Conventional Chest Physical Therapy for Obstructive Lung Disease

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Summary

Chest physical therapy (CPT) is a widely used intervention for patients with airway diseases. The main goal is to facilitate secretion transport and thereby decrease secretion retention in the airways. Historically, conventional CPT has consisted of a combination of forced expirations (directed cough or huff), postural drainage, percussion, and/or shaking. CPT improves mucus transport, but it is not entirely clear which groups of patients benefit from which CPT modalities. In general, the patients who benefit most from CPT are those with airways disease and objective signs of secretion retention (eg, persistent rhonchi or decreased breath sounds) or subjective signs of difficulty expectorating sputum, and with progression of disease that might be due to secretion retention (eg, recurrent exacerbations, infections, or a fast decline in pulmonary function). The most effective and important part of conventional CPT is directed cough. The other components of conventional CPT add little if any benefit and should not be used routinely. Alternative airway clearance modalities (eg, high-frequency chest wall compression, vibratory positive expiratory pressure, and exercise) are not proven to be more effective than conventional CPT and usually add little benefit to conventional CPT. Only if cough and huff are insufficiently effective should other CPT modalities be considered. The choice between the CPT alternatives mainly depends on patient preference and the individual patient's response to treatment. *Key words: chest physical therapy, pulmonary, mucus transport, sputum, cystic fibrosis, airway secretions, cough, huff, postural drainage, postural drainage, autogenic drainage*. [Respir Care 2007;52(9):1198–1206. © 2007 Daedalus Enterprises]

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Introduction

In health, the production and continuous transport of airway mucus is an effective defense mechanism. Inhaled bacteria and dust are cleared and the lower airways are thus kept sterile. In airway diseases that cause mucus hypersecretion or impair mucus transport, inadequate mucus clearance increases the risk of infection and related morbidities, and is associated with faster decline in pulmonary function.[1–5] In cystic fibrosis (CF) the airway secretions contain very little mucin, are largely pus, and are prone to infection; the paucity of mucus production in the CF airway may predispose to infection.

Chest physical therapy (CPT) is a widely used intervention in patients with airway diseases. The main goal is to improve mucus clearance, to decrease the risk of pulmonary infection, slow the decline in pulmonary function, and improve quality of life. Conventional CPT is used in stable patients with obstructive lung disease, to prevent complications in the perioperative period, and in some critically ill patients, such as those receiving mechanical ventilation. This paper reviews conventional CPT and alternative CPT modalities in patients with obstructive lung diseases.

Conventional Chest Physical Therapy

Historically, CPT has consisted of a combination of forced expirations (directed cough or huff [forced expiration with the glottis open from the beginning to the end of the maneuver]), postural drainage, percussion, and/or shaking. I will refer to that combination of modalities as conventional CPT.

Mucociliary clearance is the primary defense mechanism of the smaller airways, and cough is the primary defense mechanism for clearance of secretions from the larger airways. Cough is also an important mucus-clearance mechanism in the smaller airways when mucociliary clearance is not functioning optimally (ie, when disease puts secretion production and clearance out of balance and/or causes abnormal mucus rheology). During a cough, the peak intrapulmonary pressure is normally about 200 cm H_2O before the glottis opens. When the glottis opens, the explosive decompression into the upper airways normally generates a flow of 6–20 L/s. During huff the flow and intrapulmonary pressure are much lower than during cough.[6] Cough and huff can be started at low, medium, or high lung volume.

Postural drainage is the use of various patient positions to orient secretion-filled bronchi with the expectation that gravity can assist secretion drainage. Postural drainage is probably most effective when there is a large quantity of mucus that has low adhesiveness. Nine postural positions have been described.[7] Determining the locations of the secretion-filled bronchi is key to determining which patient positions to use. The time required in each patient position depends on the quantity, viscoelasticity, and adhesiveness of the mucus. If tolerated, the patient can sleep in a postural drainage position. Chest percussion is the manual application of rhythmic clapping to the ventral, lateral, and/or dorsal thorax, at about 3–6 Hz. Chest percussion is often delivered in 10–20-min treatment sessions, whenever there is ausculatory evidence of airway secretion retention. Chest shaking is a coarse movement applied to the rib cage during exhalation.[7]

Conventional CPT has been evaluated in clinical trials and systematic reviews in subjects with chronic obstructive pulmonary disease (COPD)[8] and CF[9] (Table 1).

Newton et al[10] evaluated conventional CPT combined with intermittent positive-pressure breathing in 79 subjects with COPD exacerbations. The subjects were assigned to 3 groups: (1) male subjects with $P_{aO_2} > 60$ mm Hg, (2) male subjects with $P_{aO_2} < 60$ mm Hg, and (3) female subjects. In each group, subjects were randomly allocated to drug treatment (control) or to drug treatment plus CPT and intermittent positive-pressure breathing. Changes in pulmonary function, arterial blood gases, and sputum volume between admission and discharge were evaluated, and comparisons were made between the CPT and control groups. There were no significant differences in forced expiratory volume in the first second (FEV_1) or vital capacity between the CPT and control groups. The change in P_{aO_2} was higher in the CPT group in group 1, compared to the control group, and in the control group in group 2, as compared to the CPT group. Mean sputum volume was only higher in the CPT group in group 1, compared to the control group, during the last 3 admission days. In general, CPT did not benefit subjects with COPD exacerbation.

