A Day in the Life of a Nebulizer: Surveillance for Bacterial Growth in Nebulizer Equipment of Children With Cystic Fibrosis in the Hospital Setting

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BACKGROUND: Cystic fibrosis (CF) is characterized by chronic lung infection. Minimizing exposure to pathogens is important. Treating a CF pulmonary exacerbation includes nebulizer therapies, but little is known about pathogen exposure from nebulizer equipment in CF. OBJECTIVE: To assess microbial growth in nebulizer equipment used by hospitalized CF patients. HYPOTHESIS: The small-volume nebulizer would not support the growth of the important CF pathogens: *Pseudomonas aeruginosa, Staphylococcus aureus, Haemophilus influenzae,* and *Burkholderia cepacia*. METHODS: During a 6-month period, we prospectively enrolled 30 patients who were admitted for pulmonary exacerbation of CF and were prescribed an aerosolized bronchodilator 4 times daily. Bronchodilator was administered via disposable small-volume nebulizer, prior to airway clearance. The nebulizer was not cleaned or disinfected between treatments, but instead was replaced after 24 hours. Sputum or throat cultures were obtained prior to admission or on the day of admission, and standard culture techniques were used for CF microbes. After the first bronchodilator treatment, a sample was taken from the residual fluid inside the nebulizer cup. The second, third, and fourth samples were taken from the nebulizer cup after it was filled with a unit dose of the bronchodilator but prior to administering the bronchodilator. At the 24th hour, the nebulizer was filled with 3 mL of sterile water, from which the fifth sample was obtained, then the nebulizer was disposed of. RESULTS: On respiratory culture, ten patients had *Pseudomonas aeruginosa*, 5 had both *P. aeruginosa* and *S. aureus*, 6 had only *S. aureus*, and 1 had both *S. aureus* and *H. influenzae*. Three had other organisms, 4 had normal flora, and 1 had no culture data. Of the 150 nebulizer sample cultures, only 3 showed bacterial growth. *Bacillus* species, *Corynebacterium*, coagulase-negative *Staphylococcus*, and *Candida albicans* were isolated at low colony counts. CONCLUSIONS: We suspect that the organisms identified were caused by skin contamination of the samples rather than contamination of the nebulizer cup. We conclude that there is a low risk of microbial contamination with CF pathogens from the interior of a disposable nebulizer over a 24 hour period. *Key words: cystic fibrosis, nebulizer, infection control, contamination, disposable, respiratory equipment, aerosol.* [Respir Care 2007;52(3):258–262. © 2007 Daedalus Enterprises]

Introduction

Cystic fibrosis (CF) is a life-shortening genetic disease that requires comprehensive health care to slow disease progression and optimize well-being. A major characteristic of CF is microbial colonization of the lungs at an

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early age, which leads to obstructive lung disease and destruction, which is the primary cause of morbidity and mortality. CF patients often require hospitalization for pulmonary exacerbations and they receive intravenous antimicrobial therapy, aggressive airway clearance, and aerosolized medications. Bacterial contamination of nebulizer equipment is an important research topic. Several studies have found bacterial contamination in home nebulizer equipment of patients with CF. In 1987, Pitchford et al found that 17% of home nebulizers used by CF patients were contaminated with *Pseudomonas aeruginosa*, a common CF pathogen.[1] Infection prevention and control measures in CF care are designed to decrease the risk of exposure to harmful CF pathogens, namely *P. aeruginosa, Staphylococcus aureus, Haemophilus influenzae,* and *Burkholderia cepacia*. The Cystic Fibrosis Foundation consensus conference on infection control recommended that nebulizer equipment used by CF patients be cleaned, disinfected, rinsed, and air-dried between uses, in both the home and hospital, to combat bacterial contamination.[2] As a result of the infection-control recommendations by the Cystic Fibrosis Foundation, hospitals need to review their current infection prevention and control policies, and determine how best to care for individuals with CF in the hospital.

