Vivo 50 Nebulizer Protocol

There are several different devices for administering medications to a patient receiving mechanical ventilatory support including MDI, small volume nebulizer (SVN) or jet nebulizer, and ultrasonic nebulizer. Each method has its own benefits and problems associated with its use. One of the main questions clinicians have for any of the devices used is, "where in the circuit is the optimal location to place the device?"

There have been several bench test studies as well as clinical studies to determine the optimal position or the optimal device or both. This protocol cites some of the available published material but ultimately the decision on which device to use and where in the circuit to place it is up to the clinician.

The National Institutes of Health (NIH) Critical Care Medicine Department, Critical Care Therapy and Respiratory Care Section, developed a policy and procedure to guide clinicians in this procedure:

Category: Clinical Section: Aerosol Therapy Title: Delivery of Aerosolized Medications via Metered Dose Inhaler or Small Volume to Intubated Mechanically Ventilated Patients, Policy #: 03. This policy cautions that, *"placing a SVN in-line with a ventilator will alter the flow characteristics of the ventilator-delivered breath. The tidal volume (Vt) must be monitored closely. Adjustments to the Vt (or to the pressure setting in pressure-controlled mode) must be made accordingly. In some circumstances, it may be advantageous to increase the rise time to temper the effects of the increased flow such that turbulent flow is minimized. The addition of flow for powering the nebulizer to the circuit also renders the ventilator less sensitive to the patient and may require an increase in the sensitivity for the duration of the treatment. These effects are especially important when ventilating pediatric patients."*

The NIH policy recommends positioning the nebulizer within the circuit in the inspiratory limb *approximately 18 inches (45 cm) from the patient airway and bypassing the humidifier.* According to the policy, bypassing the humidification system is necessary to minimize the tendency of water vapor to increase particle size.

Also recommended in the NIH policy is to decrease the set Vt to account for the additional flow through the nebulizer for pediatric patients whose set Vt is less than 250 ml, *"the delivered Vt should remain relatively unchanged after the ventilator adjustment with minimal increase in PIP."*

A final recommendation in the NIH policy is to note the exhaled Vt and *make adjustments to the PIP as necessary to maintain the exhaled Vt at pre-treatment levels for patients on pressure-controlled modes.*

It should be noted that the NIH policy was last revised in 2000 so the policy should be weighed against newer research published since that time.

New Research involving administering aerosol therapy during mechanical ventilation:

An article entitled, "Aerosol Therapy for Ventilator-Dependent Patients: Devices, Issues, Selection & Technique," published on CLINICAL FOUNDATIONS website: www.clinicalfoundations.org 2012-1386 by Arzu Ari details methods of medication delivery via the ventilator circuit. Ari states that, *aerosol delivery during mechanical ventilation depends on several factors. These can be divided into three categories:*

(1) ventilator-related factors,
(2) circuit-related factors and
(3) device-related factors

According to Ari, ventilator related factors such as *inspiratory flow rate, ventilator mode, inspiratory time, tidal volume, bias flow and wave patterns* make a significant difference in aerosol drug delivery to ventilator-dependent patients.

The **flow rate** at which the aerosol is delivered is an important factor in deposition of the medication in the patient's lungs. According to Ari, "since high inspiratory flow rates increase turbulent flow and inertial impaction of aerosol particles, *aerosol deposition with high inspiratory flow rates is less than with lower flow rates.* Peak flow rates of 40-50 L/min may be used to improve drug delivery during mechanical ventilation as long as this is tolerated by the patient."

Inspiratory time (I-Time) may also have an effect on deposition of the aerosol into the lungs – *a longer I-Time is usually recommended when using a small volume nebulizer (SVN)* whereas metered dose inhalers (MDI) do not seem to be affected by I-Time. Ari suggests that *since the filter in the HME is considered a barrier to aerosol delivery, it should not be placed between the aerosol device and the patient.* However there are some HME devices that are designed to be used in-line with aerosol therapy.

Several studies suggest that patient position is a key factor in deposition of aerosolized medication. It is recommended that a *semi-fowler position* with the head of the bed elevated to 20 to 30 degrees above the horizontal should be used for aerosol administration during mechanical ventilation.

