

Rain-Out: Condensation in oxygen tubing; causes and solutions.

Abstract

Condensation that develops, collects, and exits the oxygen tubing when a humidifier is used with an oxygen source, specifically an oxygen concentrator, is referred to as rain-out. Because all commonly used oxygen sources are devoid of humidity, rain-out occurs only with the addition of an external humidifier.

The quantity of condensation is related to the temperature gradient of the humidified gas as it travels through the oxygen tubing and cannula. If the condensation progresses to the point that it exits the cannula, a home medical equipment (HME) provider will need to take action to alleviate the situation for the patient.

The most important step in preventing rain-out is to eliminate the humidifier. Research indicates no clinical benefit to humidified oxygen for patients on low-flow oxygen therapy: flows ≤ 5 L/min. Over the years, humidifier use with oxygen therapy has been significantly reduced at a great savings to health care facilities, providers, and insurers.

Contributing Factors

The Humidifier

A humidifier, commonly called a bubble humidifier or simply, a bubbler, contains water to humidify the dry oxygen from an oxygen source. The humidifier supplies the water that develops into rain-out. As oxygen passes through the humidifier, it combines with water vapor. The ability of a gas to become humidified is related to the temperature of the gas, temperature and pressure in the humidifier, efficiency of the diffuser, and the flow rate. A warmer gas, whether due to a humidifier heater or an elevated outlet gas source, holds more water molecules. When the oxygen is 100% humidified and can no longer maintain water molecules in vapor form at a specific temperature, rain-out is produced.

The humidifier's diffuser breaks the gas into smaller bubbles, increasing surface contact with the water. Water consumption in the humidifier does not increase in a linear manner. A flow rate of 5 liters per minute (L/min) does not necessitate refilling the humidifier five times as often as a flow rate of 1 L/min. Bubble humidifiers typically contribute only a few ounces of water per day.

The Oxygen Source

The occurrence of rain-out increases as the temperature gradient of the outlet gas and the oxygen-carrying accessories increases. Factors that raise the outlet gas temperature or allow for rapid cooling of humidified oxygen as it travels through oxygen-carrying accessories increase condensation and rain-out.

Outlet gas temperature is dependent upon the delivery source. Cylinders, liquid oxygen systems, and oxygen concentrators have inherently different operating temperatures. Gas cylinders have an outlet gas temperature equal to the room ambient temperature, unless they have been recently installed or are located near an external heating source.

The outlet gas temperature of a liquid oxygen system is cooler than the ambient temperature because oxygen is converted from an extremely cold liquid state to a gaseous state. This necessitates a heat exchanger to warm the gas for patient comfort. Condensation may develop externally on coils of the heat exchanger; however, due to its lower outlet gas temperature, it is rarely present in the delivery gas.

An oxygen concentrator is an electro-mechanical device that utilizes an air compressor and sieve beds to separate the oxygen from the nitrogen, which is present in room air. Oxygen concentrators, due to the process of air compression and electrical use, have higher internal operating and outlet gas temperatures than the ambient temperature. Models that operate more efficiently, with less electrical power consumption, will generally have lower operating temperatures and lower outlet gas temperatures than less efficient models.

Conditions that increase the operating temperature of the oxygen concentrator increase the outlet gas temperature exiting from the unit. When the outlet gas temperature is higher than the ambient temperature, there is a greater possibility that condensation will be created in the tubing when the humidified oxygen cools down.

A concentrator relies on unrestricted air flow for internal cooling, and some models have a cabinet filter. As this filter becomes occluded, air flow is reduced, causing the unit to operate at a higher temperature. This not only increases outlet gas temperature, but may accelerate wear of temperature-sensitive components, leading to reduced oxygen production, and an eventual thermal shut-down of the unit. The cabinet filter(s), if equipped, must be maintained according to manufacturers' requirements.

Air flow is also affected when intake or exhaust vents are obstructed or blocked. Intake and exhaust vents on some concentrators are positioned at the back of the units, increasing the likelihood that recirculation may occur when these models are placed too close to a wall, compounding the rain-out issues.

If the concentrator model is vented on the bottom, it may be more sensitive to placement on carpeting.

Floor Temperature

Floor temperature greatly impacts the amount of rain-out produced. Factors that affect floor temperature include construction materials, insulation, and weather conditions. During winter months, ceramic tile and hardwood floors may be substantially cooler than the overall temperature of the room, particularly if built over a poorly insulated area. As the tubing, especially long lengths, contacts these cold surfaces, the humidified oxygen gas may cool and rain-out. Although the combination of winter months with cooler floor temperatures may exacerbate rain-out, it may also occur when oxygen tubing is allowed to coil over air conditioning floor vents. Frequently, rain-out may be traced to changes in temperature caused by nighttime settings on automatic thermostats. Since the delivery of therapeutic oxygen is essentially a “closed loop” system and the condensation occurs within the tubing, the room’s relative humidity has no effect on rain-out.