Practice patterns regarding nebulizer use and care differ markedly among hospitals and CF centers (Catherine A O'Malley, independent survey of nebulizer practice in United States CF centers, 2002, unpublished data). Many hospitals use nebulizer equipment for a certain period of time and then dispose of it, and they do not have a process for cleaning and disinfecting between uses. Clearly this practice is not congruent with the Cystic Fibrosis Foundation's recommendations. Some hospitals clean, disinfect, rinse, and air-dry nebulizers between uses, but this raises some concerns. Who is performing this task, for example, and where is it being performed? According to the American National Standards Institute and the Association for the Advancement of Medical Instrumentation, decontamination practices in the hospital should be conducted by qualified personnel in a qualified area designated for decontamination of medical devices (personal communication, 2003, Terri Rearick, Chicago Department of Public Health, Chicago, Illinois) Having a respiratory therapist "reprocess" a nebulizer at the bedside clearly does not comply with that standard. In 2003, Denton et al suggested that *Stenotrophomonas maltophilia* contamination found in nebulizers used by in-patients with CF may have been from the practice of "cleaning" the nebulizer equipment with potable water sources and inadequate drying.[3]

Another concern is the reprocessing of disposable nebulizer equipment. There are many types of disposable nebulizers available for hospital use, and each comes with specific care instructions. It is important to follow the manufacturer's recommendations for the care of the product, to maintain its integrity and proper functioning. Disposable small-volume nebulizers (SVNs) are not designed for extended use, and disinfection instructions are typically not included. Also, disposable nebulizers are labeled "single patient use only," which excludes them from being reprocessed at a central location in the hospital, because the equipment might not be returned to the same patient. A safe alternative to reprocessing is to use the disposable nebulizer only once and dispose of it after the treatment. This option, however, would be a financial challenge to most hospital budgets.

There has been little research on the safety of clinical practice of aerosol delivery to hospitalized CF patients. The present practice at our institution is to use a new nebulizer setup (tubing, SVN, mouthpiece or mask), one per day per medication. The equipment is not cleaned, disinfected, or rinsed between uses. Rather, it is placed in a plastic bag, all of which is disposed of and replaced with a new setup every 24 hours. This practice is congruent with the clinical practice guidelines of the American Association for Respiratory Care (AARC),[4] which state in section 13.3, "Selection of Aerosol Delivery Device," that "Published data establishing a safe use period for small-volume and large-volume nebulizers are lacking; however, they probably should be changed or subjected to high-level disinfection at approximately 24-hour intervals." The purpose of the present study was to determine if this practice was "safe," meaning that there was no growth of bacteria that are harmful to CF patients: *P. aeruginosa, S. aureus, H. influenzae,* and *B. cepacia*. Our aim was to assess microbial growth in nebulizers used by hospitalized CF patients over a 24 hour period. We wanted to determine whether the nebulizers were contaminated with bacteria and whether the bacterial load increased over the 24-hour period. We hypothesized that SVNs would not support bacteria growth in a 24-hour period because of the conditions in which the nebulizer is kept. The growth of most bacterial pathogens is enhanced by optimal conditions, such as a dark, warm environment rich in nutrients, whereas the nebulizer is kept in a plastic bag where there are no nutrients and the room is relatively cool (well below body temperature) and is well lit.

Methods

Thirty patients were enrolled in the study. The inclusion criteria were: confirmed diagnosis of cystic fibrosis; admission for a pulmonary exacerbation; and an order for aerosolized bronchodilator therapy 4 times daily. There were no exclusion criteria. The protocol was approved by our institutional review board. Written consent (and assent when appropriate) was obtained from all study participants.

Sputum and throat cultures were obtained on admission or at least 7 days prior to admission. Bacterial culture was performed according to our routine protocol for CF patients. Each specimen is inoculated onto 5% sheep-blood agar, MacConkey agar, haemophilus isolation agar with bacitracin, Columbia colistin-nalidixic acid (CNA) agar with 5% sheep blood, and plate count (PC) agar (all from BBL, Bacton Dikinson, Sparks, Maryland). Agar plates were incubated for at least 48 hours, except the PC agar plates, which were incubated for 5 days to isolate *B. cepacia*.