May et al[11] used a heat lamp as a placebo, compared to CPT, and found no significant effects on pulmonary function or P_{aO_2} with CPT, but found favorable effects on sputum expectoration during CPT. However, in subjects with COPD, Bateman et al[13] found a 4–5-fold increase in mucus clearance, compared to a control period and in a mixed group of subjects, Sutton et al[15] found a higher clearance rate and a higher weight of expectorated sputum. Oldenburg et al[12] found that both cough and exercise were effective, but that postural drainage had no significant effect on clearance of a radioactive tracer.

In a Cochrane systematic review, Jones and Rowe[8] assessed the effects of conventional CPT in subjects with COPD or bronchiectasis. The 7 studies included 6 comparisons and 126 subjects. The studies were small and not of high quality. CPT produced no significant effects on pulmonary function, apart from clearing sputum in COPD and bronchiectasis. The authors concluded that there is insufficient evidence to support or refute the effectiveness of CPT in subjects with COPD or bronchiectasis.

Table 1. Studies of Chest Physical Therapy Effects on Pulmonary Function and Mucus Clearance

First Author, Year	Condition	Patients (no.)	CPT Components	Duration†	Variable(s) Measured	Effect‡
Newton,[10] 1978	COPD exacerbation	79	CPT + IPPB	Short-term	FEV_1	0
					VC	0
					Sputum volume	0
May,[11] 1979	COPD	35	Percussion, postural drainage, vibration, directed cough	Immediate	PEF	0
					FVC	0
					FEV_1	0
					$FEF_{50\%}$	0
					$FEF_{75\%}$	0
					Sputum volume	+
Oldenburg,[12] 1979	COPD	8	Directed coughing	Immediate	Mucus clearance§	+
			Exercise	Immediate	Mucus clearance§	+
			Postural drainage	Immediate	Mucus clearance§	0
Bateman,[13] 1979	COPD	10	Postural drainage, vibration, percussion, shaking, directed cough	Immediate	Mucus clearance§	+
Rossman,[14] 1982	CF	6	Postural drainage	Immediate	Mucus clearance§	+
	CF	6	Postural drainage, percussion	Immediate	Mucus clearance§	+
	CF	6	Postural drainage, percussion, vibration	Immediate	Mucus clearance§	+
	CF	6	Directed cough	Immediate	Mucus clearance§	+
Sutton,[15] 1983	Mixed group	10	FET, postural drainage, directed cough	Immediate	Mucus clearance§	+
					Sputum weight	+
Mortensen,[16] 1991	CF	10	Postural drainage, FET	Immediate	Mucus clearance§	+
	CF	10	PEP, FET	Immediate	Mucus clearance§	+
van der Schans,[17] 1991	CF	8	PEP at 5 cm H_2O	Immediate	Mucus clearance§	0
			PEP at 15 cm H_2O	Immediate	Mucus clearance§	0
Pfleger,[18] 1992	CF	15	High-pressure PEP, FET	Immediate	Mucus clearance	+
	CF	15	Autogenic drainage	Immediate	Mucus clearance	+
	CF	15	High-pressure PEP, FET, then autogenic drainage	Immediate	Mucus clearance	+
	CF	15	Autogenic drainage then PEP, FET	Immediate	Mucus clearance	+

†Short term = 1–7 days
‡+ = favored CPT, 0 = no difference
§Mucus clearance measured via clearance of radioactive tracer
CPT = chest physical therapy
COPD = chronic obstructive pulmonary disease
IPPB = intermittent positive-pressure breathing
FEV_1 = forced expiratory volume in the first second
VC = vital capacity
PEF = peak expiratory flow
FVC = forced vital capacity
$FEF_{50\%}$ = forced expiratory flow at 50% of the forced vital capacity
$FEF_{75\%}$ = forced expiratory flow at 75% of the forced vital capacity
CF = cystic fibrosis
FET = forced expiration technique
PEP = positive expiratory pressure.

In a crossover-design study of 6 subjects with CF, Rossman et al[14] compared the immediate effect of 4 forms of airway clearance: directed vigorous cough, postural drainage, postural drainage with mechanical percussion, and conventional CPT. The control period included directed coughs. In this short-term study, each treatment was undertaken once, on separate days. All the interventions increased mucus transport, as measured by clearance of a radioactive tracer.

