Airway-clearance Techniques

By Jonathan Finder, MD

In respiratory medicine, one constant theme is the importance of airway clearance in maintaining health. Airway (secretion) clearance consists of two linked systems: mucociliary clearance and cough clearance.

CPT has been the standard for CF care since the 1960s, but newer techniques are finding acceptance, too

Mucociliary Clearance

The airway, from the nose to the terminal bronchiole, is lined with a specialized epithelium. The respiratory epithelium has approximately 200 cilia per cell, and they sweep at a rate of 600 to 900 beats per minute (10 to 15 beats per second) in a coordinated fashion. The cilia beat within a fluid layer of solutes (the sol layer) and move a thin layer of mucus (the gel layer) from periphery to central airway. The flow speed of the mucus layer actually increases as the mucus moves toward the airway opening. The rate in the small airways is approximately 0.5 to 1 mm per minute; in the central airways, the linear velocity can range from 5 to 20 mm per minute.

There are two primary disease states in which mucociliary clearance is impaired: cystic fibrosis (CF) and primary ciliary dyskinesia (PCD). In CF, the layer of water and solute in which the cilia beat is diminished in volume. This entraps the cilia in the gel layer, impeding ciliary beating. This, in turn, leads to stasis of secretions, chronic bacterial infection, and destruction of the airways by the toxic products of white blood cells.

In PCD, the cilia themselves do not function, leading to a similar pattern of stasis of secretions and chronic infection/inflammation. PCD is also known as Kartagener disease, after the Swiss physician who first described the triad of bronchiectasis, sinusitis, and situs inversus. It is important to remember that 50% of PCD patients do not have situs inversus, and that most patients with primary situs inversus do not have PCD.

Acquired ciliary dyskinesia is quite common, and is often unrecognized. The single most common cause of a temporary state of dysfunctional cilia is respiratory infection (viral and atypical bacterial). A period of weeks to months of a wet cough may follow what appeared to be an ordinary chest cold, with gradual resolution. Only rarely do affected patients undergo biopsy of the lower airway to diagnose these disorders, but in such cases, biopsy can reveal areas without functioning cilia, or with cilia that have random orientation and poor function.

Another quite common reason for impaired mucociliary clearance is cigarette smoking (and environmental tobacco-smoke exposure in the children and partners of smokers). Bronchiectasis, which can have many causes, is also associated with impaired mucociliary clearance (which may be localized).

Conventional Chest Physiotherapy

The long-accepted treatment for impaired mucociliary clearance is chest physiotherapy (CPT), introduced into standard CF care in the 1960s.[1] It is also referred to as percussion and drainage, and it involves using either cupped hands or a mask/percussor, often blocked at the small opening, with a soft edge. The chest wall is rhythmically struck, transmitting vibrations to the underlying lung tissue. The lobe of the lung being treated is generally in a superior position, which allows postural drainage of secretions that are then expectorated. The value of manual (conventional) CPT in

Courtesy of the American Association for Respiratory Care

improving secretion clearance in CF over spontaneous coughing alone has been established in numerous studies.[2-4] This treatment has been the gold standard for the treatment of impaired airway clearance in all diseases of impaired mucociliary clearance for many years.

A Cochrane systematic review[1] of CPT in CF identified 126 trials, but excluded all but six based on methodology. These six investigations were all short-term studies lasting less than a week, and all were crossover studies. The reviewers could not draw conclusions regarding long-term treatment (clearly, a major weakness in research in this field). Most of the studies reviewed demonstrated a greater amount of expectorated secretions with CPT than for coughing alone. Two studies compared total lung capacity and functional residual capacity (using a plethysmograph) and found no differences; spirometry results were not available. Airway clearance, assessed using radiotracers in four studies, improved clearance of the radionuclide.

There is little doubt that CPT is efficacious in treating CF and other diseases of impaired mucociliary clearance. CPT remains the single most important aspect of respiratory care in CF. As a result, a great deal of effort has been spent trying to make the delivery of airway-clearance therapies less time-consuming, burdensome, unpleasant, and uncomfortable. In addition, there is a need to make patients who use CPT less dependent on a caregiver.

