Infection Control in Cystic Fibrosis: Cohorting, Cross-Contamination, and the Respiratory Therapist

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Cystic fibrosis (CF) is a complex genetic disease characterized by lung infections that lead to early morbidity and death. Pathogens that commonly infect the lungs of patients with CF include *Staphylococcus aureus*, *Haemophilus influenzae*, *Pseudomonas aeruginosa*, and *Burkholderia cepacia*. Aggressively treating pulmonary infection with antibiotics has contributed to improved survival in patients with CF but has also promoted multiple-drug-resistant bacteria. Other complexities include the ability of bacteria to form biofilms, which makes them more resistant to antibiotics, and emerging pathogens in CF, of which the clinical importance is not yet clear. Increasing evidence of patient-to-patient transmission of CF pathogens led the Cystic Fibrosis Foundation to produce evidence-based infection-control recommendations, which stress 4 principles: standard precautions, transmission-based precautions, hand hygiene, and care of respiratory equipment. Respiratory therapists need to know and follow these infection-control recommendations. Cohorting patients infected with *B. cepacia* complex is one of several interventions successful at keeping the spread of this pathogen low, but cohorting patients who are infected/colonized with other microbes is controversial, the main argument of which is not being certain of a patient's present respiratory culture status at any given patient visit. *Key words: cystic fibrosis, infection-control, bacteria, cohorting.*
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Introduction

Cystic fibrosis (CF) is a life-shortening genetic disorder characterized by microbial infection of the lungs at an early age. Chronic lung infection contributes to lung disease and damage and is the primary cause of morbidity and early death in individuals with CF. Although the life expectancy of individuals with CF has steadily increased because of improvements in treatment, bacterial lung infection remains a large threat. Approximately 90% of CF-related deaths are due to respiratory failure caused by chronic lung infection.[1] *Pseudomonas aeruginosa*, *Burkholderia cepacia*, *Staphylococcus aureus*, and *Haemophilus influenzae* are the common pathogens in the lungs of individuals with CF. *P. aeruginosa* is the most common and clinically important pathogen. Approximately 80% of adults with CF are colonized with *P. aeruginosa*.[2]

Chronic infection with *P. aeruginosa* is associated with reduced lung function, more pulmonary exacerbations, and a shortened life expectancy.[3] Bacteria can anchor onto the airway surface and build a matrix (biofilm) that holds the colony together and shields it against host defenses and antibiotics, which makes eradication more difficult if not impossible.[4] In addition to this complexity, the clinical impacts of emerging pathogens in CF, such as *Stenotrophomonas maltophilia* and *Achromobacter xylosoxidans*, are yet to be fully understood.

Evidence of patient-to-patient transmission of pathogens and the increasing complexity of CF care pointed to the need for greater awareness and implementation of infection-prevention and control practices by both patients and clinicians,[4] and in 2001 the Cystic Fibrosis Foundation convened a committee to develop evidence-based infection-control guidelines for the CF community (Appendix).[5]

The respiratory therapist (RT) spends a great deal of time treating and educating patients with CF. Given RTs' important role in CF care, it is crucial they have a firm understanding of and commitment to the Cystic Fibrosis Foundation's current infection-control recommendations (which I will refer to as the CFF recommendations). I will discuss the sources and transmission routes of CF pathogens; the evidence of cross-contamination; the CFF recommendations for respiratory care equipment, particularly the nebulizer; and infection-control interventions, including patient cohorting. My goal is to improve clinicians' awareness of the CFF recommendations and to highlight the RT's responsibilities in infection-prevention and control in CF care.

Health-care-associated infections are caused primarily by inadequate adherence to infection-prevention practices.[6] The 3 main routes of pathogen transmission are direct (person-to-person) contact; indirect contact (a contaminated object infects another person); and droplet (large droplets of liquid emitting from exhaled breath or created by medical procedures such as aerosol administration). Airborne transmission of pathogens can also occur when a person inhales contaminated particles, such as dust particles, small enough to float in the air and that can travel long distances.[7]

Table 1 describes the most common respiratory pathogens in patients with CF. I will discuss *B. cepacia* complex in greater detail because it is currently the most threatening pathogen in CF.

Burkholderia cepacia Complex

B. cepacia complex currently includes 10 bacteria species, all but one of which have been cultured in CF sputum.[8] These species were given formal names that replaced the former designation "genomovar."[9] *B. cenocepacia* and *B. multivorans* are the 2 most common species in patients with CF; they account for approximately 45% and 40% of infections, respectively.[9] The current overall prevalence of *B. cepacia* complex in CF in the United States is about 3%,[2] but despite its low prevalence, *B. cepacia* complex is the most studied pathogen in CF research because of its high transmissibility and serious morbidity.[4]

In nature, *B. cepacia* is found in soil, water, and in and on plants and plant roots.[8] In 1950, Burkholder first described the species as *Pseudomonas cepacia* and determined it as the cause of onion rot. Although this microorganism was known to be a human pathogen in certain cases, it was not until the early 1980s that it was increasingly cultured and identified in respiratory-tract specimens from patients with CF.[8] In the early 1980s the threat of *B. cepacia* became alarmingly apparent when high fever, bacteremia, progressive necrotizing pneumonia, and rapid pulmonary decline (ie, the "cepacia syndrome") caused the death of 62–100% of patients who were infected.[10,11] In contrast, some CF patients have chronic infection with *B. cepacia* complex species, and others seem to have transient or intermittent colonization. It is not clear what role host and bacterial factors play in the different clinical presentations. The *B. cenocepacia* strain, for example, may be more virulent and transmissible than the other strains, but more study is needed to be conclusive.[4,12,13]

B. cepacia complex species can be highly concentrated in CF sputum and can live on environmental surfaces for an extended period.[14] In 1986, prior to having clear evidence of patient-to-patient spread of *B. cepacia* complex species, Thomassen et al found a decreased incidence of *B. cepacia* complex after strict infection-control practices were implemented.[15,16] It was not until 1990, however, that there was proof. LiPuma et al used genetic testing methods and discovered that *B. cepacia* complex infection spread via social contact among children attending CF summer camps in the United States.[15,17] In addition, the Summer Camp Study Group[18] investigated the epidemic

