

# Effect of Nebulizer Type and Position on Aerosol Drug Delivery during Support Mechanical Ventilation and Spontaneously Breathing for Tracheostomized Adult Patients.

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## Summary

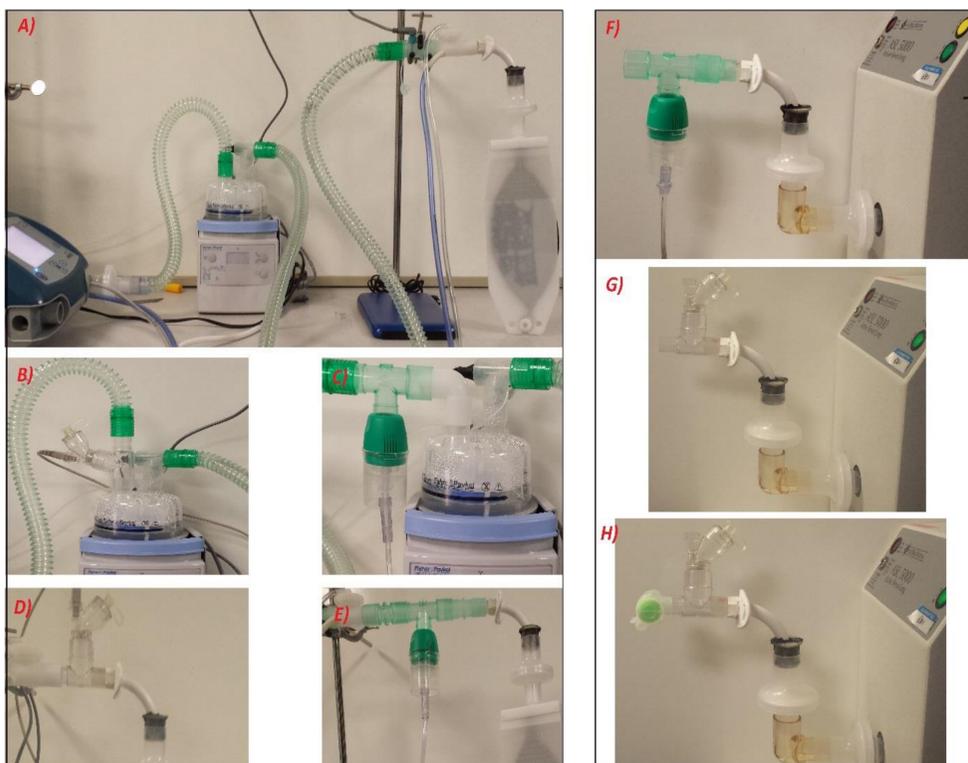
In tracheostomized patients the effect of nebulizer type/platform has not been studied in great detail. This study investigated tracheal dose delivery for a vibrating mesh nebuliser (VMN) and jet nebuliser (JN) in support (single limb) mechanical ventilation (SMV) and spontaneously breathing (SB) tracheostomized patients. Selection of nebuliser type can have a substantial influence when treating a patient. Earlier studies have shown that the VMN provides more aerosol than the conventional JN [1]. The nebulizer was placed at two positions during the SMV, 1) Dry side of the humidifier pot and 2) at tracheostomy tube (no spacers were used between the nebulizer t-piece and tracheostomy tube) and at the tracheostomy tube for SB. Results: the VMN delivered significantly greater % aerosol delivery when compared to the JN across all positions evaluated. The VMN proximal to tracheostomy tube during SMV facilitated the highest tracheal dose ( $50.78 \pm 2.65\%$ ) compared with JN ( $15.89 \pm 1.41\%$ ) at this position. Conclusion: the VMN delivered a significantly larger fractions of aerosol (P-values  $<0.05$ ) when compared to the JN for the tracheal dose for all positions evaluated for SMV and SB in tracheostomy patients.