In a 3-day crossover trial, Mortensen et al[16] compared 2 treatments: postural drainage combined with forced expiration technique (FET) versus positive expiratory pressure (PEP) therapy combined with FET (PEP plus FET). The control period included spontaneous coughing. The characteristic component of FET is that it uses huff (rather than cough) and can be combined with breathing exercises and percussion or shaking. Both postural drainage plus FET and PEP plus FET increased mucus transport.

In a crossover-design study of 8 subjects with CF, van der Schans et al[17] compared the immediate effect of 2 forms of airway clearance: PEP therapy at 5 cm H_2O, and PEP therapy at 15 cm H_2O. PEP therapy *without coughing* had no effect on mucus transport. There was also no difference between directed cough alone and PEP followed by directed cough, as measured by clearance of a radioactive tracer.

In 14 subjects with CF, Pfleger et al[18] compared 4 forms of airway clearance: PEP therapy plus FET, autogenic drainage, PEP therapy plus FET followed by autogenic drainage, and autogenic drainage followed by PEP therapy plus FET. The control period included directed coughing. Each treatment was undertaken once, on separate days. The mean weight of expectorated sputum in the control period was approximately 17 g, and in the 3 forms of CPT it was 34–45 g, although the value of measuring sputum weight as a primary outcome is questionable. Similarly, Braggion et al[19] compared the immediate effect of 3 forms of airway clearance: high-frequency chest wall compression (HFCWC) combined with FET and cough, PEP combined with FET and cough, and postural drainage combined with vibrations, deep breathing, percussion or FET and cough. The control period involved spontaneous coughing. Each regimen was used twice a day for 2 consecutive days. Mean wet weight of expectorated sputum during the control day was 6 g, and during the airway clearance therapy sessions it was 23–30 g.

In a Cochrane systematic review, van der Schans et al[9] analyzed studies of subjects with CF to assess the effectiveness and acceptability of CPT compared to no treatment or spontaneous cough alone. There were no randomized controlled trials or crossover trials eligible for inclusion in the review. The short-term crossover trials, which had to be excluded from the review, suggest that airway clearance regimens could benefit patients with CF, but van der Schans et al[9] concluded that there is no robust scientific evidence that CPT is effective in clearing airway secretions in patients with CF.

Both the van der Schans[9] and Jones and Rowe[8] Cochrane reviews concluded that CPT increases sputum expectoration and mucus transport, but has no effect on pulmonary function. These studies are summarized in Table 1.

Thomas et al[20] conducted a meta-analysis of airway clearance modalities in subjects with CF: specifically, PEP, FET, exercise, autogenic drainage, and conventional CPT. They concluded that conventional CPT resulted in significantly greater sputum expectoration than no treatment. It is important to note, however, that they based this finding on p value analysis, and not on the quantity of sputum produced. They also found that the combination of conventional CPT and exercise was associated with a moderate increase in FEV_1, compared to CPT alone. No other differences between airway clearance modalities were found.

Directed Cough and Forced Expirations

Forced expirations and coughing are the most effective and important parts of CPT.[14,21–23] As previously noted, Rossman et al[14] found that there was no significant difference between regimented cough alone and therapist-administered combined maneuvers, and concluded that in CF, vigorous, regimented cough sessions may be as effective as therapist-administered CPT in removing pulmonary secretions. Cough may even be effective in patients who do not expectorate sputum.[24] Forced expirations are as effective as cough in patients with COPD or bronchiectasis, even though patient effort is less with forced expirations.[25] However, a long-term study of subjects with CF showed less annual decline in expiratory flow during the middle half of the forced expiratory volume ($FEF_{25–75\%}$) in a group that received chest percussion, postural drainage, and FET than in a group that applied self-administered FET. There were no statistically significant differences between the 2 groups in decline in forced vital capacity, FEV_1, or number of hospitalizations.[26] Forced expirations can be manually supported, which may benefit patients with respiratory muscle weakness, but not patients without muscle weakness.[27]

Postural Drainage

In an animal model, Chopra et al[28] found an increase in tracheal mucus transport velocity during postural drainage. Other studies have found improved mucus transport in subjects with CF,[29,30] but a study of subjects with chronic bronchitis found no improvement.[12] Postural drainage may be useful when forced expirations, assisted cough, and exercise are not possible or are inadequate. Disadvantages

Table 2. Optimal Frequency for Improving Mucus Transport With High-Frequency Chest Wall Percussion

First Author, Year	Subjects	Optimal Frequency (Hz)
Flower,[32] 1979	Patients with CF	15
Radford,[33] 1982	Dogs	15–35
King,[34] 1983	Dogs	11–15
King,[35] 1984	Dogs	13
Chang,[36] 1988	Experimental-theoretical study	13
Rubin,[37] 1989	Dogs	13

are that postural drainage is relatively time-consuming and may require a special bed or table to be performed effectively.