Table 1. Selected Respiratory Pathogens in Patients With Cystic Fibrosis

Organism	Prevalence	Clinical Impact	Persistence	Selective Media	Transmission Routes*	Transmission Precautions	Multi-Drug Resistance	
							Mechanism	Antimicrobial Control (potential prevention strategy)
Pseudomonas aeruginosa	++++	Significant	Chronic	No	Person-to-person, Environmental reservoir, Environmental surface	Standard†	Acquired	+
Burkholderia cepacia complex	+	Significant	Chronic	Yes	Person-to-person > environmental surface	Standard and contact	Intrinsic	+
Methicillin-sensitive *Staphylococcus aureus*	+++	Significant	Variable	Yes	Person-to-person > environmental surface	Standard	Acquired	+/−
Methicillin-resistant *S. aureus*	+	Variable	Variable	Yes	Person-to-person >> environmental surface	Standard and contact	Acquired	+
Haemophilus influenzae	++	Variable	Variable	Yes	Person-to-person	Standard	Acquired	+/−
Stenotrophomonas maltophilia	++	Variable	Variable	Yes	Environmental surface, Environmental reservoir > person-to-person	Standard‡	Intrinsic	+
Achromobacter xylosoxidans	+	Variable	Variable	No	Environmental surface > person-to-person	Standard‡	Intrinsic	+
Respiratory viruses	Seasonal	Variable	No	Yes	Person-to-person > environmental surface	Standard and contact. Add droplet precautions for influenza, adenovirus	Acquired	−
Non-tuberculous *Mycobacterium*	++	Variable	Variable	Yes	Environmental reservoir >> person-to-person	Standard	Acquired	−
M. tuberculosis	Rare	Variable	Rare	Yes	Person-to-person	Airborne	Acquired	−
Aspergillus species	++	Variable	Variable	Yes	Environmental reservoir >>> person-to-person§	Standard	Intrinsic	−

* Environmental reservoirs such as water, sinks, or soil. Environmental surfaces include medical and nonmedical devices and other surfaces.

† Add contact precautions if *P. aeruginosa* is multi-drug-resistant.

‡ Use contact precautions if institution has evidence of person-to-person transmission

§ Airborne transmission has been documented in the setting of high organism burden, irrigation, and wound debridement.

(From Reference 5, with permission.)

spread of *B. cepacia* complex in 1990 at 3 North American CF summer camps. There was a 6% incidence of newly acquired, genetically identical *B. cepacia* complex among the campers, and environmental sampling found no natural reservoir of the organism.[15,18]

Meanwhile in Europe the incidence of *B. cepacia* complex was rising. In the United Kingdom, studies in Manchester and Edinburgh analyzed sputum isolates stored from 1986 to 1992 and found a specific genotype, which was later designated the electrophoretic type 12 (ET-12) strain and is associated with *B. cepacia* syndrome.[15,19] ET-12 was transmitted among 9 CF patients during an exercise class in 1989 in Edinburgh, and among 7 patients at a 1991 Christmas party in Manchester.[15,20] The ET-12 strain crossed continents as well. Govan et al described campers who traveled from the United Kingdom to Ontario, Canada, and transmission occurred.[4,15,20] Because of the risk of patient-to-patient spread, segregation of *B. cepacia* complex patients in Manchester began in 1992. However, the spread was not contained until strict segregation policies were followed, and the incidence fell after 1994.[15,21]

Hospital-acquired *B. cepacia* complex is associated with recent hospitalization,[4,22] poor adherence to handwashing,[4,22,23] contaminated respiratory-care equipment,[4,23,24] and hospital showers.[4,22,25] Genetic testing methods provided evidence of the spread of *B. cepacia* complex between patients in health-care settings. In 2001, for example, Chen et al used molecular typing to analyze available *B. cepacia* complex isolates at 2 CF centers as far back as 1981. They discovered a *B. cenocepacia* strain that persisted at one center for over 20 years and observed intercity spread when one of the patients transferred to the other center.[2,26] Also, in 2001, Boston Children's Hospital experienced an outbreak of what was thought to be an unusual phenotype of *B. multivorans*, but genetic "fingerprinting" determined that it was actually *B. dolosa*, and it caused clinical decline among infected patients and the death of one patient with *B. cepacia* syndrome. The hospital environment was tested as a possible reservoir, but no environmental source was found. Although the hospital had been following standard precautions and segregation policies, this outbreak triggered stricter infection-control practices, after which the outbreak ceased.[15,27-29]

The evidence of patient-to-patient spread of *B. cepacia* complex caused fear of an epidemic and led to dramatic changes in infection-control practices at CF centers worldwide. The changes in infection-control practices changed life among patients with CF, who previously enjoyed a tight social network.[4,15,17,20,30] In 1993 and the year following, CF summer camps were closed, and cohorting and segregating of CF patients infected with *B. cepacia* complex was strongly recommended.[15]

In addition to cohorting, segregating, and standard precautions, it is recommended that patients positive for *B. cepacia* complex be placed in contact isolation.[4] Patients in a *B. cepacia* complex cohort must also be kept separate from each other because it is possible to transmit a more virulent strain that can replace an existing one.[4,31] As an extra precaution, it is advisable that clinicians also be cohorted in the care of patients with *B. cepacia* complex to reduce the risk of cross-contamination.

Infection-Prevention and Control of *Burkholderia cepacia* Complex

Segregation of patients infected with *B. cepacia* complex has been widely adopted by CF centers worldwide and is considered the most successful prevention strategy,[4] though several infection-prevention interventions (eg, stronger emphasis on hand hygiene and patient, family, and clinician education; single-patient rooms and showers; contact precautions; and segregating *B. cepacia* complex patients, including out-patient areas) were implemented simultaneously, so we do not know the individual impact of each intervention. Environmental decontamination and monitoring were also emphasized. Both in and out of the hospital, the recommendations strongly advised eliminating close contact and socializing between all patients infected with *B. cepacia* complex from those not infected.[4,5] Clinics that did not implement patient segregation had ongoing transmissions.[4,26,32,33]

More study has been done of *B. cepacia* complex species than any other pathogen important in CF, and what has been learned about *B. cepacia* complex has broad application. The CFF recommendations committee concluded that the respiratory secretions of all CF patients can harbor transmittable infectious microorganisms.[5]

Pseudomonas aeruginosa

P. aeruginosa is the most common and clinically important CF pathogen, because patients with *P. aeruginosa* infection have worse pulmonary function, worse chest-radiograph scores, and shorter life expectancy.[4] According to the 2007 Cystic Fibrosis Foundation patient registry, the overall prevalence of *P. aeruginosa* is 54%. Acquisition of this pathogen increases with age. The national rate of *P. aeruginosa* infection is 39% among patients < 18 years old and 75% among patients ≥ 18 years old.[2]

The initial source of *P. aeruginosa* in CF is not known for most patients.[4] There are potential environmental sources in the home and the health-care setting. *P. aeruginosa* is a facultative anaerobic Gram-negative bacillus and is found at water sources (eg, sinks) in pediatric hospital wards for CF patients,[4,34,35] and on toys, hand soaps, baths,[4,36] pulmonary equipment, hospital drains,[4,37] and on the hands of patients and clinicians.[4,34,36,37] *P. aeruginosa* survives on surfaces. Non-mucoid strains can live for

