Ventilator-Endotracheal Tube-Lung Benchtop Model for Luminal Occlusion

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Statement of Purpose: Endotracheal intubation disrupts the physiological homeostasis of respiratory system secretion (e.g. mucus) production and clearance.[1] Airway secretions consequently accumulate inside the endotracheal tube lumen causing partial obstruction.[2] Luminal narrowing correlates with increased airflow resistance and increased endotracheal tube related work of breathing for the patient. Complete occlusion of the endotracheal tube can occur abruptly after secretion accumulation resulting in a life-threatening lack of airflow and requiring emergency intervention.[1, 2] Pre-clinical benchtop models to validate feasibility of novel tube designs to inhibit luminal occlusion are an important step prior to animal and clinical trials.

Sharklet Technologies, Inc. has developed a benchtop ventilator-endotracheal tube-lung (VEL) model for investigation of interaction of airway secretions with airway management devices such as endotracheal tubes during ventilation. Sharklet micropatterned endotracheal tube prototypes were evaluated to determine the feasibility of using this model to test new tubes for reduced accumulation of airway secretions.

Methods: A fixture (Figure 1) was developed as part of the VEL model to hold and test up to four endotracheal tubes simultaneously. Adjustable, hinged platforms were incorporated to provide the investigator the ability to mimic anatomical tracheal bending and head-of-bed position. Tubes were connected through an air splitter to a ventilator and placed inside a reservoir that was filled with test liquids such as simulated mucus. A test lung connected to the reservoir returned air to the ventilator simulating expiration. As breathing proceeded through the VEL model, simulated airway secretions were pulled into tubes to recapitulate the interaction of respiratory secretions with airway devices.

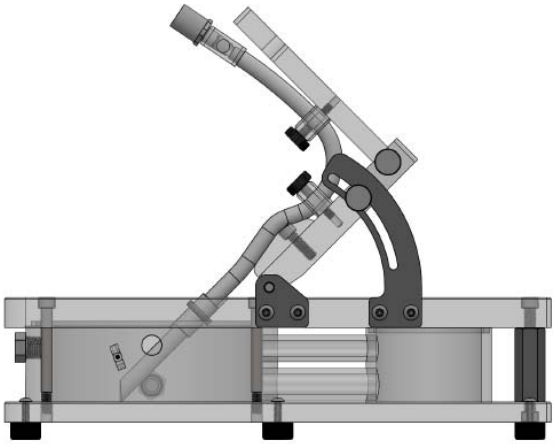

Figure 1. Schematic of VEL test fixture.

To validate the feasibility of using this model to show reduced luminal occlusion, Sharklet micropatterned endotracheal tube prototypes were tested. Four tubes, two patterned (SK) and two smooth (SM), were tested in each of three experiments. Tubes were exposed to artificial mucus[3] in the VEL model for 96 hours at 37°C. Following mucus exposure, tubes were sectioned and weighed. The simulated mucus accumulated inside the tubes was dissolved in water and the optical density (600 nm) of the resulting solution was measured. The cleaned and dried tubes were weighed and the mass of accumulated mucus was calculated.

Results: The Sharklet micropattern reduced mass of occlusion in prototype endotracheal tubes by 60%, p=0.02 in the section closest to the patient end (Figure 2) compared to smooth controls.

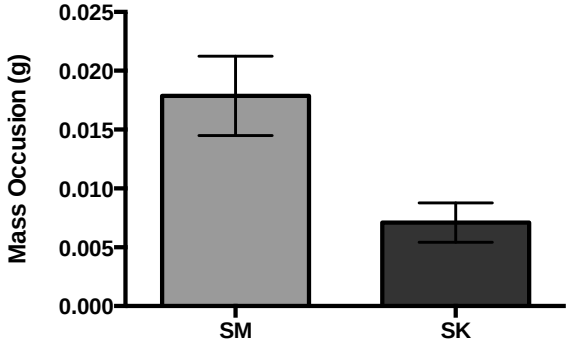

Figure 2. Sharklet micropatterns reduced accumulation of simulated airway secretions compared to smooth controls.

Additional analysis of overall mucus accumulation over the entire tube prototype showed ~50%, p=0.001 reduction by both mass of occlusion and optical density measurements in SK tubes compared to smooth prototypes.

Conclusions: These results demonstrate that this new VEL model can be used to evaluate new technologies for the inhibition of airway secretion accumulation and luminal occlusion within airway management devices such as endotracheal tubes. Additionally, we show here that the Sharklet micropattern significantly reduces airway secretion accumulation and therefore may lead to improved patency within airway management devices in animal models and clinical trials.

References:. [1] Mietto R. Anesth. Online First, DOI: 10.1097/ALN.0000000000000455. [2] Kawati, Anesthesia & Analgesia. 2005;100:889. [3] Sriramulu, D. J. Med. Micro. 2005;54,667-676.

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