

A Comparison of the Therapeutic Effectiveness of and Preference for Postural Drainage and Percussion, Intrapulmonary Percussive Ventilation, and High-Frequency Chest Wall Compression in Hospitalized Cystic Fibrosis Patients

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INTRODUCTION: Cystic fibrosis (CF) patients have abnormally viscid bronchial secretions that cause airway obstruction, inflammation, and infection that leads to lung damage. To enhance airway clearance and reduce airway obstruction, daily bronchopulmonary hygiene therapy is considered essential. **OBJECTIVE:** Compare the effectiveness of and patient preferences regarding 3 airway clearance methods: postural drainage and percussion (PD&P), intrapulmonary percussive ventilation (IPV), and high-frequency chest wall compression (HFCWC). **METHODS:** The participants were hospitalized CF patients ≥ 12 years old. Effectiveness was evaluated by measuring the wet and dry weights of sputum obtained with each method. In random order, each patient received 2 consecutive days of each therapy, delivered 3 times daily for 30 minutes. Sputum was collected during and for 15 minutes after each treatment, weighed wet, then dried and weighed again. Participants rated their preferences using a Likert-type scale. Mean weights and preferences were compared using analysis of variance with repeated measures. Patient preferences were compared using Friedman's test. **RESULTS:** Twenty-four patients were studied. The mean \pm SD wet sputum weights were 5.53 ± 5.69 g with PD&P, 6.84 ± 5.41 g with IPV, and 4.77 ± 3.29 g with HFCWC. The mean wet sputum weights differed significantly ($p = 0.035$). Wet sputum weights from IPV were significantly greater than those from HFCWC ($p < 0.05$). The mean dry sputum weights were not significantly different. With regard to overall preference and to the subcomponents of preference, none of the 3 methods was preferred over the others. **CONCLUSIONS:** HFCWC and IPV are at least as effective as vigorous, professionally administered PD&P for hospitalized CF patients, and the 3 modalities were equally acceptable to them. A hospitalized CF patient should try each therapy and choose his or her preferred modality. *Key words:* airway clearance, bronchopulmonary hygiene, chest physiotherapy, cystic fibrosis, high-frequency chest wall compression, intrapulmonary percussive ventilation, postural drainage, percussion, sputum. [Respir Care 2003;48(1):24–28]

Introduction

Cystic fibrosis (CF) is a genetic abnormality of the exocrine glands. A hallmark of this disease is abnormally viscid bronchial secretions that predispose the airway to

obstruction, inflammation, and infection that leads to lung damage. To enhance airway clearance and delay lung damage, daily bronchopulmonary hygiene therapy is considered essential. Available bronchopulmonary hygiene modalities include conventional postural drainage and percussion (PD&P), intrapulmonary percussive ventilation (IPV), and high-frequency chest wall compressions (HFCWC). IPV and HFCWC use high-frequency oscilla-

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COMPARISON OF CYSTIC FIBROSIS TREATMENTS

Table 1. Bronchopulmonary Hygiene Treatment Protocols

PD&P	HFCWC	IPV
12 total positions	8 min HFCWC at 6 and 8 Hz	8 min IPV at 2–5 Hz
First 4 positions: 2 min/position	2 min directed coughing	2 min directed coughing
2 min directed coughing	8 min HFCWC at 14 and 16 Hz	8 min IPV at 2–5 Hz
Next 4 positions: 2 min/position	2 min directed coughing	2 min directed coughing
2 min directed coughing	8 min HFCWC at 18 and 20 Hz	8 min IPV at 2–5 Hz
Last 4 positions: 2 min/position	2 min directed coughing	2 min directed coughing
2 min directed coughing		

PD&P = postural drainage and percussion
HFCWC = high-frequency chest wall compression
IPV = intrapulmonary percussive ventilation

tions to mobilize secretions, which improves sputum clearance. Although each of these therapies is considered safe and effective, to our knowledge no previous study has directly compared the 3 modalities with CF patients. Our primary objective was to compare the effectiveness of PD&P, IPV, and HFCWC by measuring the wet and dry weights of sputum cleared by hospitalized CF patients using the 3 modalities. Our secondary objective was to measure patient preferences regarding the methods.