24 hours, and mucoid strains can survive for 48 hours when suspended in saline. In the sputum from a CF patient it can live for up to 8 days on a dry surface.[4,34,36]

Most CF patients with *P. aeruginosa* infection have a unique clone of the organism that they keep throughout their life,[4,38-40] which led some to propose that acquisition of this microorganism is from the environment.[41] Strains of *P. aeruginosa* found in the health-care setting match those from patients, but it is unclear if the patient infects the environment, or vice versa.[4,34,42,43]

The best evidence of patient-to-patient spread of *P. aeruginosa* is shared strains among siblings with CF,[4,16,37,43,44] although it is possible that they simply acquire it from a common household source.[41] However, among unrelated CF patients, cross-contamination of *P. aeruginosa* has been well documented in camps, training courses, clinics, and hospitals, in many countries.[43,45-56] In contrast, some investigators did not find cross-contamination of *P. aeruginosa* among CF patients. Speert and colleagues, for example, determined that the vast majority of patients retain their own unique strain and that close contact is necessary to spread *P. aeruginosa* between patients. They concluded that the incidence of cross-contamination among unrelated CF patients is very low.[41,57]

Two reports are persuasive for the cross-contamination argument. In Denmark in the 1980s an epidemic of a multiple-drug-resistant strain of *P. aeruginosa* occurred in a CF center, which managed the outbreak by segregating culture-positive and culture-negative patients, plus several other infection-control measures, including improved hand hygiene among patients and clinicians, and establishing a larger clinic. There was a dramatic decrease in the incidence and prevalence of chronic *P. aeruginosa* infection.[45,50-53] Also, in the United States, Farrell et al studied infants diagnosed with CF via newborn screening and coincidently discovered differences between 2 Wisconsin CF centers in the early acquisition of *P. aeruginosa*. One center had a separate clinic day for the newborns, and no waiting room time. The other center had limited clinic space, and the newborns were intermixed with older and infected CF patients in a small waiting area. The latter center had earlier acquisition of *P. aeruginosa* among the infants.[56]

In summary, *P. aeruginosa* can seriously affect patients with CF. *P. aeruginosa* strains, particularly mucoid strains, can become antibiotic-resistant, and treating these infections becomes more difficult. Although the sources of transmission are not completely understood, environmental contamination with infected respiratory secretions, crowded conditions, and contaminated hands appear to contribute. Standard and contact precautions are recommended to prevent and control cross-contamination.[4]

Staphylococcus aureus

S. aureus is often the first pathogen that infects patients with CF. *S. aureus* and *H. influenzae* caused early morbidity and mortality in infants with CF before the discovery and use of antibiotics. In the mid-1940s penicillin was very effective, and the life expectancy of infants and children improved.[58]

S. aureus that is resistant to the available β-lactam antibiotics is referred to as methicillin-resistant *S. aureus* (MRSA), which is on the rise among patients with CF. In 2007 the Cystic Fibrosis Foundation patient registry data reported an overall MRSA prevalence of 21%,[2] compared to 7% in 2001.[59] There has been a similar increase in MRSA colonization among otherwise healthy individuals in the general community in the United States and elsewhere.[60-65] Community-associated MRSA has virulence factors not found in health-care-associated MRSA and includes genetic elements called staphylococcal chromosome cassette mec type IV or V. They usually carry the genes for an exotoxin called Panton-Valentine leukocidin. These virulence factors mediate the methicillin resistance.[60,66-68] Community-associated MRSA can cause skin and soft-tissue infections, necrotizing pneumonia, and sepsis.[60,69-71] However, these infections can be treated with non-β-lactam antibiotics. In contrast, health-care-associated MRSA contains other virulence factors, such as staphylococcal chromosome cassette mec I, II, and III, which have a higher rate of resistance, and the treatment options are limited.[60]

The question with respect to MRSA infection in CF is, which type is responsible for the current rise in prevalence: community-associated MRSA or health-care-associated MRSA? A recent study by Glikman et al[60] investigated MRSA isolates among patients with and without CF, from 2 hospitals, in Chicago and Dallas. They found both community-associated MRSA and health-care-associated MRSA in the CF patients, but health-care-associated MRSA predominated (65%). Among patients without CF, community-associated MRSA predominated (89%). The investigators were not surprised at the higher prevalence of health-care-associated MRSA among patients with CF, because those patients have frequent contact with health-care facilities. More noteworthy was that some of the CF patients had community-associated MRSA (with the staphylococcal chromosome cassette mec IV and the Panton-Valentine leukocidin gene). Most of these isolates were from patients with CF who had acquired MRSA for the first time, and the investigators pointed out the importance of closely monitoring this trend to keep track of this evolving epidemiology.

Although Glikman et al[60] did not find an association between pulmonary exacerbations and community-associated MRSA or health-care-associated MRSA, other inves-

tigators have. In St Louis, for example, Elizur et al[72] reported that 15% of MRSA isolates from children with CF were positive for the Panton-Valentine leukocidin strain, which was associated with severe pulmonary involvement. Those children were more likely to have a focal pulmonary infiltrate (2 developed lung abscesses), a significant decline in lung function, and the need for hospitalization and intravenous antibiotics. Elizur et al suggested that the Panton-Valentine leukocidin-positive MRSA strain is a growing threat to patients with CF.

The overall clinical impact of MRSA infection in CF is not certain,[4] but it is certain that MRSA is transmitted between patients, including from patients who do not have CF.[73] Standard and contact isolation is required to prevent the spread of MRSA.[74]

Stenotrophomonas maltophilia and *Achromobacter xylosoxidans*

The prevalences of *S. maltophilia* and *A. xylosoxidans* in patients in CF centers in the United States are approximately 13% and 6%, respectively.[2] Reports from individual centers show wide variability of infection. For example, *S. maltophilia* is reported to range from zero to 25%, and this could be due to underreporting and/or misidentification due to choice of selective media.[4] Interestingly, in study patients with CF, during the large multicenter clinical trials of inhaled tobramycin, the prevalence of *S. maltophilia* was much higher. Thirty percent of the subjects had at least one positive culture; however, this occurrence was mostly intermittent.[75,76]

S. maltophilia is present in the natural environment (eg, plants, soil) and the hospital environment (eg, sinks, medical equipment).[77] In CF, the prevalence of *S. maltophilia* increases with age and is associated with broad-spectrum antibiotic use.[76] *S. maltophilia* and *A. xylosoxidans* cause hospital-acquired infections in patients with and without CF.[76-79] For example, patients on ventilators in intensive care units and patients who are immunocompromised are more likely to be affected.