The SVNs used to administer bronchodilators (albuterol, levalbuterol, or ipratropium bromide) were sampled during the first full day of admission, when intravenous antibiotics were least likely to impact microbial growth results. All other aerosolized medications (eg, dornase alfa, tobramycin, colistin) were delivered with separate nebulizers that were not part of the study. Each bronchodilator nebulizer was sampled on 5 occasions over the 24-hour period of use. The first sample was obtained from the residual medication in the nebulizer immediately after the first treatment. The second, third, and fourth samples were taken from the nebulizer cup after it was filled with a unit dose vial of the bronchodilator but prior to administering the bronchodilator. At the end of each treatment the medication remaining in the nebulizer was discarded and the nebulizer setup was stored in a plastic bag at the patient's bedside, along with the patient's other aerosol medication equipment. The treatments were approximately 4 hours apart. At the 24th hour, the SVN was filled with 3 mL of sterile water, from which the fifth sample was obtained. Then the nebulizer was disposed of and replaced with a new nebulizer setup and a new plastic bag, per our standard hospital procedure.

The fluid inside the SVN was cultured using two 10-μL sterile loops: one to inoculate the 5% sheep-blood agar, and the other to inoculate the chocolate agar. The specimens were collected by members of the respiratory care staff, who were trained in the study protocol and assigned to this task on study participant admission. The inoculated plates were immediately sent to the laboratory. The cultures were incubated at 37°C and examined for bacterial growth at 24 hours and 48 hours. Because of the very low bacteria recovery during pilot testing, and because no study patient was found to have *B. cepacia* in their sputum or throat cultures, we did not use selective medium and extended incubation time. Bacterial growth was recorded and respiratory bacterial pathogens were identified according to standard laboratory procedures.

Results

Thirty subjects were recruited over a 6-month period. The participants' mean age was 11 years (range 1–18 years), 80% were female, 87% were white, and 13% were Hispanic. A total of 150 samples were obtained, incubated, and analyzed. Only 3 cultures (2%) had bacterial growth. Bacillus species, *Corynebacterium*, coagulase-negative *Staphylococcus*, and *Candida albicans* were isolated, with low colony counts (Table 1)

Table 1. Identified Organisms From Nebulizer Cup Cultures

Subject Number	Specimen	Organism(s)	Quantity
14	2	*Bacillus*	Rare
17	3	*Corynebacterium, coagulase-negative Staphylococcus*	1,000 colonies/mL
17	4	*Corynebacterium, Candida albicans*	2,000 colonies/mL

The admission sputum and throat cultures (76% of which were sputum) showed various organisms common in CF. Ten subjects had *P. aeruginosa*, 5 had both *P. aeruginosa* and *S. aureus*, 6 had *S. aureus*, and one had both *S. aureus* and *H. influenzae*. Four subjects grew normal flora, 3 grew other organisms, and one had no data (Table 2).

Discussion

The culture methods were designed for recovery of relatively rapidly growing bacteria important in CF, namely *P. aeruginosa, S. aureus,* and *H. influenzae*, none of which were found in the SVNs, despite the fact that the majority of subjects were known to be colonized with at least one of these organisms. *B. cepacia*, another important CF pathogen, can take longer than 72 hours to appear in a culture, and since none of the subjects' sputum and throat cultures (which were analyzed for CF microbes, using selective medium) showed current or past colonization with *B. cepacia*, we did not look for *B. cepacia*.

Only 2 patients had bacteria in the nebulizer. One grew "rare bacillus" in the second sample only (ie, prior to the second aerosol treatment). Subsequent specimens from that same nebulizer had no bacterial growth. The other subject's nebulizer grew bacteria from the third and fourth samples (ie, prior to the third and fourth aerosol treatments). The third specimen had 1,000 colonies/mL of *Corynebacterium* species and 1,000 colonies/mL of coagulase-negative *Staphylococcus*. The fourth sample culture had 2,000 colonies/mL of *Corynebacterium* species and 2,000 colonies/mL of *C. albicans*. But the fifth sample from that same nebulizer had no bacterial growth. We suspect that these 4 positive cultures were probably caused by skin contaminants, possibly from the practitioner collecting the specimen, rather than from bacteria in the nebulizer, and therefore do not indicate microbes in the nebulizer.