Methods

The study was conducted at Children's Hospital, Columbus, Ohio. The protocol was approved by the hospital institutional review board, and informed consent was obtained from each patient. Patients were invited to participate if they had CF, were ≥ 12 years old, and were hospitalized for an exacerbation of pulmonary symptoms. All patients were recruited within 48 hours of admission. Patients were excluded if they had a history of pneumothorax, massive hemoptysis, congestive heart failure, or rib fracture, or were pregnant.

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To compare the efficacy of the 3 techniques, we designed a randomized, crossover study in which each technique was used in a controlled manner 3 times a day for 2 days. Over 6 consecutive days the patient would receive one form of treatment for 2 days, then another form of treatment for 2 days, then the remaining form of treatment for 2 days. Randomizing the order in which the techniques were used controlled for temporal and sequential effects. Each of the 6 possible treatment sequences was represented equally. Four patients received each of the 6 treatment sequences. The therapies were performed and sputum was collected by respiratory therapists and nurses actively involved in the protocol. All sputum expectorated during the

treatment and for 15 minutes thereafter was collected, weighed wet, then dried and weighed again. Effectiveness was assessed by comparing the 2-day total wet and dry sputum weights. Fifteen minutes prior to each treatment, each patient received an albuterol aerosol (2.5 mg in 3 mL normal saline). All treatments lasted 30 minutes, consisting of 24 minutes of therapy and 6 minutes of directed coughing.

Treatment Protocols

Table 1 shows the treatment protocols. PD&P was delivered by one of 3 pulmonary nurses, using 12 postural drainage positions. IPV was delivered by respiratory therapists, using a percussive ventilator (IPV-1 Percussionator, Percussionaire, Sandpoint, Idaho). The impact or frequency was adjusted for each patient, based on comfort and chest movement, usually in the 2–5 Hz range. The operating pressure was in the range of 25–35 psi. The therapy was delivered with the standard recommended 15–20 mL of normal saline aerosol, and subjects were in the sitting position. HFCWC was delivered by respiratory therapists using a percussive vest (*The Vest*, Model 103, Advanced Respiratory, St Paul, Minnesota). Subjects were in the sitting position.

Sputum Collection

Each sputum collection cup was marked with its empty weight prior to use. During all forms of therapy, patients expectorated all mucus into the cup. Coughing and expectoration were encouraged throughout all treatments. The clinician facilitated coughing whenever the patient expressed a desire to cough. Patients were instructed to expectorate into the sputum cups during the (15-min) aerosol treatment as well as during the entire (30-min) duration of the treatment. Sputum collection also continued for 15 minutes following the end of each treatment session if the patient felt the need to cough or clear secretions sponta-

nously. All sputum produced over the 60-minute period was collected.

Sputum Processing

The sputum wet weight was measured by a respiratory therapist after each treatment/sputum-collection period. The samples were then frozen at -20°C until transferred to a drying oven. The dry weight was determined after the samples had been in the drying oven at 65°C for 3 days, to ensure complete dryness.

Measurement of Patient Acceptability

Following completion of the treatment sequence, patients were asked to complete a written questionnaire to rate comfort, convenience, effectiveness, and ease of use of the 3 modalities. Respondents used a 5-point, Likert-type scale; the possible responses were: extremely = 4, very = 3, somewhat = 2, not very = 1, and not at all = 0. The participants were also asked to rank the 3 modalities in order of preference.

Data Analysis

The data were analyzed using statistics software (SPSS 9.0, SPSS, Chicago, Illinois). Differences were calculated with analysis of variance with repeated measures, and we used Tukey's honest significant difference post-hoc comparison. Differences were considered statistically significant when p was < 0.05 . A retrospective effect size and power analysis was also conducted. A 2-way analysis of variance with repeated measures was performed to determine both the main effect and the interaction effect of sputum weight and treatment preference. In addition, Friedman's test was applied to the patient's overall preference rankings.