## Introduction

The administration of nebulized therapeutic agents for SMV and SB tracheostomized patients is common in reducing pulmonary complications. Nebulizer type has been shown in previous studies to have large effects on the efficiency of nebulized drug deposition in the lung, during mechanically invasive ventilation [2] and spontaneously breathing patients [3]. However, in tracheostomized patients the effect of the type of nebulizer platform has not been studied in great detail. As part of this study, we investigated aerosol delivery from a VMN and JN in a humidified adult SMV circuit with a breathing simulator generating the adult SB. The nebulizer was placed at two positions during the SMV, 1) Dry side of the humidifier pot and 2) at tracheostomy tube (no spacers were used between the nebulizer t-piece and tracheostomy tube) and at the tracheostomy tube for SB. The objective of this study was to establish which nebuliser facilitates the highest drug delivery to the lung for a tracheostomized adult patient.

## Methods

Aerosol delivery performance was evaluated by characterising the Tracheal Dose (%) (drug delivered beyond the trachea). A 2.0 mL dose of Albuterol sulphate (1 mg/mL) was nebulised as a tracer aerosol using a 1) vibrating mesh nebuliser (VMN) (Aerogen Solo, Aerogen, Ireland), with an average volumetric median diameter (VMD) of  $4.73 \mu\text{m}$  and aerosol flow rate of 0.38 mL/min (measured using the Malvern Spraytec), 2) JN (Cirrus 2, Intersurgical, United Kingdom) with a driving gas flow rate of 8 LPM, with an average VMD of  $4.14 \mu\text{m}$  and aerosol flow rate of 0.27 mL/min (measured using the Malvern Spraytec). At the end of each dose the drug was extracted and quantified using UV spectrophotometry (at 276 nm). The mass of drug eluted from the filters was determined using spectrophotometry and interpolation on a standard curve of Albuterol sulphate concentrations (200  $\mu\text{g/mL}$  down to 3.125  $\mu\text{g/mL}$ ). Results were expressed as the percentage of the nominal dose placed in the nebuliser's medication cup that was delivered.



**Figure 1:** Test Setup for SMV (A-E) and SB (F-H) with VMN and JN; A) Generic test setup for SMV, B) VMN place at the dry side of the humidifier, C) JN place at the dry side of the humidifier, D) VMN place at tracheostomy tube, E) JN place at tracheostomy tube; F) JN connected to ASL for SB, G) VMN connected to ASL for SB, H) VMN with HME connected to ASL for SB

## Support (single limb) mechanical ventilation (Figure 1, A-E)

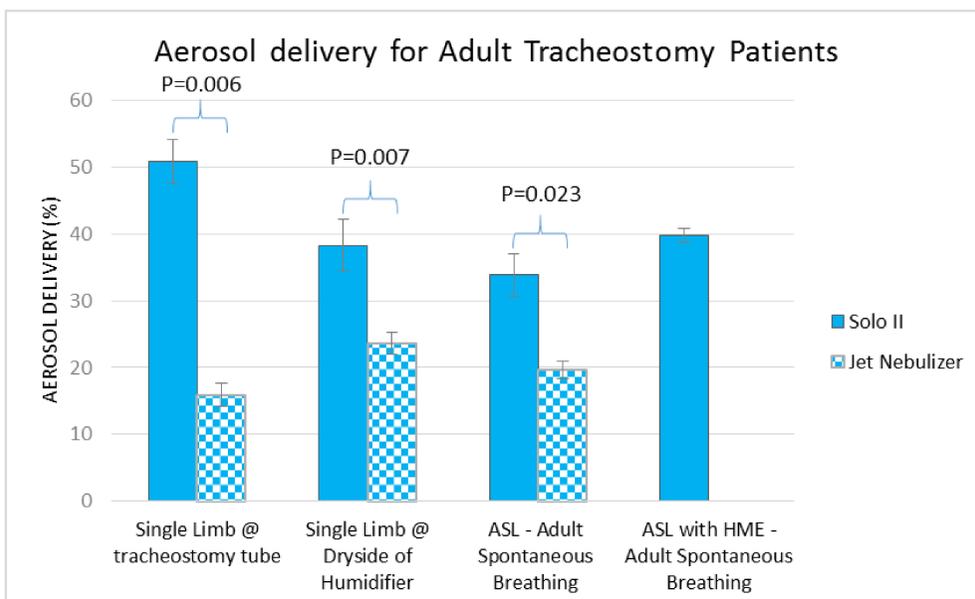
In all the experiments the model included a ventilator (Airox Supportair, Covidien, Ireland), a heated humidifier (Fisher & Paykel, Auckland, New Zealand), a heated-wire ventilator smoothbore circuit (Intersurgical, UK) and a tracheostomy tube (Shiley, Covidien, Ireland). The following mechanical ventilator breathing pattern was used (BPM 15, Vt 500 mL, I:E 1:2). The end of the tracheostomy tube cannula was inserted into a 3D printed fixture, a 22 male adaptor with a bore where the cannula was glued into position, which was then inserted into the housing of an absolute bacterial/viral filter (Respigard II 303, Baxter, Ireland). The pass-over humidifier and ventilator circuit were pre-heated during ventilation for approximately 20 – 30 min, until the temperature at the airway was stable at  $35 \pm 1^\circ\text{C}$ . The tracheostomy tube was placed in an upright position

