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Comparison of Effects of an Intrapulmonary Percussive Ventilator to Standard Aerosol and Chest Physiotherapy in Treatment of Cystic Fibrosis

Douglas N. Homnick, MD, MPH,[1] Fred White, RRT,[2] and Carol de Castro, BS, RN[1]

Summary. Impaired mucociliary clearance due to defective ion and water transport and the effects of chronic airway infections lead to stasis of secretions and progressive pulmonary damage in patients with cystic fibrosis (CF). Methods to improve removal of tenacious lung secretions in CF patients contribute to slowing the decline in respiratory function. We have evaluated an intrapulmonary percussive ventilator (IPV), which is a device designed to enhance airway clearance and preserve lung function. A previous pilot study by us had determined that the device was acceptable to patients and is safe. We undertook a 6 month parallel comparative trial of the IPV versus standard, manual chest physiotherapy in 16 CF children and adults. No significant differences in spirometric measures, numbers of hospitalizations, use of oral or IV antibiotics, or anthropometric measurements were detected between the standard aerosol/chest physiotherapy group and the IPV group over the duration of the trial. Patient acceptance, as determined by participant survey, was good. The device appeared to be safe and durable. It was concluded that the IPV is as effective as standard aerosol and chest physiotherapy in preserving lung function and anthropometric measures, and there was no difference in the use of antibiotics and hospitalizations. **Pediatr Pulmonol. 1995; 20:50–55.** © 1995 Wiley-Liss, Inc.

Key words: Chest physiotherapy, chest percussion, cystic fibrosis, aerosol therapy.

INTRODUCTION

Cystic fibrosis (CF) remains the most common lethal genetic disorder in the Caucasian population with an incidence of about 1:2,500 live births and a mean age at death in the United States of about 29 years.[1] It is characterized by a defect in ion and water transport by secretory and epithelial cells in many organ systems, including the lung, and it is associated with chronic airway infections and thickened secretions.[2] About 90% of CF patients die of respiratory failure caused by progressive pulmonary destruction due to chronic inflammation and infection with *Pseudomonas aeruginosa* and intense neutrophilic infiltration in response to this organism.[3]

Manual chest physiotherapy (CPT) has long been one of the mainstays of treatment of CF. Its goal is to enhance the disordered and defective mucociliary transport in the airway. Its effectiveness has been demonstrated in clinical trials.[4–6] However, it is time consuming and manual CPT requires a cooperative assistant. Several alternative techniques have been investigated and their aim has been to help patients administer their own CPT.

The intrapulmonary percussive ventilator (Percussinator, IPV) is a device that has been designed to achieve this end. The device combines internal thoracic percussion through rapid minibursts of air (intrapulmonary percussion) and entrained therapeutic aerosols. We have already shown that the device is safe and effective.[7] This study compares the clinical responses of CF patients to IPV therapy and standard aerosol/chest physiotherapy.

MATERIALS AND METHODS

The Device

The IPV device was developed by Forrest M. Bird, M.D., Ph.D in 1979. The IPV is F.D.A. approved. It is a light weight, self-contained unit which combines rapid minibursts of air through a jet venturi which entrains a side stream of both air and aerosol. A total of 20 mL of solution is aerosolized over 20 min (Fig. 1). Flow interruption from 3 to 5 Hz occurs via a unique sliding venturi

From the [1]Department of Pediatrics, Michigan State University, Kalamazoo Center for Medical Studies, and [2]Respiratory Care Department, Bronson Methodist Hospital, Kalamazoo, Michigan.

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Address correspondence and reprint requests to Dr. D. N. Homnick, 1000 Oakland Drive, Kalamazoo, MI 49008.