The supremacy of conventional CPT has been challenged, over the past decade or so, by the advent of mechanical airway-clearance devices. These devices include mechanical percussors, external oscillatory devices (high-frequency chest-wall compression and sonic oscillation), internal oscillatory devices (handheld airway oscillators and intrapulmonary percussive ventilation), and positive expiratory pressure (PEP) mask therapy. In addition, there are breathing techniques such as autogenic drainage, active cycle of breathing, and huffing.[5]

A Cochrane review[6] of various methods of airway clearance in CF established that although there is no demonstrable difference between conventional CPT and other forms of airway clearance, there was a definite preference among users for techniques that could be self-administered.

CPT remains the single most important aspect of respiratory care in CF.

Although no single method of airway clearance can be recommended over another in disorders of impaired mucociliary clearance, it is worthwhile to be familiar with the various devices used in both home and hospital settings.

High-Frequency Chest-Wall Compression

High-frequency chest-wall compression (HFCC), in the forms of the Vest® (Hill-Rom, St Paul, Minn), the SmartVest® (Electromed Inc, New Prague, Minn), and InCourage® (RespirTech, St Paul), was introduced in the early 1990s and has been found equivalent in efficacy to CPT in stable and hospitalized patients with CF.[7-9] In high-frequency HFCC, the patient wears a vest that rapidly inflates and deflates, compressing the chest wall and thereby oscillating the air within the lungs. This oscillation is felt to shear away adherent secretions within the airways, aiding in their mobilization from peripheral airways to the central airway (where they can be cleared through coughing). A long-term study[8] of HFCC in 16 patients with CF demonstrated reduced loss of lung function during the HFCC period in a self-controlled study. Subsequent short-term studies[6] have shown conflicting results, but overall findings indicate that HFCC is therapeutically equivalent to manual CPT (as performed by RTs). Despite a strong patient preference for high-frequency HFCC therapy over conventional CPT, adherence to treatment remains disappointingly low, at approximately 45% in most studies.[10-14]

Oscillation Devices

High-frequency chest-wall oscillation (CWO), as a term, should not be used interchangeably with HFCC. High-frequency CWO refers to the Hayek Oscillator™ (Breasy Medical Equipment, Charlotte, NC), which is a negative-pressure ventilator that uses a cuirass interface around the chest. Just one study[15] using this device in CF has been published, and the authors found that it was not as effective as techniques using the active cycle of breathing; they concluded that high-frequency CWO was not an effective airway-clearance modality in CF exacerbations.

Just as HFCC oscillates the air within the lung, handheld devices that oscillate a column of air within the airway help to shear secretions away from the wall of the airway and help mobilize them for expectoration. They are similar in function to HFCC. One difference, though, is that handheld oral airway oscillators generally provide some positive airway pressure to help maintain airway patency during breathing. Therefore, they

are often discussed in the context of PEP. The first reports[16] on oral airway oscillation demonstrated an increase in expectorated sputum volume, compared with conventional CPT. The original device (Flutter, Axcan Pharma, Birmingham, Ala) used a metal ball that oscillated based on gravity, and therefore was quite positionally sensitive. Later devices used magnetic attraction to open and close the valve (Acapella, Smiths Medical, Waukesha, Wis) or a hand-cranked mechanism to open and close a valve (Quake, Thayer Medical Corp, Tucson, Ariz), thereby rapidly opening and closing the airway's opening during expiration. The hand-cranked device also has the advantage of allowing airway oscillation during the inspiratory phase, and it does not rely on a high flow rate for function. This device may be more useful in patients with more severe obstructive defects. No head-to-head studies of these devices have ever been performed.