The clinical importance of *S. maltophilia* and *A. xylosoxidans* infection in CF is not clear, but these organisms are associated with pulmonary exacerbations.[4,80,81] Davies and Rubin point out that there is convincing evidence that it is not simply acquiring an *S. maltophilia* infection alone that is harmful to patients with CF; rather, it is the more compromised patients with poorer lung function that acquire *S. maltophilia*.[76]

Several studies of the transmissibility of *S. maltophilia* found evidence of patient-to-patient transmission. Krzewinski et al found that at 3 of 6 United States centers there were 2 patients from each who were infected or colonized with the same clone.[82] In Spain, 3 patients with CF were reported to harbor the same strain of *S. maltophilia*.[83] On the other hand, since there is "little" evidence of cross-infection with *S. maltophilia* and *A. xylosoxidans*, Davies and Rubin state that acquisition appears to be more likely from the environment.[76] Nevertheless, since these organisms are multiple-drug-resistant and their pathogenicity in CF is yet to be understood, transmission-prevention measures (eg, standard and contact precautions) are warranted.[4]

Nontuberculous *Mycobacterium*, Fungi and Molds, and Respiratory Viruses

Patients with CF are at risk of acquiring mycobacteria species, most of which are nontuberculous. Infection and colonization have been increasingly reported in CF.[4] The prevalence differs among CF centers, but the overall prevalence in the United States is 13%.[4,84] The most common nontuberculous mycobacteria species that affects patients with CF is *M. avium* complex (72%), followed by *M. abscessus* (16%).[84]

Although the clinical impact of nontuberculous mycobacteria in general is yet to be determined, *M. abscessus* is thought to be more virulent and to cause more severe disease, and early detection and treatment should be considered.[84-87] The reported risk factors of nontuberculous mycobacteria infection/colonization are associated with intravenous and aerosolized antibiotics.[4,88] In addition, in a 2-center study in Israel, Mussaffi et al found an association between nontuberculous mycobacteria and systemic steroid use and also allergic bronchopulmonary aspergillosis.[89]

There is no evidence of shared strains between CF patients, although few studies have used molecular typing to identify the mycobacteria isolates and determine patient-to-patient transmission.[4] In contrast to nontuberculous mycobacteria, *M. tuberculosis*, which may also infect patients with CF, is transmissible between patients and requires airborne isolation measures.[4]

Aspergillus is a mold that can colonize the lungs of patients with CF. The overall prevalence of *Aspergillus* in 2007 was 14%.[2] Some patients have an allergic reaction to the mold (allergic bronchopulmonary aspergillosis). The use of oral or aerosolized prophylactic antibiotics is a risk factor for colonization of *Aspergillus* in adult patients with CF.[4,90] Exposure to mold cannot be completely avoided because molds are ubiquitous in nature, but there are ways to limit exposure. Mold spores are aerosolized by various activities (eg, construction, lawn mowing). Particularly in the hospital setting, construction dust should be contained and water leaks repaired and dried to minimize mold exposure.[4,7]

Viruses can cause respiratory-tract infections, such as flu, bronchiolitis, and the common cold. Patients with CF are as susceptible to viral infections as those without CF,

but CF patients may become more ill.[4] For example, in patients with CF the respiratory syncytial virus (RSV) can cause severe illness, prolonged hospitalization, mechanical ventilation, and lung-function impairment.[4,91-93]

For infants at high risk for RSV there are strategies to prevent RSV infection, such as a monthly injection of the antibody palivizumab. Although palivizumab is not yet recommended by treatment guidelines for infants with CF, it can be considered on an individual basis, especially if other risk factors are present.[4,94,95] According to the Centers for Disease Control, RSV transmission can and should be prevented by strict attention to contact precautions, such as hand hygiene and the use of gowns and gloves in the hospital setting. In general, people with CF should be extra careful to avoid others who are sick, practice good hand hygiene, and receive an annual flu vaccination.

Guidelines for Infection-Prevention in Cystic Fibrosis

The CFF recommendations identify 4 principles of infection-prevention: standard precautions, transmission precautions, hand hygiene, and care of respiratory equipment.[4,5]

Standard Precautions

Standard precautions are the use of protective barriers with any anticipated exposure to bodily fluids. The secretions of *all* patients harbor potentially transmittable pathogens, so all clinicians should use hand hygiene, gowns, gloves, and/or masks, depending on the interaction with the patient. The standard precautions also apply to the patient's environment and medical equipment, which are subject to contamination and transmission as well.

Transmission Precautions

Transmission-based precautions apply to patients who are suspected or known to have highly transmittable pathogens, and isolation precautions are necessary to prevent spread. The categories of isolation are contact, droplet, airborne, and protective environment. Some pathogens require a combination of these isolation measures. The type of isolation required is based on the pathogen and the possible infection route(s).

Hand Hygiene

Hand hygiene is *the most important* infection prevention and control measure, particularly in the prevention of hospital-acquired infection. Observational studies in the health-care setting have found poor clinician adherence to hand hygiene practices.[96-99] The massive worldwide campaign to promote adherence and eliminate barriers to hand hygiene has included education, posters, and ubiquitous dispensers of alcohol-based hand sanitizer, and has improved awareness and adherence.[100,101]

Table 2. Recommended Steps for Cleaning and Disinfecting the Nebulizer

1. Clean nebulizer parts with dish detergent and water.
2. Disinfect with one of the following options, if permitted by the manufacturer:
5.25–6.15% household bleach solution (1 part bleach to 50 parts water) for 3 min
70% isopropyl alcohol for 5 min
3% hydrogen peroxide for 30 min
Boil for 5 min
Microwave for 5 min
Dishwasher if the water is > 70°C for 30 min
Electric steam sterilizer (eg, Avent iQ24)
3. Rinse cold disinfectant with sterile water.
4. Air-dry completely.

Care of Respiratory Equipment

The prime example of respiratory care equipment in the CFF recommendations is the nebulizer.[5] The 4 nebulizer-care steps are: clean, disinfect, rinse, and air dry (Table 2). The equipment cannot be adequately disinfected until it is cleaned, because dried-on or baked-on debris can prevent thorough disinfection.[5]

There are several disinfection options (see Table 2), but in the CFF recommendations all these options have the caveat, "if permitted by the manufacturer,"[5] so it is important to check the manufacturer's instructions or contact the manufacturer to determine which disinfection option is appropriate. Recently an electric steam sterilizer was added to the list of options for disinfection of respiratory equipment (personal communication, 2008, Lelie Hazle, Cystic Fibrosis Foundation).[5] Although, historically, vinegar (acetic acid) has been the classic disinfectant for respiratory equipment, vinegar is not recommended in the CFF recommendations. Vinegar kills *P. aeruginosa*, but it does not adequately kill other pathogens, such as *S. aureus* and *Escherichia coli*.[5,102,103]