In contrast to the NIH policy stating the nebulizer should be placed 18" (45 cm) from the patient airway and bypassing the humidifier, some researchers suggest that placement of the jet nebulizer closer to the heated humidifier and keeping it in-line during the aerosol treatment is a more optimal method [Ari A, Areabi H, Fink JB. Evaluation of position of aerosol device in two different ventilator circuits during mechanical ventilation. Respir Care. 2010;55(7):837-844]. The researchers explain their recommendation by stating that, "when the jet nebulizer is placed closer to the ventilator and operated continuously under heated/humidified conditions, the aerosol tubing acts as a reservoir because continuous output of the jet nebulizer charges the inspiratory limb of the ventilator circuit between inspiration and minimizes aerosol loss during the expiratory phase of the breathing cycle."

However when using nebulizers that do not add a gas flow to the ventilator circuit (e.g., MDI and mesh or ultrasonic nebulizers) the researchers suggest that the most efficient placement is in the inspiratory limb of the circuit 6" (15 cm) from the wye adapter.

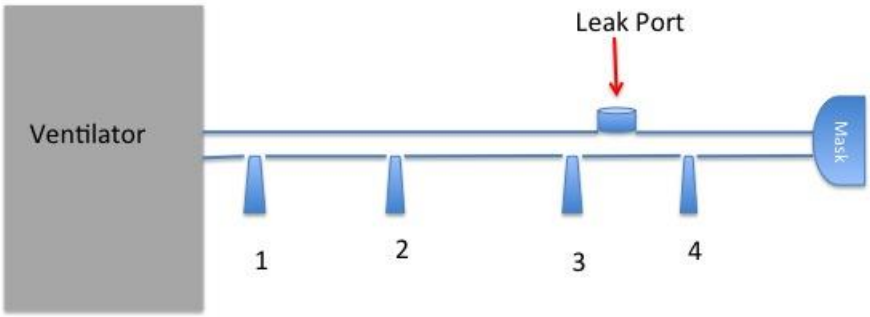
Research has also shown that with the addition of continuous bias flow in the ventilator circuit, placement of aerosol generators near the ventilator may be more efficient *[Ari A, Atalay OT, Harwood R, Sheard MM, Aljamhan EA, Fink JB. Influence of nebulizer type, position, and bias flow on aerosol drug delivery in simulated pediatric and adult lung models during mechanical ventilation. Respir Care. Jul 2010;55(7):845-851].*

Many factors can either adversely influence or optimize the effectiveness of aerosolized medication delivery during mechanical ventilation. Physicians and respiratory therapists must have a good understanding of those factors to ensure the patient receives the most benefit from aerosolized medication delivery during mechanical ventilation.

Another factor influencing deposition of aerosolized medications is whether the patient has an artificial airway (ETT or trach tube) or is being ventilated non-invasively (NIV) e.g., NPPV via nasal or full face mask.

During the 2014 ERS show in Munich, a nice overview of nebulization in a NIV application was presented by Dr Ehrmann from the CHRU in Tours, France. In one slide he showed an overview of the most recent research around the best position to insert a nebulizer in a **single limb circuit**. The slide clearly shows that the majority of published studies recommend putting it as close as possible to the patient and preferably between the leak and the mask (see below):

NIV to Mask with Nebulizer In-line in 1 of 4 Different Positions



Nebulizer position in the single limb circuit (with corresponding research articles that either recommend or do not recommend the positioning of the nebulizer: (1) at the ventilator or humidifier, (2) midway in the patient circuit, (3) in the circuit before the leak valve, (4) in the circuit after the leak valve but before the mask.

