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Changes in pediatric tracheostomy tubes exposed to home dishwashing

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ABSTRACT

Objective: Determine the effects of household dishwashing on Tracheostomy Tube safety.
Introduction: Tracheostomy tubes accumulate biofilms, which may limit their lifespan. Frequent cleaning of the tubes is a method for biofilm prevention. Cleaning practices vary widely. Some families prefer dishwashing of tubes, but its effects are currently unknown. We hypothesize that dishwashing has no significant effect on the physical properties of tracheostomy tubes and can be recommended as a safe way to clean tracheostomy tubes.
Methods: Twenty 4.0 Shiley™ pediatric tracheostomy tubes were randomly assigned into dishwashed (DW) and non-dishwashed (NDW) groups, 10/group. DW tubes were subjected to 12 wash cycles. Each tube's hardness along with the surface spectra were analyzed to assess for chemical composition changes. Three cannula samples from each group were also randomly assessed with scanning-electron microscopy and scored by blinded examiners to assess for changes in surface heterogeneity.
Results: Hardness testing revealed a statistically significant difference ($p = 0.0009$) between the NDW and the DW group indicating increased fragility in the dishwashed tubes. Spectral analysis revealed loss of plasticizers, indicating decreased flexibility. Blinded electron microscopy scoring revealed increased surface heterogeneity in the DW group ($p = 0.00007$).
Conclusion: A significant decrease in tube hardness and increased surface heterogeneity were found with dishwashing. The spectral analysis demonstrated increasing fragility. We believe these effects could potentially lead to decreased mechanical safety. With increased surface heterogeneity there is a greater potential for biofilm formation. At this time, dishwashing cannot be recommended as a tracheostomy tube cleaning method.

1. Introduction

In the bacteria-laden environment of the upper airway, tracheostomy tubes quickly accumulate respiratory secretions and biofilms. These biofilms may increase the risk of infection [1–3]. Tube degradation is known to result from complex interactions between the polymer and environmental factors. This degradation may be worsened by surface contaminants, such as biofilms [4]. Pediatric tracheostomy tubes lack disposable inner cannulas that can be removed and replaced; therefore families must endure the frequent replacement of the entire tracheostomty tube. Clinical studies demonstrate tube degradation after only 30 days and recommend against greater than 3 months of use [5,6].

Manufacturer guidance on cleaning is minimal, with a standard package insert for a Shiley™ pediatric tracheostomy tube recommending cleaning by *soaking* in half-strength hydrogen peroxide, half-strength vinegar, normal saline, or water and detergent. Standard soaking has poor efficacy for removing biofilms and associated bacteria, causing both patients and clinicians to seek

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more robust, cost-effective cleaning methods [7,8]. Though the effect of dishwashing on tubes is unknown, some parents utilize dishwashing for its common household availability. Logically, dishwashing is a readily available cleaning method likely to remove respiratory secretions and biofilm. Without evidence of its safety, concerns exist that dishwashing may degrade the tracheostomy tube. Though rare, tube breakage is most likely to occur at the union of the flange to the cannula, which is a life-threatening complication due to a possible airway foreign body [9].

The goal of this study is to determine whether home dishwashing results in material changes or surface degradation of pediatric tracheostomy tubes. The Shiley™ cuffless PVC pediatric tracheostomy tube, one of the most popular pediatric tubes, was chosen for testing. The devices were objectively measured for changes in surface hardness, alteration of surface structure, and/or a loss of surface smoothness interpreted as increased surface heterogeneity.

2. Methods

IRB approval was not required for this study since no protected patient information or human subjects were involved. Twenty 4.0 Shiley™ pediatric tracheostomy tubes (Covidien LLC, Mansfield MA) were randomly assigned into dishwashed (DW) and non-dishwashed (NDW) groups: ten in each group. To simulate the recommended three months of once-per-week cleaning, DW tubes were subjected to 12 wash cycles. A Frigidaire brand dishwasher (model FDB1100RHCO, Electrolux North America, Charlotte NC) was utilized.

Tracheostomy tubes were placed in the bottom rack utensil container of the dishwasher. Tube positions were rotated after each wash. Detergent pods (Cascade® Action Pacs, Procter & Gamble Corporation, Cincinnati, OH), were added to each dishwashing cycle, and the dishwasher was set to provide high-temperature, heat-dry, normal wash cycles. Tubes were allowed to cool to room temperature and completely dry between each of the 12 cycles. Time-based temperature values inside and outside of the tubes were recorded every 30 s using K-type thermocouples and an A/D converter on a personal computer. After completing all wash cycles, each tracheostomy tube was prepared as shown in Fig. 1 for testing. To ensure observed hardness was not the result of retained water, DW samples were placed in a sealed container with desiccant for 24 h and re-measured. Three cannula portion samples from each group were randomly analyzed using scanning electron microscopy (EM).

