Comparison of Aerosol Delivery by Face Mask and Tracheostomy Collar

In this issue of Respiratory Care, Bugis et al[1] evaluated which of 3 interfaces (tracheostomy collar, Wright mask, or face mask) provided better delivery of aerosol medication distal to the bronchi through a tracheostomy tube (TT) in a laboratory model. Although all respiratory therapists are familiar with the tracheostomy collar and face mask, the Wright mask may not be as well known. The Wright mask is a combination of a tracheostomy collar and face mask molded into one device that covers both the nose and mouth, as well as the tracheostomy. Each interface was tested using a breathing simulator at a breathing frequency of 20 breaths/min, tidal volume (V_T) of 400 mL, and inspiratory-expiratory ratios of 1:2 and 2:1 via a cuffed and fenestrated 8-mm TT with the cuff deflated. A jet nebulizer was used to nebulize albuterol, and the aerosol output was captured distal to the bronchi in a filter and measured. The authors found that the tracheostomy collar delivered the largest dose of albuterol distal to the bronchi with the fenestration closed at an inspiratory-expiratory ratio of 2:1 compared with the other interfaces under the same conditions.

Jet nebulizers are the oldest aerosol-generating devices still in use. These devices are versatile due to the ability to deliver many different medications; can be used for unconscious and ventilated adult, pediatric, and infant patients; and do not require coordination for patients to activate and inhale as with metered-dose inhalers. Aerosol deposition into the lungs has been well studied over the past several decades,[2-4] and the mechanisms are well known. Aerosol deposition is influenced by many factors, such as particle size, electrostatic charge, hygroscopicity, airway geometry, disease state, and breathing pattern. Airway models have been developed as a surrogate for studying aerosol deposition in the human airway.[5,6] Breathing pattern is known to have a significant effect on aerosol deposition. In a combined human/laboratory model, Brand et al[7] reported that subjects breathing via a mouthpiece at a very slow flow had significantly greater deposition than at higher flows, although inter- and intra-subject flows varied by as much as 22%. Aerosol delivery via a face mask has been studied in the laboratory, but mainly in infant/pediatric models.[8,9] These studies showed that mask design, flow, and breathing pattern each independently had an effect on aerosol deposition.

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How to best deliver aerosol medications to mechanically ventilated patients has been extensively discussed and researched since the study by MacIntyre et al,[10] who showed that aerosol medication delivery during mechanical ventilation was much less compared with that in spontaneously breathing subjects. Factors that affect aerosol deposition in mechanically ventilated patients have been somewhat controversial and multifactorial. Dhand and Guntur[11] reviewed the available literature on the differences in aerosol deposition between mechanically ventilated and spontaneously breathing subjects. Many possible causes were identified, including, but not limited to, patient positioning, ventilator modes, inspiratory flow and pattern, humidity, temperature, and delivery method (such as through an artificial airway versus a native airway).

Several studies have evaluated aerosol deposition through TTs, but Bugis et al[1] are the first to evaluate uncuffed TTs and subsequently test a modified mask to administer aerosol simultaneously through the TT and mouth/nose. MacIntyre[12] performed a review of the published studies of aerosol deposition to date and found a wide range of deposition rates ranging from 1.2 to 43%. These studies were heterogeneous in that both TTs and endotracheal tubes, different jet nebulizers, and different models were used. On the basis of the available evidence, MacIntyre[12] stated that the ideal aerosol delivery system would have patient-triggered breathing with a slow, long inspiratory time, an end-inspiratory pause, and a large V_T. The carrier gas should be unhumidified using a nebulizer with high output, generating particle sizes of 1–3 μm.

Bugis et al[1] found that a main contributing factor in aerosol deposition was an inspiratory-expiratory ratio of

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2:1, which confirmed the results of Diot et al,[13] who showed that long inspiratory times and lack of humidity were major contributing factors in aerosol deposition. Bugis et al[1]used one V_T and breathing pattern, which they considered to be a limitation. The effect of larger V_T on aerosol deposition has been previously confirmed as a contributor to aerosol deposition, but only to a point. Once the reservoir (tracheostomy mask in the study by Diot et al[13]) is depleted of aerosol with increasing V_T, the amount of aerosol entering the airway is decreased in a linear fashion when air entrainment begins,[14] much like the effect of the Wright mask in the study by Bugis et al.[1] Although the breathing pattern could not be altered with the simulator, the use of different V_T values would have indicated where in the V_T range aerosol deposition begins to decrease.

In the study by Bugis et al,[1] only an 8-mm TT was used. Using different size TTs may affect the deposition rate using the Wright mask because a smaller TT would provide greater inspiratory resistance, allowing more of the available aerosol to enter the trachea via the upper airway. Conversely, a larger TT may allow greater deposition. Pitance et al[15] observed a decrease in aerosol deposition in a laboratory model with smaller TTs using both a T-piece and tracheostomy collar. The authors also noted that removal of the inner cannula resulted in a statistically significant increase (3.7–31.3%, $P < .002$) in aerosol deposition distal to the bronchi in their model. Additionally, they found that the mean particle diameter produced by the nebulizer used in their study ranged from 3.3 to 3.8 μm, whereas nebulizers used in a similar study conducted by O'Riordan et al[16] produced particles 1.1 $\pm$ 1.8 μm in diameter. The particle size generated by the nebulizer used by Bugis et al[1] was not indicated, but different nebulizer brands and even nebulizers within the same brand may produce different particle sizes, which could have affected the results of the study. These differences should be considered during clinical practice. An interesting addition to the study by Bugis et al[1] would have been to compare aerosol deposition via a T-piece using their model. Studies have confirmed that the greatest aerosol deposition through TTs was achieved with this delivery method.[17,18]

Bugis et al[1] showed that, somewhat surprisingly, the Wright mask did not provide the greatest aerosol deposition in their model. This is an important finding in that the method used by many clinicians to administer nebulizers to non-mechanically ventilated patients with TTs (via a tracheostomy collar) produced the best results. Sometimes the simplest way is the best, particularly in this model. Although this study was well done and the results may be translatable to clinical care, the study used a limited set of variables. Future studies with this same model should evaluate other variables not included in this study, such as different size cuffed and uncuffed TTs with and without inner cannulas, different nebulizer brands, and the use of a T-piece to deliver nebulized aerosol. Such work may help to identify the variables or combination of variables that have the greatest effect on aerosol deposition in this tracheostomy model.

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