

The AirLife™ Closed Suction System:

The Verso™ airway access adapter's 45 degree angle represents an improvement for the care of ventilated patients

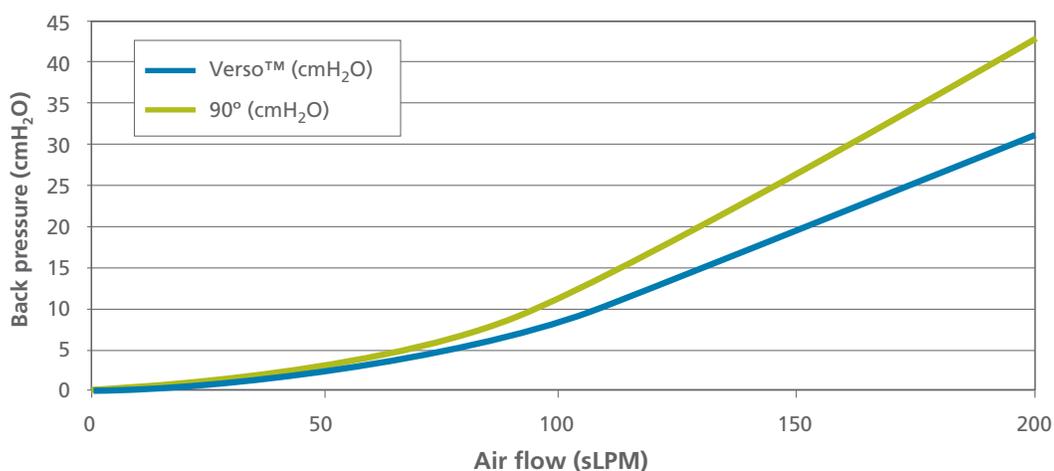
The very presence of an endotracheal tube in a patient's airway reduces the cross sectional area for ventilation. Poiseuille's Law in physics defines that the resistance of a tube is related to its radius to the fourth power. For example, if you place an endotracheal tube in the airway that reduces the airway diameter by half, then the resistance to airflow will increase sixteen-fold. This increase in resistance presents an increase in work of breathing for the patient as well as changes the dynamics of gas flow within the airway. Additionally any directional change within the airway will also increase airway resistance, and the total resistance is also affected by the 90 degree angle that is often found with closed suction catheters. For patients in respiratory failure, the objective is to minimize their work of breathing. We therefore designed the Verso™ with a 45 degree elbow rather than a 90 degree elbow to help reduce ventilation resistance.

Effect on ventilation

To examine the impact of the resistance differences between a 90 degree elbow on a closed suction catheter and our 45 degree elbow on the Verso™ adapter, we compared a Verso™ adapter with a competitive 90 degree closed suction catheter system. This test measured the back pressure of airflow through each adapter up to 200 LPM. The back pressure reflects the resistance of the circuit to airflow.

As can be seen in the graph below, a 90 degree competitive system can add as much as 37 percent more resistance than the 45 degree inlet of the Verso™ depending on the flow and endotracheal tube size. At lower flows and with smaller endotracheal tubes there is less increase in resistance due to the inlet profile. However even with a 7 mm endotracheal tube, the difference of 10 percent may be critical in patients at their limits of ventilation.

This difference in resistance can have a large impact on the work of breathing as well as can significantly affect patient ventilation, particularly when using modes of ventilation that produce very high flow rates such as with High Frequency Oscillatory Ventilation (HFOV). Remember that effective HFOV ventilation decreases rapidly in the face of increasing resistance.¹

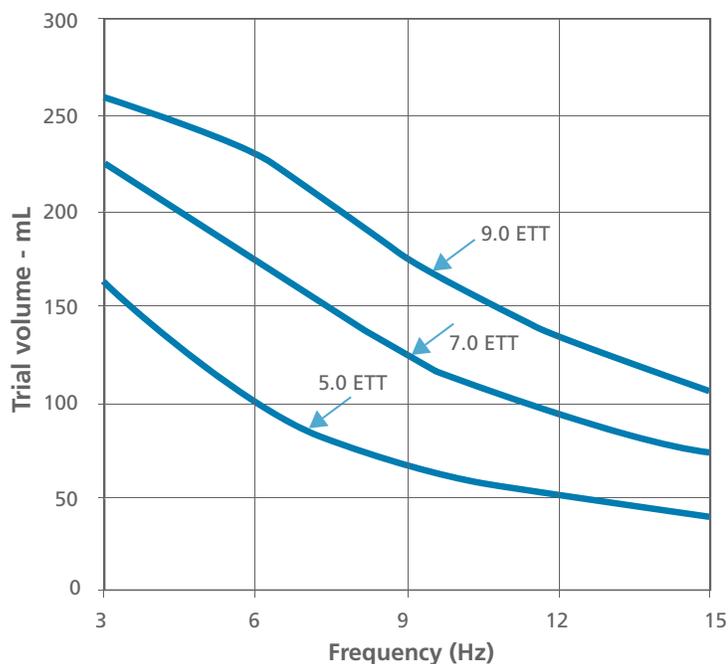


The SensorMedics® 3100B HFOV operating at 9 Hz will deliver approximately 125 mL with a 50 percent I-time through a 7 mm endotracheal tube (See Figure 3.4 from the Operator’s Manual below). The ventilator running at 9 Hz (9 cycles/second) means that the breath cycle is 0.111 seconds and with 50 percent for inspiration, the 125 mL gets into the lungs in 0.0555 seconds. Therefore, 125 mL in 0.0555 seconds is 2.27 L/sec or 136 L/min. Keep in mind that this is the average flow and the peak flow may be even higher.