Chest Percussion

Mechanical vibration and chest compression methods may induce small coughs or resonance with ciliary action. Chopra et al[28] found in an animal study that manual percussion increased tracheal mucus transport. In patients with COPD it was also found that chest percussion provided a small increase in bronchial mucus transport, but that it had no more benefit than cough and postural drainage.[31] The effect of percussion seems to be frequency-dependent, and several studies have found that the optimal frequency is well above the 6 Hz possible in manual percussion (Table 2). Bauer et al[38] compared manual chest percussion with mechanical percussion in subjects with CF during exacerbations with hospitalization and found pulmonary function improvement similar in the groups. Other studies have similarly failed to detect a difference between manual and mechanical chest percussion. In a meta-analysis of airway clearance modalities in subjects with CF, Thomas et al[20] reported no significant difference for sputum production ($p = 0.31$) or FEV_1 ($p = 0.44$) in 4 studies, which included 68 subjects and compared manual and mechanical percussion and vibration. A systematic review of airway clearance therapy concluded that there is insufficient evidence to support a benefit for the use of percussion as a technique to improve secretion clearance.[39]

Other Airway Clearance Techniques Compared With CPT

High-Frequency Chest Wall Compression

Laboratory studies suggest that the optimal HFCWC frequency for improving mucus transport is about 13–15 Hz (see Table 2). Arens et al[40] compared HFCWC to CPT in subjects with exacerbations of CF. CPT consisted of percussion, postural drainage, and albuterol inhalation 3 times a day. HFCWC was applied 3 times a day, with frequencies of 6–25 Hz, and was also combined with albuterol inhalation. There was no difference in change in pulmonary function between HFCWC and CPT during the study period.

Positive Expiratory Pressure Therapy

A Cochrane review[41] included 7 studies, with 95 total subjects with CF, that measured FEV_1 after a single treatment. There was no difference in FEV_1 after PEP compared to FET, postural drainage and percussion, noninvasive ventilation, or vibratory PEP therapy at 5 cm H_2O or > 20 cm H_2O. One study found that FEV_1 was significantly lower after autogenic drainage followed by high-pressure PEP than after autogenic drainage alone.[18] Bellone et al[42] compared PEP to directed cough in 27 subjects with COPD exacerbations that required noninvasive ventilation. Sputum weight was higher and weaning time was less in the PEP group.

Autogenic Drainage

In 2 studies, which included 36 subjects with CF, no difference in pulmonary function was found between CPT and autogenic drainage.[43] Miller et al[44] compared autogenic drainage to CPT (active cycle of breathing and postural drainage) and found no overall differences in pulmonary function or sputum weight. In subjects with COPD, Savci et al[45] found that peak expiratory flow and oxygen saturation increased more after 20 days of treatment with autogenic drainage than with CPT (active cycle of breathing). No differences were found in other lung function variables.

Exercise

Many patients with chronic hypersecretion and impaired mucus transport can increase sputum expectoration with physical exercise such as running or bicycling. The increased expiratory flow, minute volume, and sympathetic activity during exercise increase ciliary beat and may thereby increase mucus transport.[46] However, exercise can theoretically increase secretion viscosity and adhesivity by decreasing the humidification of inspired air. Assuming that expiratory flow is the most important factor, the exercise must be of sufficient intensity and duration to increase ventilatory demand. Exercise may improve bronchial mucus transport in healthy subjects[46] and in patients with COPD[12] or CF.[47] The addition of exercise to CPT significantly increases the amount of expectorated mucus.[48] It has been suggested that exercise may be a substitute for conventional CPT, but this was not supported in studies of subjects with CF.[49,50]

Vibratory PEP Therapy

In subjects with CF, Konstan et al[51] found significantly more expectorated sputum with vibratory PEP therapy than with voluntary cough or chest percussion. However, they found no improvement in pulmonary function or patient well-being after vibratory PEP therapy. Bellone et al[52] compared the short-term effects of postural drainage, vibratory PEP therapy, and forced expiration in lateral posture on oxygen saturation, pulmonary function, and sputum production in patients with chronic bronchitis exacerbations. Sputum weight was higher with vibratory PEP therapy and forced expirations than with postural drainage, but there were no differences in pulmonary function or oxygen saturation.

Identifying Patients Who Will Benefit From CPT

There is sufficient evidence that CPT improves mucus transport, but it is not entirely clear which groups of patients benefit from which CPT modalities. It has been suggested that the amount of expectorated sputum might predict which patients are likely to benefit from CPT, and that CPT should be applied in patients who expectorate more than 25–30 mL/d.[53] However, the important problem is not the amount of secretions *expectorated*, but the amount of secretions *not* expectorated (ie, retained in the airways). The amount expectorated may not be a reliable outcome measure, because pulmonary secretions may be swallowed, and those that are expectorated also include saliva. The patients most likely to benefit from secretion-clearance techniques are those with objective signs of secretion retention (eg, persistent rhonchi or decreased breath sounds) or subjective signs of difficulty expectorating secretions, and with progression of the disease that might be due to secretion retention (eg, recurrent exacerbations or infections or a fast decline in pulmonary function).