Table 2. Subject Respiratory Culture Results

Subject	Sample Location	Identified Organism(s) in Admission Cultures
1	Throat	*Staphylococcus aureus*
2	Sputum	*Pseudomonas aeruginosa, Candida*
3	Sputum	*Pseudomonas aeruginosa,* methicillin-resistant *Staphylococcus aureus, Candida*
4	Throat	*Pseudomonas aeruginosa, Staphylococcus aureus*
5	Throat	*Pseudomonas aeruginosa*
6	Throat	*Pseudomonas aeruginosa, Candida*
8*	Sputum	*Staphylococcus aureus, Stenotrophomonas maltophilia*
9	Sputum	Methicillin-resistant *Staphylococcus aureus, Pseudomonas aeruginosa*
10	Sputum	*Pseudomonas aeruginosa*
11	Throat	Normal flora
12	Sputum	*Staphylococcus aureus, Pseudomonas aeruginosa, Candida*
14*	Sputum	*Pseudomonas aeruginosa, Staphylococcus aureus*
15	Sputum	*Acinetobacter baumanii, Enterobacter amnigenus*
16	Sputum	*Pseudomonas aeruginosa*
17	Sputum	*Staphylococcus aureus, Geotrichum candidum*
18	Sputum	*Pseudomonas aeruginosa*
19	Sputum	Methicillin-resistant *Staphylococcus aureus*
20	Sputum	Methicillin-resistant *Staphylococcus aureus*
21	Sputum	Normal flora
22	Sputum	Methicillin-resistant *Staphylococcus aureus*
23	Sputum	*Haemophilus influenzae*
24	Sputum	*Pseudomonas aeruginosa*
25	Throat	Normal flora
26	Sputum	*Pseudomonas aeruginosa*
27	Throat	Normal flora
28	Sputum	*Alcaligenes xylosoxidans, Geotrichum candidum*
29	Sputum	*Pseudomonas aeruginosa*
30	Sputum	Normal flora, *Aspergillus*
31	Sputum	*Pseudomonas aeruginosa*
32	Not available	No data

*Subjects 7 and 13 were removed for incomplete study.

Our hypothesis that the nebulizers would not support bacterial growth in a 24-hour period is substantiated by the results of this study. There was no growth of *P. aeruginosa, S. aureus,* or *H. influenzae* in the SVN medication cups used to administer bronchodilators to CF in-patients. At the 24th hour, none of the nebulizers sampled had any growth of bacteria.

This study supports the AARC's infection-control recommendations in their clinical practice guidelines,[4–6] each of which recommends changing (or sterilizing) the SVN at 24-hour intervals. However, 2 of the guidelines have been retired: "Delivery of Aerosols to the Upper Airway" was retired in July 2004, and "Selection of Aerosol Delivery Device" was retired in August 2006. Thus, at present, the only active guideline that recommends changing or sterilizing the nebulizer is "Selection of a Device for Delivery to the Lung Parenchyma," which reads "Nebulizers should be changed or sterilized. . . at conclusion of dose administration or at least every 24 hours" (section 13.3).

Although the present study supports changing the SVN every 24 hours, this conflicts with other recommendations. Another AARC clinical practice guideline, "Selection of an Aerosol Delivery Device for Neonatal and Pediatric Patients"[7] recommends that, "Between treatments on the same patient, disinfect, rinse with sterile water, and air-dry," (section 13.2.1) which is essentially the same as the recommendation of the Cystic Fibrosis Foundation's infection-control committee. So the question remains, is it safe to clean, disinfect, rinse, and air-dry the aerosol equipment? Or is it better to simply dispose of it every 24 hours? To date, evidence is lacking to support the safety of cleaning/disinfecting the aerosol equipment in the patient's hospital room. More evidence is needed to determine what specific aerosol therapy practice is safe for CF in-patients.

The limitations of the present study include the small sample size (30 patients and 150 cultures). Also, only the fluid inside the SVN was sampled, which might not represent all of the possible contamination sources (eg, mouth-

piece or mask), nor did we analyze the aerosol emitted from the mouthpiece or mask. Also, we did not look for fungal pathogens; however, given the slow growth of many molds, we believe it is unlikely that they would extensively multiply in the non-nutritive conditions in the nebulizer cup. Still, the possibility of mold growth is a potential topic for future study.

Conclusion

There is a low risk of growth of *P. aeruginosa, S. aureus,* or *H. influenzae* in an SVN medication cup over a 24-hour period, which support the practice of replacing the nebulizer every 24 hours rather than cleaning/disinfecting it between uses. However, additional studies are needed to support the present findings and to further our understanding about safe and costeffective infection-prevention practices with CF inpatients.

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Petri dishes with cultured cells
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