



## AEROSOLS WITH VENTILATORS – ALL THE NOOKS AND CRANNIES

*Michael McPeck BS RRT FAARC*

In this issue we are going to embark in a new direction. We are going to explore the many aspects of aerosol delivery during mechanical ventilation. I only have a partial roadmap at the moment as to *how* I am going to approach this topic, so a lot of it will eventually come out in the wash. But I can tell you this: this topic is so convoluted and complicated that it reminds me of the television commercial for Thomas' English Muffins: it's full of nooks and crannies. So I suspect we are going to need at least 3 issues, maybe 4, to cover all the bases and review all of the interrelated factors that influence the amount of aerosolized drug that can be inhaled during mechanical ventilation. But first, let's take a little stroll down Memory Lane and I'll use this first installment to review a bit of relevant history as I remember it, and to set the stage for the technical discussions that will follow in subsequent installments.

Delivering aerosolized medications during mechanical ventilation is certainly not a new concept, although I believe its origin is not as simple as one might think. At face value it seems to make sense that patients being supported by mechanical ventilation may require an aerosolized drug for

**Aerosol delivery during mechanical ventilation is still inconsistent, non-standardized and subject to extreme variation**

many of the same reasons and indications as any other patient. I am not aware of any literature that describes aerosol delivery for patients in iron lungs and haven't taken the time to search, but I would not be surprised if it occurred. Although that's a little bit before even my time, I would just about bet that some patients in iron lungs received periodic pressurized metered-dose inhaler (pMDI) treatments. The first pMDIs, Medihaler-Iso® and Medihaler-Epi,® for isoproterenol and epinephrine, respectively, were introduced by Riker Laboratories in 1956. There were still quite a few post-polio patients in iron lungs at that point in time, although the population was waning, and they were not as concentrated into dedicated wards as they once were. Positive pressure ventilation was just coming into its own, owing to its widespread use during anesthesia, and was being selected over the iron lung because fear of prolonged tracheal cannulation had abated and patients with flail chest, obesity, COPD and other lung pathology were much more difficult to ventilate than the polio patients who generally had no pulmonary disease.

By the time I entered the new field of "inhalation therapy" in 1965, the Medihaler was a well established means of administer-

ing the two available bronchodilators mentioned above for ambulatory patients, hospitalized patients and even those sick enough to require IPPB, which was just about everybody. And, yes, we even had a pass-through actuator adapter that could be placed into the extension tube between the manifold and mouthpiece of a Bennett TV-2P or PR-1 IPPB machine to allow puffs to be administered by the "inhalation therapist" during the positive pressure insufflation phase which everyone believed was the ideal way to administer aerosolized drugs. However, at the same time, the pneumatic nebulizer was beginning to emerge as a challenger to the pMDI because other inhalation drugs were being developed that did not work well with the prevailing pMDI technology, propellants and excipients, or which were being developed by drug companies that did not have a background in MDI technology.

I still vividly recall the first three nebulizers I was exposed to in my first year as an IT OJT. One was a modification of the classic DeVilbiss No. 40 glass nebulizer that had been reworked for use with an IPPB machine. This device came with a rubber right angle adapter that allowed it to be inserted into the manifold of a Bennett IPPB circuit and a nipple for attachment of oxygen tubing instead of the squeeze bulb. However, the Bennett IPPB circuit could be obtained with its own single capillary jet nebulizer that was a precursor to the Bennett Twin Jet Nebulizer and this was typically used with the Bennett TV-2P or PR-1. The third device was the Bird Micronebulizer that came with the Bird Mark 7 and 8 Respirators that were widely used for IPPB. Perhaps many will

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**"I may be incompetent, but I don't let it interfere with my job performance."**

recall that Dr. Bird was a proponent of a certain brand of racemic epinephrine solution (known as Bird Micronephrine®) and could cite dozens of reasons why it should only be administered with a Bird Micronebulizer on a Bird Respirator.