Warm tap water is acceptable only for cleaning the nebulizer parts prior to disinfection. Following the cleaning step, if a cold disinfectant is used, the final rinse must be with sterile water. Tap water or distilled water are not recommended for the final rinse because they can harbor pathogens.[5] Distilled water, for example, is regulated to prevent only coliform bacteria (eg, *E. coli*, *Klebsiella*, and *Enterobacter*), and contamination with *B. cepacia* can occur during manufacturing.[5,104]

After cleaning, disinfecting, and rinsing, air-dry the parts completely. This step is very important, because items that remain wet can grow bacteria.[5,6]

Several studies referenced in the CFF recommendations provide evidence of nebulizer contamination in the home and hospital settings. Home nebulizer contamination is well-documented.[105-107] Hutchinson et al[105] examined the home nebulizers of 35 patients with CF and found 3 contaminated with *B. cepacia* and 4 contaminated with *S. maltophilia*, and only one of the 7 contaminated nebulizers had concordance with a sputum isolate. There was minimal to no contamination if the cleaning, disinfecting, and drying recommendations were followed. Thus, stringent home nebulizer care is very important, and is logistically feasible. It is not difficult to control the decontamination space (ie, sink and counter), and patients and family can be educated on the importance and practice of aseptic technique and cleaning, disinfecting, rinsing, and air-drying.

The evidence in the CFF recommendations on nebulizer contamination in the hospital setting points to several factors and, with one exception, does not pertain to the spontaneously breathing patient using a hand-held nebulizer. Three studies found that multi-dose medication bottles were responsible for cross-contamination and hospital outbreaks.[108-110] Hamill et al reported that an outbreak of *B. cepacia* in mechanically ventilated patients was mainly caused by multidose medication bottles used with multiple patients, in some cases over several days.[108] The other factors included the nebulizer remaining in the ventilator circuit and being contaminated by ventilator-tubing condensate, lack of aseptic technique by clinicians, and poor adherence to handwashing.

One study referenced in the CFF recommendations applies to spontaneously breathing patients using hand-held nebulizers in a day-hospital setting. Vassal et al[111] studied 44 patients who had CF and sputum cultures positive for *P. aeruginosa*. After a single aerosol treatment, the entire disposable nebulizer setup (ie, nebulizer cup, mouthpiece, T-piece, and corrugated tubing) was tested for microorganisms, and two thirds of the nebulizer setups were contaminated with pathogens.

In contrast to the home setting, following the CFF nebulizer-care recommendations in the hospital setting is logistically difficult, and there is conflict between the CFF recommendations and those of the American National Standards Institute and American Association of Medical Instrumentation, which recommend that in-hospital decontamination practices be conducted by qualified personnel in an area designated for decontamination of medical devices (personal communication, 2003, Terri Rearick, Children's Memorial Hospital, Chicago, Illinois). Busy RTs cleaning/disinfecting nebulizer equipment at a patient's bedside conflicts with that standard. Also, there is the issue of quality and safety control. If nebulizer cleaning/disinfecting/rinsing/drying is done in the patient's room, are there measures in place to determine the safety and efficacy of that procedure? Is the nebulizer clean/disinfect/rinse/dry process being done in the hospital room sink—a notorious source of pathogens?[112] Is the rinse water sterile, and how is that sterility determined and assured? In 2003, Denton et al[113] suggested that cleaning the nebulizer with tap water, and inadequate drying, caused contamination with *S. maltophilia*.

It is a dilemma when a hospital protocol conflicts with the CFF recommendations. In response to the CFF recommendations on nebulizer care, O'Malley et al[114] studied their hospital's nebulizer practice and found it "safe" (ie, the nebulizers were not contaminated with *P. aeruginosa, S. aureus, H. influenza,* or *B. cepacia*). Their system involved no nebulizer cleaning, but, instead, nebulizer reuse for 24 hours, then disposal. The nebulizers of 30 patients with CF, most of whom had sputum and/or throat cultures positive for various CF pathogens, were tested for bacteria 5 times over a 24-hour period during their first full day of hospitalization. None of the 150 cultures found any CF pathogens. The hospital retained its nebulizer practice.

Vassal et al[111] tested the entire nebulizer setup, whereas O'Malley et al[114] tested only the fluid in the nebulizer cup. Cobben et al[115] studied a severe outbreak of *P. aeruginosa* from contaminated nebulizers, and the outbreak ceased after they adopted the policy of changing the mouthpieces every 24 hours. The practice of changing the mouthpiece between treatments deserves investigation. Clearly, more evidence is needed to determine a cost-effective and safe nebulizer practice for hospitalized patients with CF.

In 2002 I surveyed CF center and program directors in the United States about their nebulizer care policies (unpublished data). The survey response rate was 30%. Nebulizer-care practices differed markedly. Most respondents used disposable nebulizer equipment exclusively. The frequency of nebulizer disposal/replacement ranged from daily to weekly: 22% every 24 hours, 25% every 48 hours, 25% every 7 days, and the remainder every 3, 4, or 5 days. Nearly half reported no routine process for the nebulizer between treatments. Approximately 16% rinsed the nebulizer with sterile water, and 20% rinsed the nebulizer with hospital tap water! One respondent used a vinegar solution, one used a "weak" bleach solution, and one "hot sterilized" their nondisposable nebulizers.

I repeated the survey in 2007 (unpublished data) to the same CF centers and program directors, and approximately 30% responded. The CFF recommendations had affected both home and hospital practice. In the home setting, teaching patients the CFF nebulizer-care recommendations increased from 16% in 2002 to 37% in 2007, and following the CFF nebulizer-care recommendations at least daily increased from 16% to 52%. The home-nebulizer-care practice of disinfecting with vinegar decreased from 66% to 5%, and the practice of final-rinsing with tap water decreased from 55% to 11%. In the hospital setting, daily replacement of the nebulizer equipment increased from

22% in 2002 to 40% in 2007, and the practice of rinsing the nebulizer with hospital tap water decreased from 20% to 7%. Although no respondents reported using disinfectant, 2 mentioned "cleaning" between uses, and 2 reported sending their nondisposable nebulizers out to be sterilized. Remarkably, 3 centers reported using disposable nebulizers only once (ie, disposing of it after one treatment), which might provide infection-prevention but is an expensive practice.