Selecting and Applying CPT Components

The most effective and important part of CPT is directed cough. The other components of CPT, including percussion, shaking, and postural drainage, probably add little or no benefit and should not be used routinely. Understanding airway physiology and using the equal pressure point (the point at which the pressure inside the airway equals the surrounding plural pressure) and the collateral ventilation system between airways will make airway clearance activities most effective. Finding a match between an effective airway clearance method and a patient's preference is the challenge for the clinician.[54] Alternative airway clearance modalities have not been proven more effective, and usually add little or no benefit to cough and/or huff. Figure 1 shows a proposed algorithm for choosing secretion-clearance interventions.

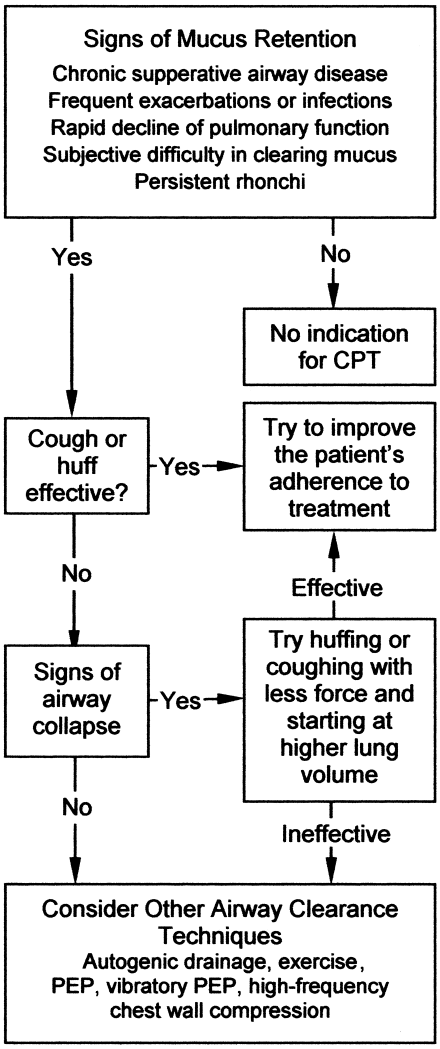

Fig. 1. Algorithm for choosing secretion-clearance interventions.

Dynamic airway compression during exhalation increases the airflow velocity in the compressed airway, which increases secretion transport, unless complete collapse obstructs the airway, which interrupts mucus transport upstream to the obstruction. In the flow-volume curve, a sharp decrease in flow is usually a sign of airway collapse. During a forced exhalation, wheezing often accompanies a sudden decrease in flow. If cough and/or huff are not effective, HFCWC (at about 15 Hz), postural drainage, and autogenic drainage should be considered. Exercise should also be considered, if the patient can tolerate it. The choice of airway clearance modality depends mainly on patient preference and the individual patient's response to treatment. An *n* of 1 study (ie, the patient tries various treatments and acts as his or her own control to determine which treatment works best for him or her) might be worth-

while. As yet, however, we do not have a valid, sensitive, reliable, and clinically feasible outcome measure to determine which patient groups benefit from which airway clearance modalities. On the group level, radioactive tracer clearance and amount of expectorated sputum correlate, but on the individual level, the amount of expectorated sputum is not a reliable or valid measure, because some of the secretions may be swallowed and the expectorated secretions include saliva. The combination of the patient's subjective preference and the amount of expectorated secretions is, at present, the best way to measure the clinical effectiveness of an airway clearance modality or combination of modalities. Potential long-term outcomes include frequency of exacerbations and decline in pulmonary function.

Promoting Patient Adherence to CPT

In addition to identifying which treatment(s) is/are effective for the patient, it is also essential that the patient adhere to the treatment plan sufficiently to obtain benefit. Only about 30% of patients with CF reported undertaking prescribed daily CPT.[55] The problems include fitting CPT into their lifestyle, a perception that CPT does not help, physical consequences of doing CPT, doing exercises instead, and doing CPT only when the patient perceives it necessary.[55] Adherence to CPT is reported to be lower than to medication, and it is challenging to get patients to increase their adherence to CPT. However, there are some behavioral techniques that might help.[56]

Risks and Adverse Effects of CPT

CPT is not necessarily a benign therapy. There are numerous reports of adverse effects, mainly in young children and in acute unstable conditions, including hypoxemia,[57,58] increased oxygen consumption,[59–64] gastroesophageal reflux in infants,[65–68] increased intracranial pressure,[69,70] grade III/IV intracranial hemorrhage in preterm infants,[71] encephaloclastic porencephaly (brain injury similar to that from nonaccidental shaking injury in low-birthweight infants),[72] and rib fractures.[73] Though these adverse effects have been reported only in hospitalized patients and not in stable patients with obstructive lung disease, the risk of adverse effects must be considered. CPT should not be used in patients with chest wall or spinal cord injury.

