity decreases as it goes down the airway if no/inadequate moisture is added to the gas by the mucosa

Dew Point

- It is the temperature at which gas is fully saturated. Below this temperature vapor is lost as water condensate
- When the exhaled air is exposed to a glass slide, as the temperature drops (body temperature to room temperature) the vapor condensates on it as dew drops

Isothermic saturation boundary

- When the inspiratory gas reaches the airway, the junction at which the temperature reaches 37°C and 100 % RH is called the isothermic saturation boundary

In spontaneous breathing this junction is in distal trachea or in the proximal bronchi. In hyperventilating infants it migrates distally. In the absence of humidification, in infants on CPAP or ventilation, as the inspired gases are cool, dry and at a high flow, this junction migrates more towards the alveoli. The more distal the isothermic saturation, the more the damage to the airway and greater are the chances for air way blockade and respiratory infections

Optimal Humidity

When the upper airway is bypassed (intubated infants) the inspired gases should be warmed to 37°C and be fully saturated (100% RH or 44mg/L of vapor) when they reach the airway.

In infants on CPAP or non invasive ventilation the inspirited gases should be warmed to at least 34°C and 85% saturated (85RH).

Practical Aspects

- The medical gases are cold and dry. They are at a temperature of 20°C with RH as low as 5%.
- Compressed air and oxygen hence should be warmed and humidified before delivering them to the infant's airway
- Optimal humidity is achieved by active humidification. These humidifiers actively heat and add water vapor to the inspired gases
- The gas exiting the humidifier chamber should be at body temperature and with 100% RH. This temperature and humidity should be maintained till it reaches the infant.
- After the gas exits the chamber it is heated further by 2 to 3°C (fall in RH) in the inspiratory limb (heated wire circuit) and again allowed to cool by the same temperature (rise in RH) in the last segment of the inspiratory limb.
- Excess heating would dry the airway of the infant and excess cooling in the inspiratory limb would lead to condensation in the inspiratory limb. Avoid raining out in the inspiratory limb.
- It is ideal to have minimal beading (dew drops) in the inspiratory limb and some condensation in the expiratory limb
- Condensation in the inspiratory limb is avoided by:
    - o Placing the distal segment of inspiratory limb inside the radiant warmer or in the incubator
    - o Keeping the room temperature at 26 to 28°C

Adverse effects of Poor Humidification

1. Drying of the mucosa and secretions in the airway
2. Damage to the immature muco-ciliary function
3. Accumulation of secretions in the lower airways and predisposition to pneumonia or recurrent collapse
4. Dried secretions and thick mucus narrow the airway diameter and lead to increased Work of Breathing (WOB)
5. Exposure to dry and cold gases leads to bronchoconstriction