Like the nebulizer, other semi-critical medical devices (eg, spacers, valved holding chambers, positive-expiratory-pressure-therapy devices) that come into contact with the patient's mucous membranes must, according to the Centers for Disease Control, undergo high-level disinfection.[6] To my knowledge, the only report on contamination of these devices has been by Cohen et al,[116] who found that 35% of spacers and masks used by patients with asthma were contaminated with various microorganisms, including *P. aeruginosa*, *S. aureus*, and *Klebsiella pneumoniae*. They suggested that these devices be washed and dried completely after each use.[116] In conflict with that suggestion, though, the manufacturer of one valved holding chamber recommends washing with dish soap, rinsing, and air drying weekly,[117] but a representative of the manufacturer said that the reason for that instruction pertained to removing the medication residue inside the chamber, not to infection control (personal communication, 2008, Corey Lodico, Monaghan Medical).

As with the nebulizer, following the recommended clean/disinfect/rinse/dry procedure with these other medical devices is easier at home. Determining the cleaning/decontamination protocol for reusable medical devices will require collaboration among the infection-control department, the respiratory care department, and, if applicable, whatever department is charged with the cleaning/decontamination procedure. This collaboration must include an awareness of the CFF recommendations, which coincide with the Centers for Disease Control guidelines on medical devices in the hospital setting.

Cohorting

Cohorting is the grouping of patients according to their airway culture results. Cohorting patients infected with *B. cepacia* complex is universally accepted at CF centers, and has decreased the incidence of *B. cepacia* complex worldwide.[15] In the 1980s a CF center in Copenhagen, Denmark, took cohorting to a new level in response to an epidemic of a multiple-drug-resistant strain of *P. aeruginosa* in their center. They cohorted 5 groups of patients: without *P. aeruginosa* infection; with intermittent *P. aeruginosa* infection; with a chronic antibiotic-sensitive strain of *P. aeruginosa*; with a chronic antibiotic-resistant strain of *P. aeruginosa*; and with *B. cepacia* complex.[118] They implemented stricter infection-control measures, such as improved hand hygiene, single-patient hospital rooms, cleaning and disinfecting rooms between patients, and clinician gowning and gloving with each patient. These measures, plus early and aggressive antibiotics, decreased the incidence of *P. aeruginosa* infection in that center.

But should other pathogen-specific patient groups be cohorted? Opinions differ. On the one hand, if a center has the space and time, why not employ the extra precaution, especially in light of the fact that the clinical impact of emerging pathogens (eg, *S. maltophilia* and *A. xylosoxidans*) is uncertain? But not many centers have the necessary space and time, and so far those emerging pathogens are not known to pose a big clinical threat. Davies and Rubin[76] pointed out several important limitations of cohorting. First, on any given day a patient could be inoculated with a new organism, so we never know if the culture results indicate the patient's current status, even a day after the secretion sampling. Also, a more virulent strain of a species could be transmitted to a patient within a cohort. And organisms with multiple-drug-resistance often undergo changes in their antibiotic susceptibility.[76] These limitations make the value of further cohorting questionable. However, under all circumstances the overriding, crucial conclusion is always to adhere to the basic infection-prevention and control practices.

Table 3. Infection-Prevention Strategies for People With Cystic Fibrosis

Contain your respiratory secretions.
Practice appropriate hand hygiene.
Maintain a 3-foot distance from others who have cystic fibrosis (no handshaking or other physical contact)
Clean, disinfect, rinse in sterile water, and air-dry your respiratory equipment.
Do not share common items.

The Respiratory Therapist's Responsibilities

The RT is an educator. In the home setting, educating patients and parents on the use and care of their respiratory care equipment is a responsibility often delegated to the RT, which requires a full understanding of the current CFF recommendations on cleaning/disinfecting/rinsing/drying respiratory care equipment. The RT must also carefully consider the manufacturer's recommendations. RTs can teach patients with CF specific strategies for preventing cross-contamination, performing hand hygiene, containing secretions, and avoiding close personal contact with other CF patients (Table 3).

The RT is a clinician. In the hospital setting, the RT must anticipate exposure to pathogens, wear protective barriers, and remove the barriers properly. The CFF rec-

Table 4. The 10 Commandments of Cystic Fibrosis Care for the Respiratory Therapist

Practice appropriate hand hygiene.
Do not wear artificial fingernails.
Practice standard precautions with all patients. Anticipate exposure to pathogens and practice barrier precautions accordingly.
Obey transmission-based isolation precautions.
Assure implementation of standardized protocols for cleaning, disinfecting, rinsing, and air-drying respiratory equipment.
Handle and dispense medications aseptically.
Use only sterile water to rinse equipment.
Know your expertise and acknowledge your limitations.
Use the cystic fibrosis resources at PortCF.org and CFF.org. Contact the Cystic Fibrosis Foundation at RegHelp@cff.org.
Advocate the current Cystic Fibrosis Foundation infection-prevention recommendations via example and education.

ommendations provide a rigorous infection-prevention standard for CF care, and RTs must strive to prevent cross contamination with respect to patients *and* respiratory equipment. The most common infection risks are poor adherence to the handwashing protocol, use of multi-dose medication bottles, lack of aseptic technique, and leaving the nebulizer in the ventilator circuit. The RT can be an influential advocate for appropriate CF care by promoting the CFF recommendations in his or her department.

RT responsibilities will increase as new therapies/devices are introduced, and one challenge will be to make sure that the manufacturers' recommendations for cleaning and disinfecting new respiratory devices holds up to the standards established by the CFF. Table 4 sums up the RT's CF care responsibilities into 10 "Commandments." As with *the* 10 Commandments, they are imperative and an important obligation of clinicians.

Summary

Clinicians, particularly those who have years of experience in CF care, understand and appreciate the huge burden of care this disease places on patients and families. In response to the evidence and threat of patient-to-patient spread of pathogens, the implementation of infection-control practices is yet another burden. In particular, avoiding close contact with others with CF is a difficult limitation on lifestyle. This burden may be easier for recently diagnosed patients and families, but it is a heavy one for patients who remember when being with other CF patients was the one good thing about having CF. But the evidence indicates that with strict infection-prevention and control practices CF patients can reduce the risk of pathogen transmission. Along with support and compassion, it is up to all of us—clinicians, patients, and families—to implement these practices and reduce the risk of infection. The life expectancy of individuals with CF has steadily improved over the years, and the hope is that it will continue to do so.