Control tracheostomy tubes were not submitted to any dishwashing or cleaning method. The purpose was to see the effects of dishwashing on the mechanical properties of the tubes themselves. The tracheostomy tubes were analyzed with the same parameters by sectioning and examined for hardness. This group was similarly randomized for selection into the scanning electron microscopy. This provided 10 sets of data points for hardness and uptake to compare to 10 sets of data for dishwashing points.

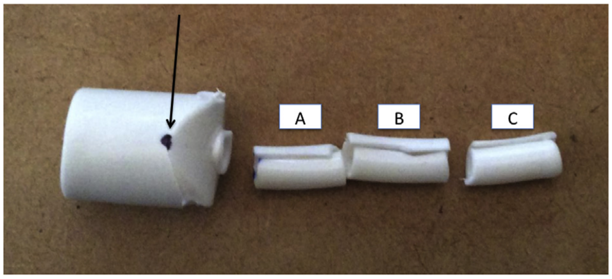

Fig. 1. Tracheostomy tube as sectioned prior to measurement. The cannular portion was sectioned into A) Proximal, B) Middle, and C) Distal segments. The arrow indicates the point of measurement for hardness analysis on the connector portion. The cannular segments were bisected to allow for testing of both the inner and outer surfaces.

2.1. Hardness analysis

Hardness was analyzed utilizing a Shore A Durometer according to standardized methods [10,11] with applied force of 0.825 kg. The measurement location was at the thickest point, identified as the connector portion, near the union of the cannula and the flange of the tube. This point was chosen because it allowed for reproducible hardness measurements, along with satisfying the requirement for material thickness of the ISO standard.

2.2. Surface Fourier Transform Infrared spectroscopy (FTIR)

Each cannula of the DW and NDW tubes were bisected, as shown in Fig. 1, to access the internal and external surfaces for analysis. Infrared spectra was obtained (16 scans at 2 cm^{-1} resolution) between 800 and 4000 cm^{-1} for each tube using a Fourier Transform Infrared (FTIR) Spectrometer (FTS-40, Digi-Lab, BioRad, Cambridge, MA). The infrared spectrum of a common plasticizer for PVC materials, DEHP (Bis(2-ethylhexyl) phthalate) (Sigma-Alrdich, St. Louis, MO) was obtained using similar conditions as reference of comparison.

2.3. Electron microscopy

Three tubes from both the DW and NDW groups were randomly selected for Electron Microscopic (EM) analysis. The tube segments were oriented so that both the inner and outer surfaces of the tubes could be imaged in a scanning electron microscope (FEI XL30, Philips, Hillsboro, OR) at 500X to 2000X magnification. To determine changes in surface heterogeneity, three blinded examiners were utilized. Examiners were then asked to examine a series of (30) randomized 1500X micrographs (14 from the NDW samples and 16 from the DW samples). They were then asked to score each micrograph from 1 to 5, with 1 being the most homogenous and 5 being the most heterogeneous. Statistical testing was performed using software (SigmaPlot for Windows V11.0, Systat Software Sanjose, CA). Data from EM analysis was first tested for normalcy of fit (Shapiro-Wilk) and equal variance before analysis using Student's T test. All statistical testing was performed at a pre-set alpha of 0.05.

3. Results

3.1. Hardness

Hardness analysis showed a statistically significant decrease ($p = 0.0015$) in Shore A hardness between the NDW 76.6 (95% CI: 76.1–77.1) and DW 74.1 (95% CI 73.6 to 74.6) groups. As expected there was a similar significant decrease in hardness with post-desiccation DW specimens, 74.8 (95% CI: 74.3 to 75.3). There was no significant difference in hardness between DW and desiccated DW samples ($p = 0.3200$), indicating that retained water was not a confounding factor for the measured results of hardness.

3.2. Surface Fourier Transform Infrared spectroscopy (FTIR)

A spectral comparison for the inner and outer surfaces of NDW tubes is shown in Figure, 1a, with the “fingerprint” absorption regions in Fig. 1b. These plots demonstrate greater absorption values