Summary

Conventional CPT is a widely used intervention in patients with airway disease. It is not clear which groups of patients benefit from which airway clearance modalities, so an *n* of 1 study with the various airway clearance modalities is probably the best way to determine which, if any, will benefit a given patient. At present, the patient's subjective preference is the best measure of which modality to use. The most effective and important part of conventional CPT is directed cough and/or huff.

Many questions about conventional CPT have not been studied, so much of CPT practice is not evidence-based and differs markedly at different institutions. For example, CPT is often started in infants and young children with CF who have very small amounts of retained secretions and thus probably do not benefit from CPT. On the other hand, introducing the patient to CPT an early age may lead to better patient adherence to the CPT regimen in the long term. CPT is often increased during exacerbations, on the reasoning that there are more secretions during exacerbations, but in a patient who is severely ill and weak and therefore has a low cough flow, CPT might not provide clinically important benefit. CPT is often withheld if there is hemoptysis, on the reasoning that chest percussion might dislodge a clot and/or worsen the bleeding, but bleeding within the airway will produce clots and airway obstruction, and the inflammation from the bleeding is likely to increase secretions, which suggests that CPT might be of greater benefit in a patient with hemoptysis. Finally, the optimal frequency and duration of any of the CPT interventions has not been well studied.

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Discussion

Hess: I actually have several questions for you, Cees. Is there any role for CPT to prevent postoperative atelectasis and postoperative pulmonary complications?

van der Schans: That's a completely different field. I think for patients at risk for postoperative complications, the older patients, the smokers, etc, I think then there is a role for routine CPT. But not for all patients.

Hess: Even a patient who has no prior pulmonary history and doesn't have phlegm, and . . .?

van der Schans: No. Patients who underwent heart surgery are usually mobilized within 1 or 2 days, so these patients, if they are not smokers, are not at risk. I don't think there's a need for it.

Hess: I'd like to ask another question. What about chest wall squeezing as has been described by some groups?

van der Schans: Well, it helps to force expiration. I just see it as a support of the forced expiration. And then it works the same as forced expiration, so when the patient doesn't have enough force himself for an effective cough or effective huff, or forced expiration, you can support that. But I think it's not something completely different.

MacIntyre: I guess the older I get, the more suspicious I become of making decisions based only on physiology. In your reviews, does chest PT actually have a meaningful clinical outcome? Does it keep people out of the hospitals? Does it shorten lengths of stay? Does it reduce important things like cough and health care utilization?

van der Schans: We define these outcomes in our Cochrane reviews.[1,2] We didn't find any studies about it. But I agree that we need studies using these kinds of outcomes, because only an improvement in mucus transport, or only a small improvement in FEV_1, that's not enough. You want to prevent exacerbations. You want to prevent the decline in pulmonary function. But these studies are very hard to do, because you have to follow patients for at least 1-2 years.

1. Main E, Prasad A, Schans C. Conventional chest physiotherapy compared to other airway clearance techniques for cystic fibrosis. Cochrane Database Syst Rev 2005; CD002011.
2. van der Schans C, Prasad A, Main E. Chest physiotherapy compared to no chest physiotherapy for cystic fibrosis. Cochrane Database Syst Rev 2000;CD001401.

MacIntyre: This may be a silly question, but is there any evidence that chest PT might actually cause irritation and increase mucus production?

van der Schans: I don't think so. I'm not aware of any formal studies looking at that. I know that rumor goes around, that percussion or coughing causes hypersecretion. I don't think that there is any evidence for that.

Schechter: For my talk tomorrow, which is limited to pediatric studies, I was specifically interested in focusing on clinical outcomes, as opposed to some of the theoretical endpoints. Most of the studies that even *try* to look at outcomes don't do a really good job; but there are some studies that do look at a variety of clinical outcomes, at least in children. There will be some discussion of theoretical stuff, but one of the issues I specifically address is the role of airway clearance therapy on prevention of postoperative atelectasis.[1] This was evaluated in one older study, and no benefit was found.[2] Again, I didn't review this in adults, so I can't speak to that. But stay tuned tomorrow.

1. Schechter M. Airway clearance applications in infants and children. Respir Care 2007; 52(10): in press.
2. Reines HD, Sadde RM, Bradford BF, Marshall J. Chest physiotherapy fails to prevent postoperative atelectasis in children after cardiac surgery. Ann Surg 1982;195(4):451-455.