Results

Twenty-eight patients were recruited. Four patients either withdrew from the study or were discharged prior to completing the study. The remaining 24 patients ranged in age from 14 to 34 years, with a mean age of 24 years. Ten of the participants (42%) were female and 14 (58%) were male. On admission their mean percent-of-predicted forced vital capacity and forced expiratory volume in the first second (FEV_1) were 55% and 39%, respectively.

Table 2 shows the mean wet and dry sputum weights. The mean wet sputum weight for PD&P was based on 144 samples, for IPV on 142 samples, and for HFCWC on 143 samples. One sputum sample cup was lost prior to weighing, one was contaminated by emesis, and one was left uncovered and permitted to dry before being weighed wet. Analysis of variance found statistically significant differ-

Table 2. Sputum Collected with 3 Bronchopulmonary Hygiene Techniques

	PD&P	IPV	HFCWC	p
Wet weight (g)	5.53 \pm 5.69	6.84 \pm 5.41	4.77 \pm 3.29	0.035
Dry weight (g)	0.35 \pm 0.28	0.34 \pm 0.25	0.26 \pm 0.19	0.165

PD&P = postural drainage and percussion
IPV = intrapulmonary percussive ventilation
HFCWC = high-frequency chest wall compression
Values are mean \pm SD

Table 3. Ratings and Ranking of Patient Preferences for Bronchopulmonary Hygiene Techniques

	PD&P	IPV	HFCWC	p
Comfort	2.48 \pm 1.04	2.17 \pm 1.07	2.00 \pm 1.48	0.364
Convenience	2.35 \pm 1.27	2.65 \pm 0.93	2.74 \pm 1.05	0.359
Efficacy	2.96 \pm 0.86	2.58 \pm 0.88	2.38 \pm 1.10	0.100
Ease of Use	2.83 \pm 1.17	2.92 \pm 0.83	3.12 \pm 0.85	0.453
Overall preference	2.00 \pm 0.74	1.96 \pm 0.77	2.04 \pm 0.98	0.957

PD&P = postural drainage and percussion
IPV = intrapulmonary percussive ventilation
HFCWC = high-frequency chest wall compression
Values are mean \pm SD

ences among the mean wet sputum weights ($p = 0.035$). The IPV wet sputum weights were significantly greater than the HFCWC wet sputum weights ($p < 0.05$ by Tukey's honest significant difference test). The significant difference between the mean HFCWC wet sputum weight and the mean IPV wet sputum weight was associated with a large effect size (partial eta squared = 0.159, $f = 0.43$), as established by Cohen.¹ The mean dry sputum weights for PD&P and HFCWC were based on 144 samples, and for IPV on 142 samples. The differences among the mean dry sputum weights did not reach statistical significance. This finding for mean dry sputum weight was associated with a medium to large effect size (partial eta squared = 0.091, $f = 0.32$), and the observed power was 0.444.

All 24 subjects completed the questionnaire and rated the comfort, convenience, efficacy, and ease of therapy, and ranked their first, second, and third preference overall. Table 3 shows the mean \pm SD ratings and ranking. Ten participants chose HFCWC, 7 chose IPV, and 7 chose PD&P as their most preferred modality. Two-way analysis of variance with repeated measures found no statistically significant correlation between treatment preference and wet or dry sputum weight, indicating that treatment preference is not related to the amount of sputum produced, either as a main effect or as an interaction effect. Friedman's test found no significant difference in preference among the 3 techniques.