## Spontaneously breathing (Figure 1, F-H)

The nebulizer was connected to a breathing simulator (ASL 5000, Ingmar Medical, PA, USA) via an absolute filter. A simulated adult breath was used (BPM 15, Vt 500 mL, I:E 1:2). For the VMN, the Heat and Moisture exchanger (Hydro-Trach II, Intersurgical, UK) was connected to the 15 mm male end of the Aerogen T-piece (Paediatric T-piece, Aerogen, Ireland). The tracheostomy tube was placed in an upright position.

## Results

Based on the results presented in Figure 2, the VMN was seen to have a significantly greater % aerosol delivery when compared to the JN across all positions evaluated. For the SMV setup, the largest aerosol delivery in this study was observed for the VMN at the tracheostomy tube at  $50.78 \pm 2.65\%$  (D), this compared to the JN at  $15.88 \pm 1.41\%$  (E). The % aerosol delivery for the dry side of the humidifier was substantially higher for the VMN at  $28.28 \pm 3.13\%$  (B) when compared to the JN at  $23.57 \pm 1.36\%$  (C). For the SB setup, the VMN with HME facilitated the highest drug delivery at  $39.70 \pm 0.84\%$  (H), however a direct comparison for the JN with a HME was not completed as part of this study, as it was not possible to directly connect the HME to the T-piece of the JN without a series of connectors/adaptors. The only direct comparison completed as part of the tracheostomy SB study showed the VMN was also superior to the JN at  $33.87 \pm 2.609\%$  (G) and  $19.03 \pm 1.03\%$  (F). The lower delivered dose associated with JN was due to larger losses to the circuit as a result of the high gas flow and the residual drug remaining in the reservoir upon ceasing aerosol generation (Note: was not quantified as part of this study, but has been report up to 50% remaining [4],[5]).



**Figure 2:** Aerosol delivery to for Adult Tracheostomy Patients for SMV and SB

## Conclusions

Results demonstrate that the VMN delivered significantly larger fractions of aerosol (P-values  $<0.05$ ) for the tracheal dose for all positions evaluated for SMV and SB in tracheostomy patients when compared to the JN. The delivered aerosol dose for the VMN and JN was seen to range from 33.87-50.784 % and 15.88-23.57 % respectively, depending on position. The positioning of both nebulizers on the spontaneous breathing patients may require additional review as the position may not be clinically applicable due to the close proximity to the patient and therefore further evaluation should be undertaken to understand the influence of spacers placed between the nebulizers and tracheostomy tube on aerosol delivery.

## References

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