Preventing and Reducing Rain-Out

The best way to prevent rain-out is to eliminate the humidifier. Throughout the years, humidifier use with oxygen therapy has significantly decreased, especially for patients on low flows. Research by Campbell (1988), Andres (1997), and Estey (1982) indicates that using humidifiers on oxygen equipment with flow rates up to 4 or 5 L/min merely adds cost and does not benefit the patient. The American Association for Respiratory Care guidelines specify that oxygen supplied via nasal cannula at flow rates ≤ 4 L/min does not need humidification (2002, 2007). The American Thoracic Society and European Respiratory Society standards for the care of COPD patients describe the lack of evidence supporting the use of humidification when oxygen is delivered via nasal cannula at flows ≤ 5 L/min (2004).

HME providers have achieved the most success in reducing rain-out by removing the tip of the diffuser or the diffuser tube completely to form a pass-over system, as with continuous positive airway pressure (CPAP) therapy. Care should be taken not to overfill the humidifier or to add warm water. Some humidifiers have internal designs that minimize the expulsion of water droplets directly into the oxygen tubing. Regardless of its origin, once water is present in the tubing, it will likely remain there until the humidifier is removed, or the water emptied, to allow the flow of oxygen gas to dry the tubing.

It is beneficial to locate the concentrator in a cool, shaded, well-ventilated area to reduce the temperature gradient, which causes condensation. Appropriate location selection includes maintaining adequate distance from walls, furniture, privacy curtains and other objects to allow room air to freely circulate around the

concentrator. It may be beneficial to turn the concentrator at a 90° angle to the wall to maintain this distance.

The concentrator should not be permitted to directly pull in warm air from a heating source or become heated externally by the sun, as would occur in a sunny location, or if positioned too close to heating registers or ducts. Inappropriate unit placement in the home care environment may include confined areas such as bathrooms, closets, and under desks, since warm exhaust gas may become localized, heat the area, and re-circulate back into the unit. To improve the clearance and circulation, the concentrator can be placed on a mat, such as a carpet sample or welcome mat, even upside down if there is deep pile carpeting. A mat may also reduce rain-out by insulating the tubing from a cold surface. Shortening the length of tubing may reduce the production of rain-out by reducing the time available for the oxygen to cool. The concentrator's cabinet filter, if equipped, must be kept clean and requires more frequent attention in dirty environments.

Some HME providers use in-line water traps to collect the condensation when a large temperature difference exists between an oxygen unit's outlet gas and the surface of the floor, making rain-out unavoidable. This device consists of a chamber that accumulates water and prevents it from reaching the patient. For maximum effectiveness, locate the water trap close to the patient.

Alternatives to Oxygen Humidification

Oxygen therapy-dependent and other acutely ill patients are prone to dehydration. This causes the mucus membranes to dry out, which may be misinterpreted as a side-effect of the oxygen therapy (Wotton, Crannitch, & Munt, 2008). It is important to maintain hydration with adequate fluid intake. Irritation from the cannula tips may be treated with a petroleum-free, water-based nasal moisturizer.

When continuous flow oxygen therapy is initiated, patients may initially experience dryness of the upper airway, which decreases with time. This decrease in symptoms occurs with or without the use of humidification (Andres, Thurston, Brant, Flemons, Fofonoff, Ruttimann, Sveinson, & Neil, 1997). Research does not support the use of humidification to reduce initial dryness complaints or the severity of symptoms (American Thoracic Society/European Respiratory Society, 2004).

Humidified oxygen does not compensate for an inherently dry environment, since the patient inhales a majority (83 to 96%) of room air along with therapeutic oxygen. Inspired oxygen levels of 24%, 28%, and 32% correspond to ratios of 25:1, 11:1, and 6:1 parts, respectively, of room air inhaled to therapeutic oxygen (American Thoracic Society/European Respiratory Society, 2004). For dry environments, consider the use of an inexpensive ultrasonic humidifier, which increases the relative humidity of the room. Many of these models sell for less

than \$70 USD, and add one to two gallons (3.8 to 7.6 liters) of water into the environment within a 24-hour period.

Discussion

The trend to eliminate the bubble humidifier continues, as research does not find the demonstration of any advantage to humidified oxygen for patients on low-flow oxygen therapy. In addition to causing rain-out, if the humidifier is not properly cleaned and assembled according to the manufacturer's instructions, other secondary issues can be created. The risk of bacterial contamination is associated with humidifier use (American Association for Respiratory Care, 2007). Contamination is most frequently caused by skin flora introduced during refill or reassembly of the humidifier (Henderson, et al., 1993). The humidifier is also a potential source of leaks or reduced oxygen flow to the patient.

The number and severity of patient complaints are comparable between humidified and non-humidified groups. A possible explanation may be that patients need time to become accustomed to oxygen cannulas, as one does to eye glasses. Patients require adequate fluid intake for proper hydration to maintain airway health. HME providers have struggled with periodic complaints relating to rain-out from oxygen patients. The frequency of rain-out may be reduced by analyzing the oxygen source and set-up and taking corrective action. Depending upon the location or installation of the oxygen therapy equipment, rain-out may be unavoidable, but its occurrence is likely temporary. Removing the bubble humidifier will eliminate rain-out without creating additional issues for the patient. Proper hydration, room humidifiers, and oxygen-compatible, water-based nasal moisturizers will improve patient comfort, in conjunction with the use and frequent replacement of a high-quality cannula to ensure soft and hygienic nasal prongs.

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