Discussion

To be effective, PD&P usually requires assistance, and dependence on a caregiver sometimes affects compliance with daily therapy. In recent years, mechanical mucus clearance devices have been developed to permit greater patient independence. Our aim was to compare the short-term efficacy of 2 mechanical devices (IPV and HFCWC) to the short-term efficacy of PD&P. Measurement of the amount of sputum cleared from the airways during and following treatment has been used to assess the short-term efficacy of bronchopulmonary hygiene therapy. Our principal finding is that PD&P, IPV, and HFCWC all produce similar short-term sputum clearance and consequently have similar short-term efficacy.

Daily bronchopulmonary hygiene is essential therapy for individuals with CF. Desmond et al² reported that patients who did not receive PD&P for a 3-week period suffered lung function deterioration that was reversible with the renewal of regular PD&P. Reisman et al³ found that subjects who discontinued PD&P and used the forced expiratory technique alone had a significantly greater decline in pulmonary function test results. They concluded that PD&P should remain a standard component of CF therapy. Thomas et al conducted a meta-analysis of 35 studies and determined that standard PD&P resulted in significantly greater sputum expectoration than did no treatment.⁴ These studies support conventional PD&P as a valuable and effective technique for CF patients.

Recent studies suggest that IPV is as effective as PD&P and that HFCWC is as effective as or possibly more effective than PD&P.⁵⁻⁹ However, as far as we know, no previous study directly compared PD&P, IPV, and HFCWC in a single group of CF patients. Natale et al,⁵ in a crossover study of 9 in-patients, compared sputum volume expectorated using PD&P and IPV. They found no difference in the volume of sputum collected. Homnick et al⁶ measured pulmonary function in CF patients over a 6-month period using IPV and PD&P and concluded that IPV was as effective as standard PD&P. Hansen and Warwick⁷ compared expectorated sputum volumes in 5 CF patients using HFCWC and PD&P. They concluded that HFCWC was more effective than standard PD&P. Arens et al⁸ measured wet and dry weights of expectorated sputum from 50 CF patients admitted for pulmonary exacerbations. Although sputum wet weights at 1 hour were significantly greater in the HFCWC group than in the PD&P group, dry weights at 1 hour were not significantly different. Both wet and dry sputum weights did not differ significantly at 24 hours. They concluded that HFCWC and PD&P were equally safe and effective.

Kluft et al⁹ also evaluated the effectiveness of HFCWC in promoting the expectoration of secretions. They studied 29 hospitalized CF patients who received both conventional PD&P and HFCWC over 2 consecutive 2-day pe-

riods, in random order. Patients were enrolled in the study following 4 days of aggressive intravenous antibiotic therapy and pulmonary toilet. Expectorated sputum was collected for the length of the treatment session and during the 15 minutes following treatment. Wet and dry sputum weights were measured. Significantly more sputum (both wet and dry) was expectorated with HFCWC. Although our study design was similar to that of Kluft et al, we did not find a significant difference between the sputum weights (wet or dry) collected with HFCWC and PD&P. The differences between ours and Kluft's results may be due to differences in treatment protocols. For example, Kluft et al performed 5-position PD&P, whereas our protocol used 12-position PD&P. In our study, 3 nurses were retrained to administer vigorous 12-position PD&P. Sputum wet and dry weights produced by PD&P in our study were higher than those reported by Kluft et al. Also, Kluft et al administered nebulized saline during HFCWC, to prevent airway drying. We administered albuterol aerosol (2.5 mg in 3 mL normal saline) prior to HFCWC treatment sessions to ensure uniform timing of bronchodilator delivery. In our study no aerosols were delivered during HFCWC therapy sessions. The HFCWC wet and dry sputum weights reported by Kluft et al were higher than ours. Aerosol administration during HFCWC may play an important role in sputum mobilization. The higher PD&P sputum weights and lower HFCWC sputum weights in our study may account for the differences between the 2 studies. Minor differences in the way the modalities were delivered may have resulted in significant differences in the amount of sputum produced. In any case, Kluft et al concluded, as do we, that HFCWC is at least as effective as conventional bronchopulmonary hygiene therapy.