The emergence of these three nebulizers, and others like them that were designed for insertion into a positive pressure breathing circuit, and the associated marketing claims that came with them, introduced our young field to the concepts of sidestream and mainstream nebulization. The DeVilbiss and Bennett nebulizer were connected to a breathing circuit in sidestream fashion wherein the aerosol output was introduced into the main gas flow from the side, like a side street that feeds into a main thoroughfare. In contrast, the Bird Micronebulizer was a mainstream device wherein the main gas flow passed through the nebulizing chamber itself on its way toward the patient, becoming saturated with aerosol particles along the way. Marketing claims of superiority were, of course, made for both approaches.

A feature of the early positive pressure breathing devices, which were used variously as IPPB machines as well as continuous ventilators, was that they typically included a high pressure gas source for powering the nebulizer. The Bennett TV-2P had a small needle valve take off on its 50 psig gas inlet to which a small bore nebulizer tubing could be attached. The Bennett PR-2 had a nipple for attaching small bore tubing to a nebulizer built in to its body and even had separate needle valves for regulating flow to the nebulizer during the inspiratory and expiratory phases. Thus, the practitioner had some control over the flow going to the nebulizer and the portion(s) of the respiratory cycle during which it operated. Without the benefit of science or detailed studies, there were many different prevailing theories as to how these two needle valves should be operated: during inspiration only, during exhalation only (to "charge" the main inspiratory tubing), and during both inspiration and exhalation. Different clinicians had seemingly rational reasons for each approach. The Bird Mark 7 and Mark 8 Respirators shunted 50 psig gas from the 'center body' to power not only the nebulizer but to push a diaphragm over an orifice in the exhalation valve during the inspiratory phase.

So, at this stage in the early development of aerosol delivery during positive pressure ventilation we can see some controversy brewing along with the establishment of at least two of the factors involved with the efficacy of aerosol delivery during mechanical ventilation: (1) sidestream vs. mainstream circuit interfacing and (2) powering the nebulizer from the ventilator itself. Contemporarily, we see that sidestream nebulizer connection seems to be the norm for pneumatically powered nebulizers; the same gas that it used to generate the aerosol is also used as the carrier gas to propel that aerosol out of the device and into the delivery circuit. The mainstream method seems to be used predominantly for electronic nebulizers that do not have a separate carrier gas flow to propel the generated aerosol out of the device. The main gas flow in the breathing circuit also fulfills this function. Which is better, sidestream vs. mainstream? Do ventilators differ in their ability to power a pneumatic nebulizer? It should be no surprise that different ventilator makes and models approached this concept differently. In a subsequent installment we will explore these two issues and provide some results of studies that may answer these and other vexing questions.

As I mentioned earlier, there are more nooks and crannies in this topic than in a Thomas' English Muffin. So we will have a great



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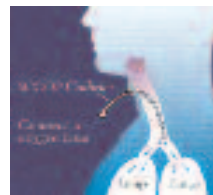
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deal of material to look over. As we further develop this series, we will look at many of the other factors that influence the quality of aerosol delivery during mechanical ventilation: (1) the effect of the endotracheal or tracheotomy tube; (2) the effect of breathing pattern (combinations of rate, tidal volume, inspiratory time, waveform and mode); (3) the effect of nebulizer placement location in the circuit relative to the airway opening; (4) the type of nebulizer (pneumatic vs. electronic) and further breakdown of the electronic devices into ultrasonic and vibrating mesh types; and (5) the effect of humidification on delivery of aerosol introduced into a ventilator circuit. I believe that one of the realizations that will emerge during this exploration will involve the relationship between aerosol delivery and sophistication of the ventilator. As ventilators have become increasingly more sophisticated through adoption of computerized control, various triggering schemes, and a staggering array of modes and waveforms, their effect on nebulizer function and aerosol delivery has not always been salutary. As a result, aerosol delivery during mechanical ventilation is still inconsistent, non-standardized and subject to extreme variation depending on which permutation of a large number of influencing factors are present in a given clinical situation. It's sort of like no two English Muffins are exactly alike.

*Mike McPeck, RRT, FAARC is a veteran therapist, lecturer and author considered by many to be a leading expert on the use of Aerosols in medicine. He can be reached at [michael.mcpeck@gmail.com](mailto:michael.mcpeck@gmail.com)*