# Ventilator Associated Pneumonia Prevention

Department of Biomedical Engineering, Chemistry and Biological Sciences
Yona Bauzil[1], Shaan Huq[1], Moon Jung[1], Anthony Whittaker[1], Dr. Glen Atlas[2]
[1]Stevens Institute of Technology, Hoboken, NJ 07030
[2]Rutgers New Jersey Medical School, Newark, NJ 07103

**Abstract – UV-C radiation is a promising, alternative technique to traditional suctioning for the sterilization of endotracheal tubes. The VAP ZAP device is a flexible wand that is inserted into an endotracheal tube to emit UV-C radiation to destroy bacterial pathogens of ventilator associated pneumonia (VAP). A bacteria mortality test was completed which showed that UV-C radiation which was emitted from the VAP ZAP device was successful in sterilizing endotracheal tubes, thus preventing the occurrence of VAP.**

## I. Introduction

Ventilator associated pneumonia (VAP) is a nosocomial infection which develops 48 hours after a patient receives tracheal intubation and mechanical ventilation. Every year, 27% of intensive care unit patients, amounting to about 250,000 patients, develop VAP in the United States. VAP kills a third of those patients and costs the healthcare system $3-$10 billion annually [1]. The current method for prevention is to suction secretions in the endotracheal tubes; however, it is ineffective in reducing VAP occurrence. Our product, the VAP ZAP, is a portable sterilizer that utilizes UV-C radiation to safely and efficiently reduce the accumulation of VAP causing agents such as Pseudomonas aeruginosa. Several parameters were considered when creating the design. The design must uniformly distribute UV-C radiation through an optically transparent material within a safe time frame. The VAP ZAP must also be reusable.

## II. Materials & Methods

Fig.1 shows the overall design and components of our device, the VAP ZAP. It must be inserted into the endotracheal tube to kill bacteria through the use of UV-C radiation. The handle was 3D printed using acrylonitrile butadiene styrene (ABSplus) material. Flexible metal tubing was used as a connector between the housing of the light source and the handle in order to provide a greater degree of freedom between the illuminating tube and the operator's hand. Aluminum was used for the housing due to its reflective properties of the UV spectrum which prevented the release of the radiation. The housing contained two lenses to concentrate light within the illuminating tube. An HG2 low-pressure Mercury glass lamp was used to provide light to the illuminating tube, and was powered by a Haraeus Noblelight C430 power supply specifically designed for use with the bulb which was plugged into a wall outlet. Dimensions of the power supply were 150 x 76 x 50 mm, and it contained three leads that connected to the bulb. The illuminating tube was made of fluorinated ethylene propylene (FEP) with an inner diameter of 6 mm and an outer diameter of 6.55 mm.

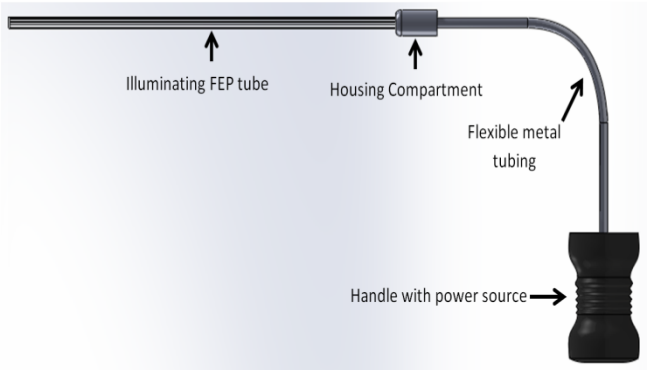



Fig. 1: Overview of the VAP ZAP and its components

*Pseudomonas aeruginosa* required UV dosage of 11,000 µW-s/cm$^2$ for 99% mortality rate. While it is most often the cause of VAP in mechanically ventilated patients, it is a biosafety level 2 organism and is moderately hazardous in the lab environment. Therefore a biosafety level 1 organism, *Bacillus subtilis*, was chosen as a surrogate. This specific bacteria was used due to its similar UV resistance to *Pseudomonas aeruginosa*.

Six groups of agar plates with bacteria, which were each incubated at 37°C until they reached a population of 15 million. Each group were then exposed to different UV light exposure times ranging from 0 - 40 seconds. The group that was not exposed to UV light was used as the control group. The *Bacillus subtilis* was diluted with Trypan Blue dye and placed on hemocytometers. The hemocytometers were then observed using a microscope; only the cells that did not absorb the dye were counted in order to determine the number of bacteria remaining on the plates.

The following equation, equation 1, was used to determine the optimal time for exposure:

$$\frac{Energy\ required\ for\ mortality\ \left(\frac{\mu W-s}{cm^2}\right)}{UV\ Bulb\ Output\ \left(\frac{\mu W}{cm^2}\right)} \qquad Eq.\ 1$$

This equation gave a theoretical value of 1.29 seconds, which was lower than the expected value of 30 seconds. These values were used to assess if the expected time of 30 seconds, based on precedent work [2], was sufficient enough to sterilize the endotracheal tube.