Mechanical insufflaton-exsufflation has gained widespread acceptance in the United States ... and has become the standard of care

Two other devices, which were designed for hospital use, also deliver nebulized medications via positive, oscillating pressure: the PercussiveNEB® (Vortran, Sacramento, Calif) and intrapulmonary percussive ventilation (IPV®, Percussionaire, Sandpoint, Idaho). The PercussiveNEB has not been shown to be effective, and its use remains limited. IPV uses small, rapid, high-flow bursts of air to help loosen secretions; it has been studied[17,18] in patients with neuromuscular weakness and atelectasis. Anecdotal reports have indicated that IPV is a useful adjunct in clearing atelectasis in patients with neuromuscular weakness. IPV has also been evaluated[19] in CF in comparison with the Flutter and CPT. No differences were found, suggesting that IPV is no less effective than other forms of airway clearance. IPV was also well tolerated. The largest study group consisted of 16 subjects, limiting, to some degree, the usefulness of this work. Despite these promising reports from the mid 1990s, no larger follow-up studies have been published.

Positive Expiratory Pressure

Nonoscillating positive–airway-pressure masks (TheraPEP®, Smiths Medical, Waukesha, Wis) have also been used in an attempt to improve airway clearance. These masks generate airway pressures in the range of 5 to 25 cm H_2O. One theory is that the positive airway pressure generated by partially occluding the airway opening during expiration leads to better patency of collapsible, bronchiectatic airways. In addition, back pressure can improve collateral ventilation to aid in mucus clearance. A Cochrane review[20] of this therapy demonstrated weak evidence for PEP therapy, and found it no more effective than other forms of airway clearance, despite patients' preference for it. High-pressure PEP therapy has been used; this involves pressures of 40 to 100 cm H_2O.[21] Two long-term studies of PEP versus handheld airway oscillation had conflicting results: one[22] demonstrated a significant decrease in rate of decline in lung function in the PEP group during a year's evaluation, but a subsequent study[23] favored the airway-oscillator group. At this time, the PEP mask should be considered an acceptable alternative (without advantages) to other therapies, based on the limited data available.

Breathing Techniques

The active cycle of breathing and autogenic drainage are related huffing techniques in which the patient uses breathing with an open glottis, at varying volumes and varying levels of inflation, to help expel secretions. In these forms of airway clearance, the glottis is kept open to avoid elevating the intrathoracic pressure, which could collapse bronchiectatic airways. Few RTs are trained to teach these techniques, and, as a result, few patients use this therapy for airway clearance. With a trained RT and a cooperative patient, however, both techniques are effective in aiding airway clearance. Only one comparison study[24] has been published in final form. It demonstrated, in a short-term crossover study, that autogenic drainage was as effective as the active cycle of breathing in improving ventilation and aiding in secretion clearance. Neither therapy improved pulmonary function or saturation.

Assisted Coughing

The other arm of airway clearance is coughing. In cough clearance, secretions that have been cleared from the peripheral airways to the central airways are expelled through coughing. Cough clearance is impaired in patients with neuromuscular weakness. Patients who may benefit from assisted cough clearance include those with various muscular dystrophies, spinal muscular atrophy, amyotrophic lateral sclerosis, spinal-cord injuries, and even profound injuries of the central nervous system. In addition, postoperative patients (such as those who have undergone sternotomies, laparotomies, or other procedures leading to pain during coughing) will benefit from short-term use to improve airway clearance. Coughing can be assisted manually using a self-inflating bag-and-mask combination to insufflate the lungs maximally; this is followed by a thoracic squeeze or abdominal thrust to force the air out, expelling secretions.

A mechanical device (CoughAssist®, Respironics, Murrysville, Pa) has been in use since 1993 and has been extraordinarily successful in aiding this population. Mechanical insufflation-exsufflation is based on the simple principle of applying alternating negative and positive pressure across the airway opening. Mechanical insufflation-exsufflation has gained widespread acceptance in the United States, and it has become the standard of care for patients with insufficient cough clearance secondary to neuromuscular weakness. Although the initial literature was largely anecdotal, subsequent prospective controlled trials[25,26] have demonstrated significant improvement in outcomes when this treatment was used. It is important for RTs to become familiar with this device, as its use appears to grow daily. ■

Editor's note
References are available with the online version at www.rtmagazine.com

Jonathan Finder, MD, is associate professor of pediatrics, University of Pittsburgh.