S Chatmongkolchart, Crit Care Med 2002 (recommends position 3 but not position 1)
MP Branconnier, Resp Care 2005 (recommends position 4 or delivery directly to the mask)
LD Calvert, J Pharm Pharmacol 2006 (recommends position 3 primarily or position 4 secondarily but not position 1)
CC White, Resp Care 2013 (recommends position 4 primarily or position 3 secondarily but not position 1)
JB Michotte, J Aerosol Med Pulm Drug Deliv 2014 (recommends position 4 but not position 3)
B Dal, J Aerosol Med Pulm Drug Deliv 2014 (recommends position 2)
ME Abdelrahim J Pharm Pharmocol 2010 (recommends position 4 but not position 3)

Other considerations in determining the optimal device and placement for delivery of aerosolized medications during mechanical ventilation:

1. Nebulizer: performance varies with the diluent volume, gas flow, gas density, operating pressure and nebulizer model or type. When used during mechanical ventilation nebulizers producing aerosol particles in the 1-3 micron size are more likely to achieve deeper deposition into the lower airway. If an ultrasonic nebulizer is being used the ultrasonic frequency setting can be a determining factor.

2. Ventilator Settings: Peak flow rate, respiratory rate, Vt, flow wave pattern (wave form) and mode (volume versus pressure).

3. Patient-related factors: bronchospasm, secretions, intrinsic PEEP, respiratory rate and pattern.

4. The conduit between the aerosol device and the patient's lower airway: tubing, swivel adapter or elbow adapter (e.g., a 90 degree elbow adapter can increase turbulence and inertial impaction).

5. Heated humidification: according to research done by Maher Al Quaimi, Dammam University, using heat and humidity causes greater aerosol deposition in the ventilator circuit and artificial airway (ETT or trach) and that, both heat and humidity decreases deposition by up to 40%.

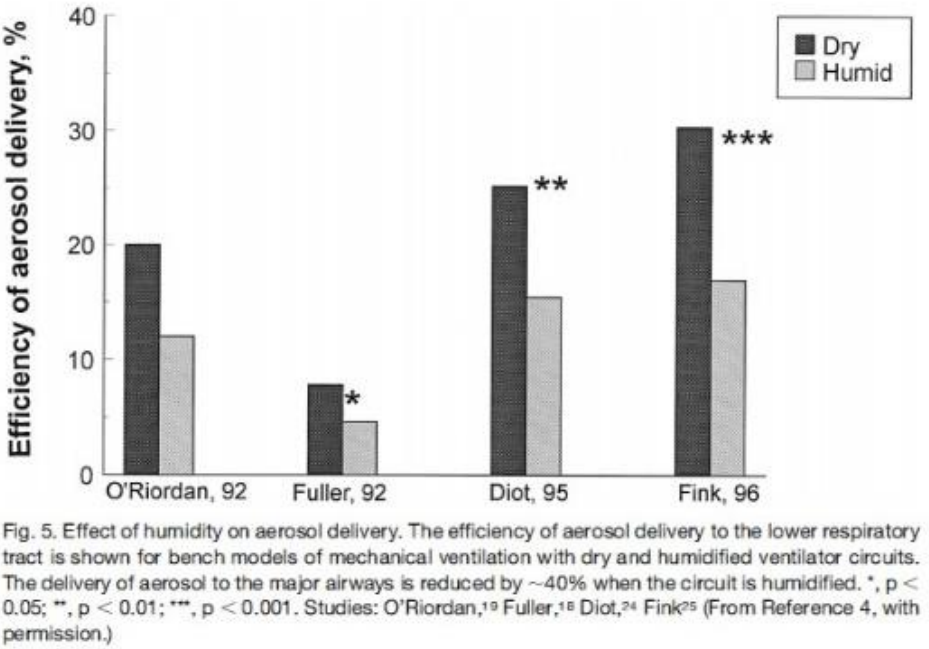
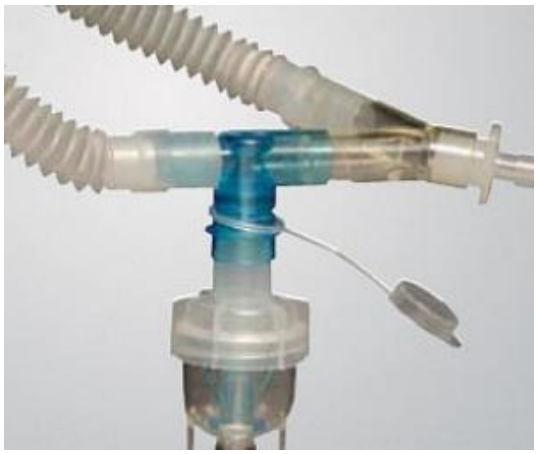


Fig. 5. Effect of humidity on aerosol delivery. The efficiency of aerosol delivery to the lower respiratory tract is shown for bench models of mechanical ventilation with dry and humidified ventilator circuits. The delivery of aerosol to the major airways is reduced by ~40% when the circuit is humidified. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$. Studies: O'Riordan,[19] Fuller,[18] Diot,[24] Fink[25] (From Reference 4, with permission.)