Tecklin:* I don't want to sound like a broken record, but again, there were numbers of studies in the '60s and '70s that you chose not to include, or even *consider* in your list of studies that were not appropriate for the meta-analysis. I'm surprised that they weren't even considered—number one. And I've talked to Ammani Prasad, a co-author of that Cochrane review about that issue. Number two, it's tough to get newborn infants who have lung disease and CF, or even toddlers, to do autogenic drainage, PEP, or any of the other devices. So, the question I have is: What about the newborn infant who is developing lung disease? Do we just not treat those kids with anything? What do we do with them?

van der Schans: Good question. I'm not a clinician anymore, but I would say to improve ventilation, make ventilation as good as possible, to use tricks, to get some kind of forced expiration maneuvers, these kinds of things.

Tecklin: Again, getting rid of the secretions is really the question for those kids. And that is actually one instance when doing traditional postural drainage with percussion has been shown to be detrimental, because it is likely to cause a significant amount of reflux, so that today's approach is not tipping the kids, but rather, keeping them flat, or even head-up. And doing, in fact, the percussion that many of us have always done. And we can thank Brenda Button for that.[1]

1. Button BM, Heine RG, Catto-Smith AG, et al. Chest physiotherapy in infants with cystic fibrosis: to tip or not? A five-year study. Pediatr Pulmonol 2003;35(3):208-213.

Chatburn: In the study by Zahm[1] that you mentioned, where increasing the frequency increased the mucus clearance, was that multiple occlusions of a single exhalation?

1. Zahm JM, King M, Duvivier C, Pierrot D, Girod S, Puchelle E. Role of simulated repetitive coughing in mucus clearance. Eur Respir J 1991;4(3):311-315.

van der Schans: It was a model study, so it was—I don't know what the time difference between the different coughs was, but I think it was very short. So when you would like to translate it to a sort of a clinical setting, I think it is the repeated coughing during one expiration.

Rubin: If that's the study I think it was, it was from Edith Puchelle's group, and Jean-Marie Zahm actually was able to control the force and volume of a cough using the cough machine.[1] So it was measuring transport of a mucus bolus, within the cough machine, by giving very exact timed coughs, all of exactly the same size. Clinical translation, to my knowledge, hasn't been done.

And also, to answer your earlier question, I'm not aware of any studies that show that physical therapy would increase mucus secretion. But on the other hand, I know of no decent ways to measure increased or decreased mucus secretion in vivo anyway. And if somebody can come up with a way, radiographically, to quantify the total airway mucus burden, I think it would be a wonderful way to advance this field.

1. Zahm JM, King M, Duvivier C, Pierrot D, Girod S, Puchelle E. Role of simulated repetitive coughing in mucus clearance. Eur Respir J 1991;4(3):311-315.

Rogers: It has been done using MRI [magnetic resonance imaging] in rats.[1] They analyzed the MRI images to get a quantitative measure of amount of mucus in the lung. I do not know if it could be translated into visualizing mucus in a more complicated system such as human airways and lungs.

1. Karmouty-Quintana H, Cannet C, Sugar R, Fozard JR, Page CP, Beckmann N. Capsaicin-induced mucus secretion in rat airways assessed in vivo and non-invasively by magnetic resonance imaging. Br J Pharmacol 2007;150(8):1022-1030.

Rubin: They've done it with cervical mucus ex vivo, and been able to

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measure, actually, rheology, viscoelasticity by the T1/T2 ratio on MRI. I don't know that the resolution of MRI in that has been good enough to—you can distinguish mucus from airway, but I don't know that you can actually quantify 3-dimensionally. It would be interesting; I haven't seen that, unless you've got a really, really strong, powerful coil.

Schechter: The rationale for patients to get bronchodilators before chest PT is to prevent possible bronchospasm. In the world of anecdotal medicine, there are several review articles that I found that described bronchospasm as a complication of CPT. But I found no research study that actually documented that phenomenon.

Tecklin: Again, in one of these early studies to which you referred, we had 26 subjects with CF, 6 of whom were wheezing by auscultation. We looked at 6 out of 26 who were wheezing before and after our interventions, and really found no difference in regard to whether the wheezing reduced their pulmonary function. They had increases similar to the group who weren't wheezing.

1. Tecklin JS, Holsclaw DS. Evaluation of bronchial drainage in patients with cystic fibrosis. Phys Ther 1975;55(10):1081-1084.

Fink: A question about postural drainage. At least in the United States there is a tendency for clinicians to be somewhat time-limited for procedures. That means maybe having 15 minutes for the total procedure, and in many cases trying to do 10 or 11 positions in that period of time. What's a reasonable period of time to get an effective response in terms of positioning the patient for a single position for drainage of secretions?

van der Schans: I don't know. My guess is something around 20, 30 minutes. That's what everybody does, and that's what you see in the studies.

Fink: For *individual* positions? Or for the whole treatment?

van der Schans: Yeah, but sometimes patients with bronchiectasis, they know that when they are lying in a certain position and very watery mucus comes out, it comes out almost immediately. So they don't have to lie in position for 20 minutes. It's very fast, but when the mucus is thick and sticking to the airways, it may take much longer. I know that we advised in the past that our patients sleep in a certain position. But you ask a lot of patients to do that, and it costs a lot of time for the patient. So when you talk about compliance, the compliance will be low, I think.

