



## AEROSOLS WITH VENTILATORS – ALL THE NOOKS AND CRANNIES

*Michael McPeck BS RRT FAARC*

Someone recently sent me an e-mail and inquired about whether they should turn the humidifier off, or bypass it altogether, during nebulization into the ventilator circuit. She stated that she had heard that the presence of heated humidification in the vent circuit decreases the aerosol delivery to the patient. I was impressed with the way the question was stated because she specifically asked about “delivery” and not “deposition.” This, coincidentally, is an excellent question to address in this installment of our ongoing series about delivering aerosols during mechanical ventilation.

The principle and the problem we are concerned about here is known as “hygroscopic growth.” Aerosol particles of certain compositions of inhalation medications, particularly those of weak salt solutions such as bronchodilators, will absorb water

from the vapor phase, time permitting, when introduced into a hot humid gas stream. (Particles may also experience hygroscopic growth within the hot humid respiratory tract, but even though the mechanism is the same, we’ll talk about that later because it is a different issue with a different outcome).

**What is the consequence of a drug-containing aerosol particle that suddenly increases its diameter by 2-3 times its original size?**

Due to hygroscopic growth, liquid particles containing dissolved drug are thought to become roughly 2-3 times larger in the amount of time available. This phenomenon does not apply to solid particles such as those emitted by dry powder inhalers.

What is the consequence of a drug-containing particle that suddenly increases its diameter by 2 or 3 times its original size? What happens to drug mass carried by the particle? Nothing. It remains the same. Same mass, larger particle, seemingly not an issue; but let’s not rush to judgment. We’ll come back to this in a little while. OK, then what about the aerodynamic properties of the larger particle? This is where we need to be concerned. If a particle is quite large to begin with – at the upper end of, but still within, the so-called “respirable range,” for example – and it doubles or triples its diameter before it even reaches the airway opening, its aerodynamic properties will very likely change for the worse. Now this “dimensionally challenged” particle may never make it out of the ventilator circuit or beyond the endotracheal tube due to premature impaction or sedimentation. Conversely, if a particle is especially small or at the lower end of the respirable

range, and it doubles or triples its diameter, it may possibly remain at a size that is still aerodynamically stable and not likely to suffer the same fate as its larger brethren.

Let’s revisit the issue of drug mass because, after all, the whole point of aerosol therapy is to deliver an effective mass of drug to the lung. In the preceding paragraph we may have been tempted to assume that, since drug mass carried by a hygroscopically enlarged particle does not change, all is well. However, this is not necessarily true. The drug mass imparted to a theoretically spherical particle as it is formed is directly proportional to the third power of the radius ( $r$ ):  $Mass = r^3$ . (It’s actually more complicated than this, but this over-simplification will demonstrate the point). For example, a particle that is double the diameter of another will have 8 times more mass and, in general, the majority of the drug mass emitted by any given pneumatic nebulizer will be carried by the larger particles. And so, if it is the larger particles that are subject to premature rain-out in the circuit due to hygroscopic growth, delivery of drug mass to the patient will be severely compromised. The burden of efficiency now shifts to the smaller particles and the deck is stacked against them because a particle that is one-half the diameter of another will contain 8 times less drug mass.

In one of the first studies in this area from our group at SUNY Stony Brook in the early-1990s, the “Inhaled Mass” of medication (actual mg of drug delivered or inhaled) in an in vitro investigation was reduced by about 41% in a circuit with an operating heated molecular humidifier (O’Riordan, et al. *Nebulizer function during mechanical ventilation*. *Am Rev Respir Dis*. 1992 May;145(5):1117-1122). Similar results have been obtained by others in variety of simulated clinical conditions. E-mail me to request a complete reference list by return e-mail. Accordingly, most investigators have elected to remove or bypass the humidifier in aerosol delivery studies with ventilators in order to eliminate the potential for variability (i.e., different humidifiers and settings may produce different results). While this removes a confounding variable from the study design, the results derived from this approach are not fully transferable to the clinical environment and tend to overestimate aerosol drug delivery.