SAMPLE PROTOCOL (not Vivo 50-specific)

1. Add medication to nebulizer (nebulization varies with brand)
2. Place nebulizer in-line ~18" (45 cm) from the patient wye
3. Add gas flow to the nebulizer at a rate of 6-8 L/M
4. Adjust ventilator Vt to compensate for additional flow from nebulizer
5. Adjust minute volume alarm to compensate for additional flow from nebulizer
6. Adjust sensitivity setting to compensate for additional flow from nebulizer
7. Monitor patient during entire therapy
8. When medication has been completely administered discontinue flow to nebulizer
9. Adjust ventilator settings to pre-treatment values
10. Remove nebulizer from circuit

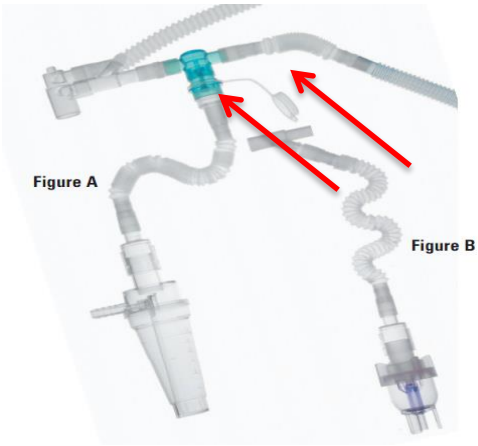
SAMPLES OF VARIOUS IN-LINE NEBULIZER CONFIGURATIONS



In-line at patient wye

In-line in circuit ~ 18" (45 cm) from the patient wye adapter or connector

In-line at the patient wye



In-line in circuit ~ 6" (15 cm) from patient connector (2 different nebulizer models)

In-line Nebulizer Set-up with the Vivo 50

1. Breas recommends using a bacteria filter at the air output port of the Vivo 50 to protect the ventilator from medication residue.
2. If nebulizer treatments will be administered routinely it is recommended that the clinician set a Profile for use during treatment, which includes Vt, sensitivity, and alarm adjustments.
3. Add medication to nebulizer (nebulization rate and particle size varies with brand of nebulizer).
4. Place nebulizer in-line according to company/facility policy, e.g.,
    a. ~18" (45 cm) from the patient; or
    b. as close to the patient as possible (Prefered); or
    c. in-between the humidifier and the patient circuit (if a heated humidifier is used).
5. If a **Profile has been set** for nebulizer therapy, select that **Profile** now.

6. Add gas flow to the nebulizer at a rate of 6-8 L/M or according to the manufacturer's recommendations.
7. If a nebulizer therapy **Profile has not been set**:
    a. Adjust the Vivo 50 Vt to compensate for additional flow from nebulizer (the Vt setting may or may not need to be reduced);
    b. If necessary, adjust the Vivo 50 High Tidal Volume and High Minute Volume alarms to compensate for additional flow from nebulizer;
    c. Adjust Vivo 50 sensitivity setting (Insp and Exp Trigger) to compensate for additional flow from nebulizer.
8. Monitor patient during entire therapy and make adjustments as required or as clinically indicated.
9. When medication has been completely administered:
    a. Discontinue flow to the nebulizer;
    b. Inspect the exhalation valve (if applicable) to ensure proper function and that it has not been contaminated with medication residue – clean or replace exhalation valve if indicated.
10. Change **Profile** setting back to pre-treatment **Profile** or adjust Vivo 50 ventilator settings to pre-treatment values.
11. Remove nebulizer from circuit.
12. Observe patient to ensure adequate ventilation, inspiratory triggering and alarm function.

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