Our study design was most similar to that of Braggion et al,¹⁰ who assessed the short-term effects of PD&P, HFCWC, and positive expiratory pressure therapy with 16 CF patients who were admitted for acute exacerbation of pulmonary symptoms. In that study and ours, 2 days of each therapy were randomly administered, and wet and dry sputum weights were compared. Braggion et al found no difference in efficacy between the 3 modalities they studied. The significantly greater wet sputum weight produced by IPV in our study is probably explained by the fact that IPV delivers aerosol and percussion simultaneously, through a mouthpiece. The aerosol and salivation related to the use of the mouthpiece may increase the sputum moisture content, and airway irritation produced by IPV may increase airway secretion production. Our retrospective effect size and power analysis suggests that the difference between the HFCWC and IPV mean wet sputum weights is large and potentially clinically important. Though we found no statistically significant difference among mean dry sputum weights, the results approached statistical significance ($p = 0.165$) and the effect

size was in the medium to high range. The lack of statistical significance may be a result of the modest sample size and the relatively low power (observed power = 0.444), so it is important to consider the possibility of a Type II error when interpreting the dry weight results. The roughly 30% greater dry sputum weights seen with HFCWC, compared to PD&P and IPV, may be clinically important.

Overall, our results are similar to those of previous studies.^{5,8-10} Taken together, these studies strongly suggest that HFCWC, IPV, and/or PD&P all have similar short-term effects on sputum clearance during pulmonary exacerbation in hospitalized CF patients. In our study, direct comparison of these 3 modalities provides convincing evidence that PD&P, IPV, and HFCWC have similar short-term efficacy. Although sputum production is the immediate goal of all clearance modalities, it has not been clearly established that short-term increases in clearance preserve pulmonary function, decrease morbidity, or improve quality of life. Larger long-term studies of those outcomes will be necessary to establish the clinical efficacy of the various airway clearance methods.

Our questionnaire results suggest there is no positive or negative patient consensus regarding the effectiveness, comfort, convenience, or ease of use of any of the 3 modalities. Homnick et al⁶ also included a patient satisfaction survey in their study of IPV and PD&P. After completion of the trial, they surveyed the 8 members of the IPV group regarding frequency of therapy, time spent on therapy, reliance on others, and comfort of IPV. In general, the participants thought they performed more bronchopulmonary hygiene with IPV, spent less time on therapy, relied less on others for therapy, and thought IPV was relatively comfortable. All 8 participants completing the survey said they would continue to use IPV if given the opportunity. Our results do not dispute Homnick et al, but suggest that each patient should decide which treatment modality has the right balance of comfort, convenience, ease, and efficacy for his or her situation. Quantitatively determining which modality is the most effective is important, but the patient's acceptance of and willingness to use the therapy must also be considered. This conclusion is supported by the results of the 2-way analysis of variance for treatment preference and both wet and dry sputum weight; no statistically significant correlation was found, indicating that treatment preference is not related to the amount of sputum produced, either as a main effect or as an interaction effect.

Limitations

One important limitation of this study was the use of sputum weight as the outcome measure. Although sputum production is the immediate goal of all bronchopulmonary modalities, it has not been clearly established that short-term increases in clearance preserve pulmonary function,

decrease morbidity, or improve quality of life. Larger long-term studies examining outcomes such as pulmonary function test results and disease exacerbation rate will be necessary to establish the clinical efficacy of the various airway clearance methods. Another important limitation is the possibility of Type II error in concluding there was no difference in dry sputum weights. The lack of statistical significance may result from the modest sample size and the relatively low power (observed power = 0.444), and the roughly 30% greater dry sputum weight with HFCWC may be clinically important.

Conclusions

In the in-patient setting, the amount of sputum produced using HFCWC and IPV devices appears to be equivalent to the amount produced by vigorous professional PD&P. This suggests that HFCWC and IPV are as effective as PD&P and might reasonably be substituted for PD&P during CF exacerbations. Our study also suggests that each patient should have the opportunity to experience each therapy and to choose his or her preferred modality.

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