Use of an Optically Directed Endotracheal Tube Clearing Device to Reduce Biofilm-Associated Occlusion

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INTRODUCTION

Recognizing the huge consequences of VAP and concomitant use of anti-infectives, a multitude of device/strategies have been recently evaluated, directed at the endotracheal tube (ETT); luminal microbial biofilm colonization and subsequent infections in approximately 10-15% of mechanically ventilated (MV) patients. We reported in 2005 a seven day luminal delay of a five species complex using a 7.5% (w/v) silver coated ETT using an in vitro simulator. We unmasked in 2009 the collateral damage of biofilm accretion build up and increased Work of Breathing (WOB) in 100% of MV patients, reinforcing the biophysical nature of ETT intervention in ventilator Associated Pneumonia: microbial and immunologic.

In this study, we wanted to evaluate the “Green” EndoClear Cleaning Device (ECCD) engineered to extract the ETT luminal biofilm accretion build up, using a reusable filter optic support for optimum positioning and evaluation.

RESULTS

The pressure drop generated by the flow at a given means flow rate was compared to control ETTs, sizes 7, 7.5, and 8.0 in the head/anatomically correct ETT position vs the original upright data published in CHEST, 2009 (Wilson, Thomas, et al). Compared to the head/anatomically correct ETT position, there is a reduction in WOB when ETT’s are in their natural curve position and not in the correct “Ω” of Head Design, as representative of intubated patients. Extracted ETTs showed significant range of increased WOB for sizes 8.0 to 7.0. Many of which showed resistance to flow similar to 1-2 sizes smaller than the largest tested ETT. This reduction in effective minimal diameter results in a relative increase in resistance of ~70%. The National ICU survey showed 50% of clinicians believe a 20% increase in resistance is significant. Following ECCD clearing, ETT resistance was reduced in a range of 90% to 99% transitioning back to an almost brand new ETT. Microbial quantification showed IF and mucosal accretion composition ranging from 3-5 organisms, most commonly: Sphingobacterium, Pseudomonas aeruginosa, and Candida albicans. (last Ponidizaje and Consolado algorithms). Volume of ETT recovered was 1.5:2.0 µl’s or even in “clean” ETTS. Following clearing, the CFUs were reduced by 10^3-4, with minimal residual biofilm or planktonic structure visible under SEM, particularly focused on section B (middle) where turbulent forces often enhance biofilm 3-D structure. Optical analysis showed the uniquely engineered bullet tip and small diameter did not dislodge biofilm accretion material during device insertion.

CONCLUSIONS

In preliminary studies, the ECD demonstrated both pathways of the biphasic impact of ETT BF-accretion build up: microbial and immunologic. It returned the function of the ETT, airway to “normal” without the use of anti-infectious and/or dislodging biofilm-infectious materials into the distal airway. By using a heated, properly proportioned ETT, true value of airway resistance can be assessed recognizing impact of shape of the ETT, thermal conductivity of the tube at 37°C, and the true application of Hagen-Poiseuille equation (to the 4th power).

HYPOTHESES

The AEs were to expand the 2009 study with: 1) Updated/modeled PTE-2000 evaluation of ETT occlusion and WOB, and 2) Measure the impact on microbial reduction and remaining biofilm architecture/microbiomes, ultimately assessing the return of the ETT to a “nominal” function.

METHODS

We followed the Protocol detailed in CHEST, 2009 (Wilson, Thomas, et al). Briefly, de-identified ETT’s from adult MV patients for more than 24 hrs were transported in a humidified transport “test” box and assayed in 2 hours. WOB was tested using a combination of both the Puritan Bennett PTE-2000 instrument and the Puritan Bennett Respirator (B-210, Rev. B) software, installed on a PC. The ETT was positioned in a 37°C heated, automatically correct “Ω” of Head Design and elevated to 30% in concert with IBI VAP Bundle Guidelines. A natural and regulated flow rate of compressed air was then administered at 100 LPM over 30 sec to an ETT with a HEPA filter attached to the distal end and compared to controls of similar size. Biofilm and mucosal accretion extraction were followed using methods detailed in BMC Health, 2011 (Ghosh, Cal, et al) and SEM was utilized to analyze the bioacet of the removed biofilm and mucosal accretion and the cleared ETT lumens.

REFERENCES AND SUPPORT


College of Engineering and Mineral Resources, West Virginia University. (Imaging)

Support: EndoClear

Figure 5: Picture of multi-stage measuring device in 852 safety hood with computer graphics (Y) or measuring increase in air pressure (X) over time. The PTE-2000 G was used to detect resistance to air flow.

Figure 6: Comparison colony counts (CFUs) of collected sample pre and post cleaning using various media.

Figure 7: Highlighting the impact of device utilization in regards to biofilm reduction. The image on the left displays the biofilm matrix present within the lumen of the ETT. Image on the right obtained from the lumen of the tube highlights the efficacy of the device in reducing the biofilm/bioaccumulation.

Figure 8: A representation of the difference in tube function pre (left) and post (right) cleaning with the device under investigation.

Clinical Application

A huge expenditure of time and money has been spent in the last 20 years on VAP focusing initially on ventilator equipment. With the recent recognition of the ETT lumen as a major reservoir, newer strategies have addressed biofilm and airway occlusion, using a variety of anti-infectives with limited degrees of success. We now recognize that the biofilm is a bridge, linking ETT colonization to accretion build up increasing airway resistance in 100% of patients in unpredictable way. The device investigated in this study has a unique wiper action and the capacity to return the ETT function to essentially normal or normal with one application, without using anti- infectives which lead to collateral antibiotic resistance. (Figure 9)