Tecklin: I think we're talking about 20-30 minutes for the entire session. And the only thing I can refer to is a study on Flutter. One of the original ones done at Cleveland,[1] where their definition of chest physiotherapy was 10 minutes, 12 different positions. Ten minutes total. In that first study, Flutter was much more effective in reducing and pulling out secretions.

When that study was replicated a couple of years later, with a more appropriate definition of chest physiotherapy, which was more like—I think it was either a 20- or 30-minute treatment—there was essentially no difference in the sputum produced between the 2 techniques. So, chest physiotherapy doesn't equal chest physiotherapy. You really have to identify your terms when you're discussing it.

1. Konstan MW, Stern RC, Doershuk CF: Efficacy of the Flutter device for airway mucus clearance in patients with cystic fibrosis, J Pediatr 1994;124(5 Pt 1):689-693.

Fink: I recall when the first AARC guideline came out on postural drainage,[1] there were a couple of references that led us to believe that the recommendations should be a minimum of 3-5 minutes per position, but I don't remember the references off the top of my head. The seminal descriptions of postural drainage described individual positions being drained from periods as short as 10 minutes up to several hours.[2]

1. American Association for Respiratory Care. AARC Clinical Practice Guideline: Postural drainage therapy. Respir Care 1991;36(12): 1418-1426.
2. Pryor JA. Physiotherapy for airway clearance in adults. Eur Respir J 1999;14(6):1418-1424.

Hess: I guess I'll play the devil's advocate. If you could get the same result in a 10-minute Flutter treatment compared to a 30-minute conventional chest PT treatment, why wouldn't you take the 10-minute treatment?

Tecklin: As I recall, the Flutter treatment was longer than the traditional 10 minutes. It might have been 20 minutes. They tried to do equivalent times, which they often do. And again, some of us might say if you're doing a 5-10 minute Flutter treatment as your treatment, that in and of itself might not be an appropriate use of Flutter, because you're also talking about the need for FET afterwards, and the active cycle of breathing and huffing, and coughing.

Rubin: Not to take from later presentations, but that study, the first one in the States by Mike Konstan and colleagues,[1] *was* set up to match the duration between the two. But even more interesting is that their primary outcome variable in that study was pulmonary function, and there was no pulmonary function change. Their secondary outcome variable was wet- and dry-weight of sputum, and that's where they saw the differences, which was an interesting thing.

You showed—and again, I hope I'm not taking from Rob Chatburn's talk later on chest wall oscillation—but you showed a study that suggested the resonant frequency of the thorax was about 8-10 hertz, and in the initial studies that Arnold Zidulka did in devel-

oping the Vest with Malcolm King,[2] they showed it was somewhere about 10-15 hertz. Yet, frequently we'll have people apply the Vest and cycle over a period of time different frequencies, as opposed to turning it on and just leaving it at 10-12 hertz. Is there any advantage to cycling the frequency up or down every 10 minutes or 5 minutes or so, as opposed to just leaving it close to the resonant frequency?

1. Konstan MW, Stern RC, Doershuk CF: Efficacy of the Flutter device for airway mucus clearance in patients with cystic fibrosis, J Pediatr 1994;124(5 Pt 1):689-693.
2. King M, Phillips DM, Gross D, Vartian V, Chang HK, Zidulka A. Enhanced tracheal mucus clearance with high frequency chest wall compression. Am Rev Respir Dis 1983; 128:511-515.

van der Schans: I wouldn't know, but I could imagine that the lungs, especially in cystic fibrosis, are not homogeneous. Different parts of the lung have different conditions and may need a different approach, but I'm not aware of any studies.

Schechter: I can tell you that Warren Warwick, in particular, has a very complicated and elaborate 30 minute regimen with 3 different frequency levels associated with different pressure settings. But he has no proof that this is more efficacious than any other, simpler regimen.

I also want to point out that the studies that have demonstrated efficacy of CPT in cystic fibrosis have primarily demonstrated an increase in quantity of sputum production rather than any improvement in FEV_1. This was one of the points of the Cochrane analysis done by Cees.[1] So if you are going to use FEV_1 as your outcome measure in comparing alternative methods of airway clearance to CPT, I think you're on shaky ground.

1. van der Schans C, Prasad A, Main E. Chest physiotherapy compared to no chest physiotherapy for cystic fibrosis. Cochrane Database Syst Rev 2000(2): CD001401.

Homnick: I think the study that Bruce is referring to also showed that at the higher frequencies, with the Vest, the volume of oscillation went down as well, and it was dependent on the frequency, but also on the background pressure in the Vest at the time it was applied. I'm not sure totally how to interpret that, but I think a larger volume of oscillation is probably better for mucus clearance, and therefore, higher frequency may not be helpful. It seems like it would be useful to spend more time in that 10-15 range than at other frequencies.