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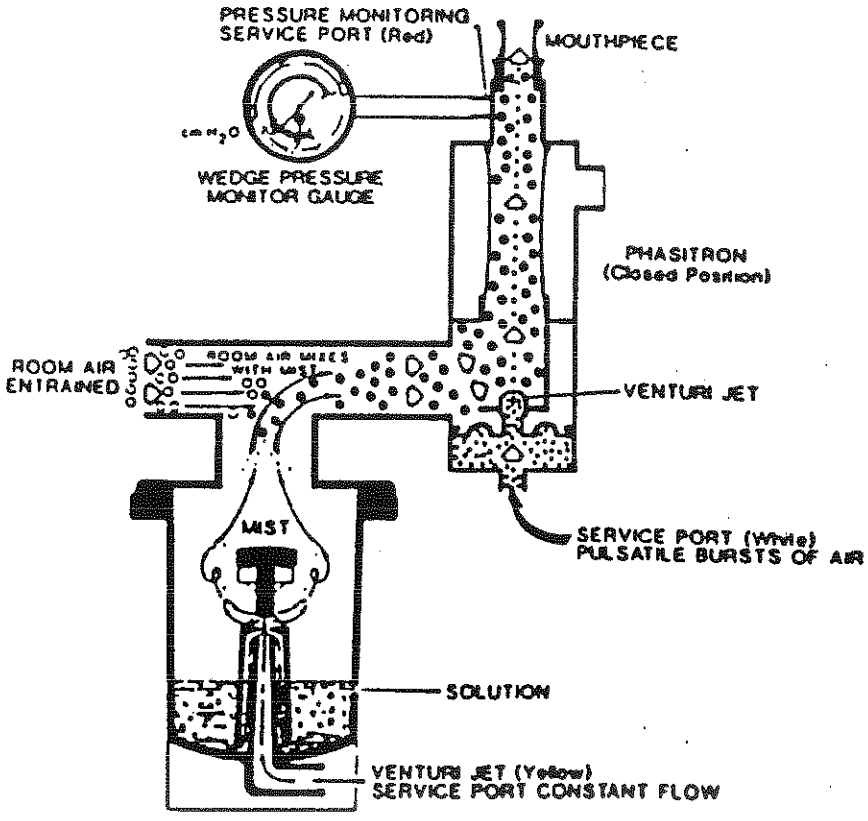

Fig. 1. Aerosol solution and air is entrained into the venturi body. Subtidal bursts of air through the venturi jet direct this to the patient mouthpiece.

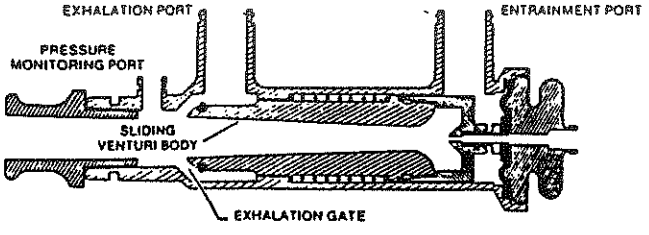

Fig. 2. The sliding venturi body moves back and forth to open and close the phasitron exhalation gate by an orificed diaphragm. Bursts of air and aerosol are delivered to the patient during forward movement of the phasitron.

(Fig. 2), termed the phasitron, and is patient actuated. Driving pressure and frequency can be preset and peak pressures at the mouth of 10–30 cm H_2O can be achieved. The pressure delivered is titrated to patient comfort and visual external thoracic movements. The duration of therapy is selected by the patients and is usually 20–30 min.

Study Design

Subject Selection

The study was approved by the Bronson Methodist Hospital Human Use Committee. Patients with CF who attended the MSU/KCMS CF Center and who were using standard CPT and aerosol therapy at home were eligible to participate. Twenty participants were stratified by Shwachman score and randomized into either a standard treatment group (CPT group) or an IPV group.[8] Inclusion criteria consisted of a diagnosis of CF by CF Foundation approved pilocarpine iontophoresis, an age greater than 5 years, clinical stability at the time of study entry, ambulatory status at the time of study entry, no history of pneumothorax or hemoptysis, and an ability to tolerate at least 2 IPV or standard CPT sessions per day.[9] Patients were asked to maintain a daily log and perform spirometry according to American Thoracic Society standards.[10]

Study Interventions

The study consisted of two arms. To begin, standard CPT according to CF Foundation guidelines was reviewed with each subject. This consisted of manual percussion for about 2 min in each of 10 postural drainage positions. Each subject participated in a 30 day run-in period during which each participant kept a daily log of each CPT and aerosol treatment administered. Patients returned at 30 days to the clinic and underwent measurements of baseline anthropometrics and spirometry. Spirometry was performed on a Puritan-Bennett PB-900