So now the question arises, what should we do during actual clinical practice? This calls for a “nuanced” answer rather than a definitive answer. It depends quite a bit on the diligence of the RT department and its practitioners as to whether or not

• Reduce Contact with Infectious Condensate  
 • No Tube Occlusions Reported<sup>1</sup>  
 • No Pneumothorax Reported<sup>1</sup>

Humidify with Confidence  
 ThermoFlo™  
**ARC Medical, Inc.**  
 800-950-2721  
 arcmedical.com

1. data on file

**CIRCLE READER ACTION CARD # 19**

**Aerosols with Ventilators..** Continued from page 30

to bypass or turn off the humidifier during nebulizer therapy. There are basically three scenarios that can happen:

If you do bypass or turn off the humidifier temporarily, you will eliminate the chance for decreased inhaled mass due to hygroscopic growth in the circuit (although inhaled mass will still be influenced both positively and negatively by other factors including nebulizer placement location, presence or absence of bias flow, whether the nebulizer is operated continuously or intermittently and, of course, the breathing pattern, particularly minute ventilation and % inspiratory time). This procedure will probably ascertain the greatest aerosol delivery (highest inhaled mass) and possibly should be considered for medications other than routine bronchodilators (e.g., antibiotics).

If you bypass or turn off the humidifier and are unable to promptly reconnect it or turn it on again when the nebulizer reaches sputter, the patient may be exposed to a period of time without supplemental humidification. This is the main argument against this practice and its validity is really a function of staff availability and response time more than anything else. Because treatments on ventilators take so much longer, it is unreasonable and unnecessary for the therapist to “stay with the patient” during the treatment. However, this leads to the possibility that heated humidification will not be immediately restored once the treatment has concluded.

If you don't bypass the humidifier, and chose to administer the aerosol into the hot humid ventilator circuit, the patient will likely receive less medication than otherwise. But, depending on the medication in use, particularly if it is a bronchodilator, this

can be compensated for by the usual methods (increasing nebulizer charge and/or increasing treatment frequency).

Indeed, it seems that a vast conspiracy exists against the efficacy of aerosol delivery during mechanical ventilation. Similar constraints may apply to use of an MDI and placement of either MDI or nebulizer at different locations in the circuit relative to the humidifier position. And, DPIs, while their emitted solid drug particles are not subject to hygroscopic growth, have other problems with respect to interfacing into the vent circuit. Other factors confound all of these approaches (Miller, et al. Aerosol delivery and modern mechanical ventilation: In vitro/in vivo evaluation. *Am J Respir Crit Care Med* 2003;168:1205-1209) and will be discussed in a later installment.

Personally, I feel that this needs to be a policy decision to ensure consistent performance in the department. If you decide to invoke practice whereby the humidifier is actually bypassed prior to therapy, this approach has the advantage of removing the heat and humidity in the circuit after just a few breaths. However, the main disadvantage, and this is a big one, is that it opens the circuit and may result in loss of the patient's FRC, etc, etc. If, instead of bypass, you merely turn off the humidifier, then before you turn on the nebulizer, you might want to have an external thermometer in the circuit to know when circuit temperature has dropped to near ambient. Alternately, you could wait a specified period of time that has previously been determined to be sufficient for the latent heat in the humidifier and tubing to dissipate. Thus, both of these approaches may be ideal, as far as delivery efficacy is concerned, but they also have a serious downside, are quite labor intensive and may be logistically impractical to perform consistently. Ordinarily, I am a proponent for having respiratory therapists reach into our bag of tricks and pull out something that will improve and maximize aerosol delivery efficiency. However, in recognition of the fact that aerosol delivery during mechanical ventilation is already subject to so many variables that influence its quality, my best advice for routine practice is to leave the humidifier in the circuit and do not turn it off. Accept the fact that aerosol delivery is probably compromised and we may need to compensate in some other effective way, if possible. Fortunately, assessment of bronchodilator therapy is easy to do, especially for ventilator patients, thanks to the sophisticated respiratory mechanics monitoring capabilities of modern ventilators. The toxicity threshold of contemporary bronchodilators is so high that toxicity is rare, the dose-response relationship is easy to quickly determine, and the drugs are relatively cheap. We can compensate by increasing nebulizer charge and/or increasing frequency. I believe that humidifier bypass procedures ought to be reserved for special drugs or special cases where everyone can be on high alert. I am cautious about the complacency that might creep in if we regularly start turning off or bypassing humidifiers during routine bronchodilator therapy. All of this should continue to remind us that effective aerosol delivery really is not as easy as it looks like it ought to be, and there are many things that conspire against it. Mechanical ventilation with heated humidification is one of them.

*Mike McPeck, RRT, FAARC is a veteran therapist, lecturer and Executive Director, Respiratory Therapy Services at Long Beach Memorial Medical Center and Miller Children's Hospital in Long Beach, CA*



**Join us May 14-16, 2009 in Orlando for the 9th Annual Focus Conference at Disney's Coronado Springs Resort**