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Appendix

The Cystic Fibrosis Foundation's Infection-Control Recommendations

The Cystic Fibrosis Foundation's infection-control recommendations use the Centers for Disease Control/Healthcare Infection-Control Practices Advisory Committee system for categorizing recommendations, according to their basis in scientific evidence:

IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies

IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and a strong theoretical rationale

IC. Required for implementation, as mandated by federal and/or state regulation or standard

II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale

No recommendation; unresolved issue. Insufficient or conflicting evidence and no consensus regarding efficacy

In-Patient Setting

Transmission Precautions

With all patients with cystic fibrosis (CF), in addition to standard precautions, use contact precautions with patients who are infected/colonized with methicillin-resistant *Staphylococcus aureus* (MRSA), *Burkholderia cepacia* complex, multi-drug resistant *Pseudomonas aeruginosa*, respiratory syncytial virus, para-influenza virus, or vancomycin-resisitant enterococci. With patients infected/colonized with adenovirus use contact and droplet precautions. With patients infected/colonized with influenza use droplet precautions. *Category IA*

Room Placement

- Single-patient room with separate shower and bathroom for each CF patient colonized/infected with *B. cepacia* complex, MRSA, or vancomycin-resisitant enterococci. *Category IA*
- Whenever possible, single-patient room for a CF patient who is not colonized/infected with *B. cepacia* complex, MRSA, or vancomycin-resisitant enterococci. If single-patient room not possible, the other patient in the room should not have CF and should be at low risk for infection. *Category II*
- Single-patient room for lung, heart-lung, and liver transplant recipients. *Category II*
- Ensure that proper dust-containment and water-leak policies are followed in areas where patients with CF are hospitalized. *Category IB*, *IC*

Activity Outside Hospital Room

- Instruct patient on proper hand hygiene before he or she leaves the hospital room. *Category II*
- Avoid direct contact between CF patients (exception: those who cohabitat, such as siblings). *Category II*
- Patient should only attend hospital activity rooms (eg, playroom, school, exercise) when no other CF patients are present. *Category II*
- Maintain a distance of 1 meter between CF patients. *Category II*
- After a CF patient has left the activity rooms, use disinfectant/detergent to clean all surfaces and items handled by the CF patient. *Category IB*
- Whether a CF patient should routinely wear a mask when outside of the hospital room is an *unresolved issue*, unless the patient is on droplet precautions. *No recommendations*

Respiratory Therapy

- Assume all CF patients have transmissible pathogens in their respiratory secretions, particularly when not yet identified via culture. *Category IA*
- When treating CF patients, adhere to standard precautions, including protective barriers when performing cough-inducing procedures (use the appropriate combination of gown, gloves, eye protection, and mask). *Category IA*
- Conduct all respiratory-therapy interventions (eg, aerosol therapy, airway clearance) in the patient's room. *Category IB*

- Dedicate each airway-clearance device (eg, positive-expiratory-pressure-therapy device, vest) to one patient, and encourage patients to use their own home airway-clearance devices. *Category II*
- Dispose of sputum-soiled tissues in a covered, no-touch receptacle. *Category II*
- Between nebulizer treatments on a given patient, clean, disinfect, rinse (with sterile or 0.2-µm filtered water), and air dry the nebulizer. *Category IB*
- Ensure proper cleaning, drying, and storage of aerosol therapy mask. *Category II*
- Use only sterile fluid for nebulization, aseptically dispense medication into nebulizer. *Category IA*
- Use single-dose vials, if possible. If multi-dose bottles are used, handle, dispense, and store according to manufacturer's instructions. *Category IA*
- Do not share nebulizers. *Category IA*
- Disinfect non-disposable, non-critical patient-care equipment between patients. *Category IB*

Out-Patient Clinic Setting

Clinic Logistics

- Access each patient's most recent respiratory culture and antimicrobial susceptibility results. *Category IB*
- Schedule and manage patients to minimize (or avoid) waiting-room time. *Category IA, IC*
- On arrival and before leaving clinic, instruct patient and family on proper hand hygiene. *Category IB*
- Ensure readily available alcohol-based hand sanitizer. *Category IA*
- Instruct patients on proper secretion containment: use of tissue, disposal of tissue into a no-touch covered receptacle, and hand hygiene after coughing. *Category II*
- Discourage hand-shaking and other physical contact between CF patients, to prevent direct and indirect contact with respiratory secretions. *Category IA*
- Maintain a minimum distance of 1 meter between patients, to prevent droplet transmission of respiratory pathogens. *Category IB*
- Discourage the use of common items that can not be cleaned and/or disinfected between patients. *Category II*
- *No recommendation* regarding the routine use of masks outside of the clinic examination room. *Unresolved issue*

Clinic Logistical Strategies

- Staggered clinic schedule
- Place patient immediately into an examination room
- Use a pager system
- Patient remains in examination room while the CF team staff rotates in and out

Organism-Specific Circumstances

- Observe contact *plus* standard precautions with a CF patient who is coughing and infected with epidemiologically important CF pathogens (eg, *B. cepacia* complex, MRSA, or multidrug-resistant *P. aeruginosa*). *Category IA*
- For patients infected with *B. cepacia* complex:
  - Segregate from other patients. *Category IB*
  - Segregate from others with *B. cepacia* complex. *Category IB*
  - Schedule on a separate day or at the end of clinic. *Category IB*
  - Place patient in examination room immediately. *Category IB*
- Multidrug-resistant *P. aeruginosa*: place in an examination room immediately. *Category IB*
- Other multidrug-resistant bacteria (eg, *Staphylococcus maltophilia* and *Achromobacter xylosoxidans*): manage according to hospital policy. *Category II*
- Acid-fast bacilli:
  - Place positive acid-fast-bacilli smears in airborne isolation until *Mycobacterium tuberculosis* is excluded. *Category IA*
  - Use standard precautions for nontuberculous mycobacteria. *Category IC+B*
  - Use airborne isolation precautions for patients with documented *M. tuberculosis*, until clinically improved *and* 3 acid-fast-bacilli smears > 8 hours apart are negative. *Category IA*

With permission from: Saiman L, Siegle J; Cystic Fibrosis Foundation. Infection control recommendations for patients with cystic fibrosis: microbiology, important pathogens, and infection control practices to prevent patient-to-patient transmission. Infect Control Hosp Epidemiol 2003;24(5 Suppl):S6-S52.

Discussion

Newton: In the hospital do you disinfect nebulizers?

O'Malley: No, we dispose of them daily.

Newton: Do you rinse them out after the treatment?

O'Malley: Not currently. We're studying our nebulizer policy. Two concerns include whether the rinse water would be sterile, and where we would dry the nebulizer. So far we've found nothing wrong with our current policy.

Volsko: With patients whose cultures are suspicious for *B. cepacia* and they're cohorted with the confirmed *B. cepacia* patients, what extra precautions do you use to prevent *B. cepacia* transmission?

O'Malley: Patients in the *B. cepacia* group are kept separate, and standard isolation precautions apply.

Flume: At my facility the infection-control folks tend to focus on what they know and ignore what they don't know. We culture our CF patients very frequently, but the rest of the patients are screened only for MRSA and vancomycin-resistant enterococcus. There is not the same sense of awareness. On the medicine ward we have rooms dedicated to long-term mechanical ventilation, and in one of those rooms a patient had *B. cepacia* but didn't have CF, and it never occurred to the RTs, or nurses, or even the infection-control folks that this was something of concern. We had to insist that the nurse who cared for that patient could not care for any of the patients with CF.