Patients with severe CO₂ retention need all the ventilation they can get. This graph represents a single specified compliance. With a more compliant lung, the volume would be greater and therefore more volume in the same time period would result in an even higher flow.¹

If you use a 9 mm tube, the volume rises to approximately 175 mL which at the same duty cycle and frequency would deliver mean flows during inspiration of 3.15 L/sec or 189 L/min. Therefore resistance is a real factor for some patients.

Figure 3.4



Effect on drug delivery

The other area where flow dynamics may be important is with drug delivery. When using an airway access adapter or closed suction catheter system while delivering aerosol treatments, the increased resistance of the fittings and the more tortuous path can significantly affect the delivery of the drug out the other side of the adapter and therefore determine the amount of drug available to the patient.²

Aerosol deposition in the lung is determined by many factors and among them are particle size and the turns required by the particle carrying gas stream. Very large particles are usually captured in the upper airway. With an endotracheal tube in place, more of the particles can be delivered to the airway as long as the gas flow geometry is favorable. Although the very small particles under 1 micron can make the turns the ventilator circuit presents to the gas flow, because they are so small, the great majority remain in the air and are discharged from the lungs during the subsequent exhalation. Therefore the major interest is in delivering mid-sized particles.²

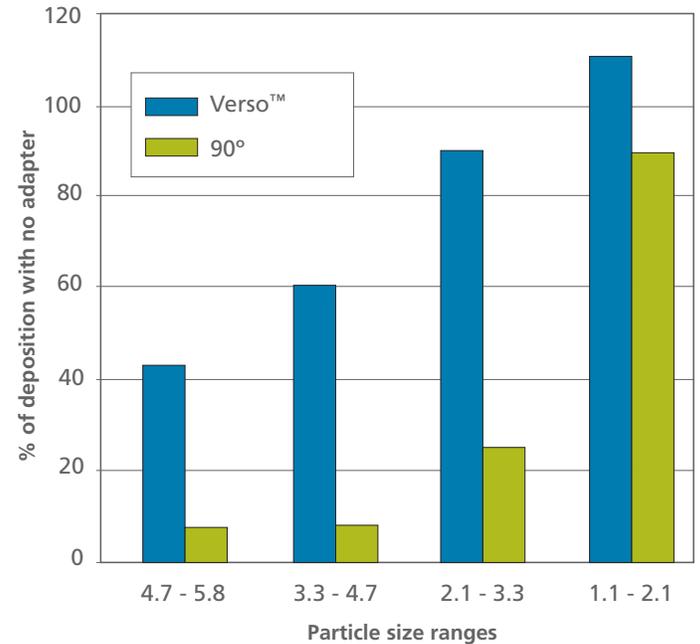
The second important aspect of drug delivery is determining where the drug should be delivered. For example, although there are more beta receptors in the periphery of the lung, the majority of smooth muscle that can respond to bronchodilators is in the third to seventeenth generations of airways where larger particles impact. There is a compelling argument that the best bronchodilation can be done with moderate sized particles in the 3 to 5 micron range rather than with smaller particles in the 1 to 2 micron range.²

To examine the impact on aerosolized drug delivery of a 90 degree elbow with a built-in closed suction catheter from our major competitor and the 45 degree elbow of the Verso™ adapter, we compared their effect on particles flowing down a standard ventilator circuit, through its wye connector and down an 8.0 mm endotracheal tube. This standardized test using an Aerogen Aeroneb Pro nebulizer and an Anderson Cascade Impactor, measured the particles exiting the endotracheal tube and drawn through the Anderson cascade at 28 LPM. After eight repeat sets of data were collected for the endotracheal tube alone connected to the ventilator circuit, the Verso™ or 90 degree adapter was added between the ventilator circuit and the endotracheal tube and eight repeat sets of data for each were collected.

Endotracheal tubes reduce aerosol particle delivery in intubated patients. However, since it is a constant in all patients, the aerosol delivery performance results from the addition of the other adapters was compared to the aerosol delivered with just the endotracheal tube as a base value. All results are therefore normalized and reported as a percentage of the amount delivered with no additional adapter present.

As can be seen in the graph to the right, the 45 degree angle of the Verso™ adapter has far less impact on aerosol delivery than the 90 degree fitting of other closed suction catheter systems. In the 3.3 to 4.7 micron range, the reduction in particles delivered through the 90 degree fitting is more than seven fold greater than through the Verso™ adapter. In the very small particles in the range of 1.1 to 2.1 micron, the gradual directional change with the Verso™ adapter actually complemented the directional change produced by the ventilator circuit wye and enhanced particle delivery by a few percentage points.

Aerosol deposition comparison



Summary

This report explored the different affects of a 90 degree versus 45 degree bend on airway access fittings associated with closed suction catheter systems. As is intuitive and as would be expected, the 45 degree fitting of the Verso™ adapter has less affect on circuit resistance than the 90 degree fitting. In some ventilation modes, such as with high frequency oscillatory ventilation, this difference can be clinically significant.¹

Additionally, the drug delivery data also demonstrates that a 45 degree angle has far less impact on reducing aerosol particle delivery down an endotracheal tube than a 90 degree closed suction catheter system. This data would support consideration of using the Verso™ whenever ventilated patients need to receive inhaled aerosol drug delivery when compared to a 90 degree closed suction catheter design.

References

- ¹ Operator's Manual 3100B High Frequency Oscillatory Ventilator, Viasys 2002: Rev L.
- ² Usmani OS, Biddiscombe MF, Barnes PJ. Regional lung deposition and bronchodilator response as a function of beta2-agonist particle size. *Am J Respir Crit Care Med*, 2005 Dec 15;172(12):1497-504.

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