A transmission test was also completed (with the use of a UV radiometer) in order to indicate the percent transmittance of the UV-C light through the FEP tubing of thicknesses 1mm, 2mm, and 3mm. This test was crucial in the determination of the efficacy of the VAP ZAP. Percent transmission through each sample will be calculated via the

following equation: % Transmittance =$I/I_0$*100, where I is final intensity, and $I_0$ is initial intensity.

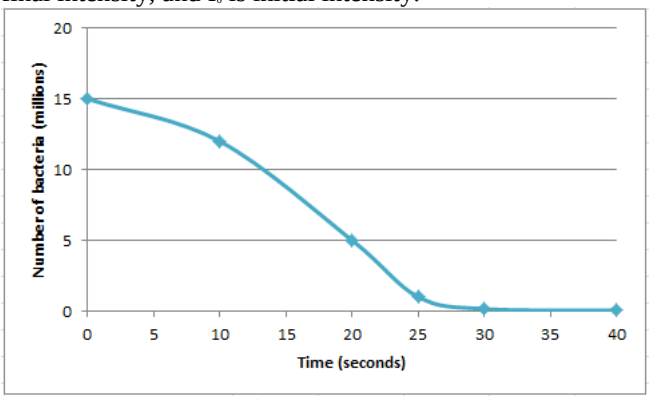
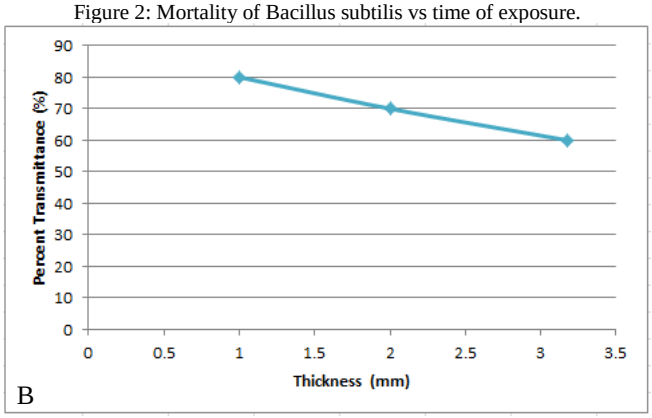



Figure 2: Mortality of Bacillus subtilis vs time of exposure.




B

Figure 3: Percent Transmission of light through thickness of FEP tubing

## III. Results

The obtained results indicated that at 30 seconds, 99% of the bacteria on the internal surface of the endotracheal tube were killed (Fig. 2). However, only approximately 80% of the bacteria cells on the outside surface of the endotracheal tube were killed. These results were preliminary, updated results will be provided at the conference.

## IV. Discussion

Figure 2 shows the mortality rate of the *Bacillus subtilis* with respect to time; it can be seen that 99% of bacteria were killed within 30 seconds of exposure to a UV-C bulb output of 15,000 µW/cm$^2$. This goes along with our expectations from equation 1 and meets the predetermined requirements for full sterilization. The VAP ZAP achieved an 80% mortality rate outside of the endotracheal tube. This was due to attenuation of the UV-C light by the polyvinyl chloride material, which endotracheal tubes are commonly made of. Thus, there was a decrease in the UV-C output on the external surface of the endotracheal tube.

The obtained exposure time of approximately 30 seconds verifies that the VAP ZAP can operate within a safe time frame for the patient. The discrepancy between the calculated and experimental exposure times was attributed to the lack of representation of several factors in equation 1. The intensity of the UV-C output closest to the light source was stronger than that of the output at the farthest end of the tube. It was assumed that some attenuation of the UV-C radiation occurred in the space between the outer surface of the illuminating tube and the inner surface of the endotracheal tube. According to equation 1, a weaker output would result in a higher exposure time as was found in the experiment. Another factor of duration of exposure was the thickness of the FEP tubing. Through transmission testing, it was determined that a thinner thickness would allow more UV-C transmission. Thicker FEP tubing would be less transmissive but would ultimately be more durable than thinner tubing . Refer to Fig. 3 for the trend between FEP thickness and transmission percentage.

## V. Conclusion

The results of the *Bacillus subtilis* mortality test and FEP transmission testing show that the VAP ZAP device is a potentially valid method for the prevention of VAP. Future work on the VAP ZAP device will include the research and development of custom, edge emitting fiber optic cables capable of emitting UV-C light which can be incorporated within the illuminating FEP tube. This will increase the intensity and uniform distribution of the UV-C radiation.

## Acknowledgements

The team would like to acknowledge the following people for their support and valuable knowledge: Dr. Helen Kambic, Dr. Vikki Hazelwood, Dr. Thomas Cattabiani, Dr. Marvin Hutt, and Dr. John Cusack. The team would also like to recognize the precedent work accomplished by the 2010 Senior Design Team.

## References

[1] Richards, M.J., Edwards J.R., Culver D.H., Gaynes R.P., 1999. Nosocomial infections in medical intensive care units in the United States. National nosocomial infections surveillance system. Crit. Care Med. 27: 887-892.

[2] PORTABLE VAPP UNIT. Unpublished manuscript, 2010. Stevens Institute of Technology, Hoboken, NJ.