O'Malley: That is interesting. We too have a cohort of ventilated patients who are kept in a separate wing. And every now and then as people get discharged it goes down to one and then none, and then if they are readmitted we again cohort. But, yes, patients without CF who are ventilated long-term can harbor *B. cepacia*. And staffing becomes a problem because you have to make sure that no one is assigned to other patients outside of that cohort.

Ratjen: If I understand you right, you use disposable nebulizers in the hospital. We stopped using those because they have pretty poor lower-airways deposition. With CF patients we switched to just the Pari LC Star. And if our patients don't come in with their own nebulizer, we give them one to make sure they get adequate lower-lung deposition in the hospital. The rooms are big enough that they can keep their equipment clean in the room.

I know it's challenging, but I think we have to keep a certain standard of aerosol delivery, no matter where the patient is, because we've seen some patients deteriorate on the ward because initially a disposable nebulizer was not giving adequate lower-lung delivery. They may be fine for asthma treatments, but they are inadequate for CF.

O'Malley: We use Pari disposable nebulizers for medications such as Pulmozyme [recombinant human deoxyribonoclease] and TOBI [inhaled tobramycin]. Now the makers of TOBI give us nebulizers for delivering TOBI in the hospital. So it is the one exception of a non-disposable nebulizer, but there, again, we're not reprocessing. We give it to them to take home and tell them to clean and disinfect it. And recently we switched to the AeroEclipse breath-actuated nebulizer. So, with the exception of the Pari LC Plus for TOBI, in the hospital we use the AeroEclipse, which is disposable but has much better delivery.

Geller: On the in-patient side we have a conflict between economics and what we'd like to do for delivery. Probably not 2 weeks go by without an e-mail from somebody asking, "Can I use this or that nebulizer?" And the answer has to be a balance between those two. The AeroEclipse is breath-actuated, so if you used it for TOBI you wouldn't be sure what dose the patient was getting, right?

O'Malley: Right. I wouldn't do that.

Geller: If you use if for Pulmozyme, which has no known toxicity except a little hoarseness, it's OK, because if you get more in, maybe it'll work better, and it's not a dose-dependent drug. And maybe the patient can even use the AeroEclipse a few more times after they take it home. It's an issue—the balance between economics, cleanliness, and delivery—and won't be resolved until someone comes up with a really efficient, disposable, cheap, nebulizer.

Marshall: You mentioned that there have been dramatic changes in infection-control practices during your career. Has that impacted your or your colleagues' job satisfaction? Is it a major aspect of what you do? How does it impact your day-to-day life and your job satisfaction?

O'Malley: I'm sure it has been difficult for everyone: patients, families, and certainly the staff. I remember when I first started, I knew therapists who would pick up patients and meet them outside the hospital in groups and do things. I've never been in favor of that; I draw a line between my professional relationship with patients and doing something socially. But I'm sure that for people who developed relationships with these families that this was tough on them as well.

If you're referring to the requirements that staff use gowns, gloves, and masks, yes, that is an added burden, but everybody, including the families, with sincere understanding and education, has really appreciated the added effort. In fact, they're going to the other extreme, asking "Why aren't you doing this too?" So I think everybody's come full circle to know that the intention is good.

Rosenblatt: Patrick Flume and I served on the Cystic Fibrosis Foundation center committee and performed inspections of programs throughout the country. The infection-control guidelines were published in 2003, but I would estimate that 80% of the centers I visited did not comply with all the recommendations.

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O'Malley: In what respects?

Rosenblatt: I don't think all of the centers are changing nebulizers daily or cleaning them after each use. In only one place I visited did the physicians gown and glove with each patient they saw. In my institution I watch people's gloving and gowning practices. As an example, dietary will bring a tray into a room and then take another tray into the next room. They have gloves on, but don't change gloves between rooms.

So I think it is not just an economics argument. The practice between centers and individuals is not uniform. I think it is the one Cystic Fibrosis Foundation guideline that is not being followed by the majority of centers. I don't know if there are any data on adherence to the recommendations. I don't think the center committee collects those data.

O'Malley: I did an unpublished survey of United States CF centers and asked about their nebulizer cleaning and disinfecting practices, and I got about a 30% response. Absolutely the infection-control recommendations have had an impact, but, you're right, adherence is variable, and there are still centers who throw away nebulizers only when they "look dirty," or when the patient is discharged.

Rosenblatt: I think the guidelines have caused some changes, but I suspect that no centers adhere to all the guidelines. Regarding your survey, I suspect that the centers who responded were more likely the ones that made some changes. I don't think we have tracked adherence to the guidelines.

Marshall: You're right. Lisa Saiman has been working on some follow-up studies to the guidelines. She assessed adherence and barriers to adherence among clinicians,[1] and now she's extending that to patients and families.[2] She's systematically surveyed some centers, with a scientifically sound sampling. It's across the spectrum, from relatively good to very poor adherence. There have been some major changes in practice and substantial improvement, but this is going to be an ongoing effort to educate people and implement these guidelines.

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O'Malley: In that paper by Garber et al, 60% of the centers weren't even aware of the infection-control recommendations. That surprised me. So, awareness should be number one.

Davies: What's the evidence in favor of gloves and gowns over careful handwashing? Is there actually any evidence for it?

O'Malley: I don't know.

Davies: Does anyone know?

Ratjen: There isn't any.

Flume: What is known is that people don't wash their hands, and so you make them jump through a different hoop to get the same goal.

O'Malley: There's something to be said on that for masks too. For example, the recommendations state that the use of masks is an unresolved issue. However, if you have a routine—you put on a mask, you gel—it is a reminder of what you're trying to avoid.

Ratjen: For masks some data indicate that they don't help at all after a certain amount of time.

O'Malley: About 10 minutes?

Ratjen: Yes. So they may give you a false sense of security. In Toronto the SARS [severe acute respiratory syndrome] epidemic completely changed the practice of using gloves and gowns in the hospital with newly admitted patients.[1] That probably had much more impact than anything else on infection-control practices. With regard to regular use of gloves and gowns with CF patients, I don't think we have the evidence. We should stick to measures that have good evidence.

REFERENCE

1. Jefferson T, Foxlee R, Del Mar C, Dooley L, Ferroni E, Hewak B, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses: systematic review. BMJ 2008;336(7635):77-80.

Davies: I think it might partly explain people's reluctance to take it up, because if people are aware that there's no evidence for a practice they find cumbersome, they might not do it. And, certainly, we have moved toward more use of the patient-segregation guidelines you discussed, Cathy, but one of the things we don't do is gloves and gowns. I could see many of my colleagues being very reluctant to take that up without a shred of evidence that it's beneficial.