TABLE 1—Baseline Demographics, Anthropometrics, Spirometry, Shwachman Scores, and Respiratory Treatments in CF Patients

	IPV Group	CPT Group	*P* value
Age (years, range)	12 (5–24)	10 (5–18)	
Sex	5 m, 3 f	5 m, 3 f	
Height (cm)	134.9 ± 12.4[1]	141.0 ± 24.6	0.60
Weight (kg)	28.9 ± 12.4	37.5 ± 16.7	0.26
Body mass index (wt/ht^2)	15.2 ± 1.7	7.9 ± 2.0	0.01
FVC (% pred.)	92 ± 12	80 ± 15	0.10
FEV_1 (% pred.)	70 ± 12	59 ± 12	0.09
FEF_{25-75} (% pred.)	37 ± 10	35 ± 19	0.80
Shwachman score	77 ± 11	74 ± 13	0.63
Number of IPV Tx/day	2.08		
Number of standard aerosol Tx/day		2.27	
Number of standard CPT/day		2.42	

[1]Mean ± SD.

(Wilmington, MA) spirometer, using Polgar reference values for children and Morris reference values for adults.[11,12] Measurements of forced vital capacity (FVC), forced expiratory flow over 1 sec (FEV_1), and mid-expiratory flow rate (FEF_{25-75}) were recorded. The IPV group then received instructions on the use of the IPV machine and were given saline and albuterol for use in the device. Dosing for albuterol in both the standard aerosol and IPV groups ranged between 1.25 and 2.5 mg/treatment. Pressures and frequencies were individually determined by the investigator respiratory therapist (FW). Individuals in the IPV group were instructed to use the machine at least twice a day and record the frequency daily on a log sheet. The IPV group was also asked to provide a satisfaction index to be completed after each 30-day period of using the device. This survey inquired about comfort, time spent in therapy, and compliance with the IPV device.

The CPT group was asked to continue their standard CPT and aerosol therapy at least twice each day and to record this on a log sheet. Standard aerosol therapy consisted of 2 mL saline or Na-cromolyn with an appropriate amount of albuterol given by compressor and updraft nebulizer. All patients were instructed to return to the clinic at 30 day intervals.

The comparative trial consisted of 5 sequential 30-day periods for a total study period of 180 days. During this interval patients returned logs at each clinic visit and underwent anthropometric measures and spirometry. Patients were asked about adverse effects, and patient satisfaction sheets were collected from the IPV group. Both outpatient and inpatient antibiotic use and hospitalization data were tabulated for both groups. All subjects continued their assigned treatments while hospitalized, usually at a frequency of 4 times per day.

Statistical Analysis

Descriptive, univariate statistics were used to summarize patient demographics, anthropometric measurements, pulmonary function data, and Shwachman scores. Paired, two-sided *t* tests were used for all within group comparisons and unpaired, two-sided *t* tests were used for all between group comparisons. The level of significance was set at 0.05.

RESULTS

Eight participants completed the study in each group. Demographic, anthropometric, Shwachman score, and spirometric data at baseline are shown in Table 1. No significant differences were noted between groups for baseline spirometry, weight, and Shwachman scores. However, the IPV group showed a significantly greater body mass index (weight/height^2) than the CPT group. Average daily IPV, standard aerosol, and standard CPT therapy sessions during the comparative trial are shown also in Table 1. Spirometry and weight are compared between the groups at the end of the run-in period (30 days-start of parallel trial) and at the end of the study (180 days). No significant differences were noted for mean FEV_1 ($P = 0.88$ and 0.99), FVC ($P = 0.88$ and 0.99), and FEF_{25-75} ($P = 0.71$ and 0.73) values for IPV and CPT groups at 30 and 180 days. No significant changes in anthropometrics measured and calculated, including weight and body mass index occurred in either group between 30 and 180 days. Anthropometric measurements and spirometric data are summarized in Table 2. When average total days of hospitalization, days of oral antibiotic use, and days of intravenous antibiotic use were compared for the two groups, no significant differences were noted. The IPV group experienced 46.3 ± 25.9 days of oral antibiotic use versus 33.3 ± 25.3 for the CPT group ($P = 0.33$). Mean days of IV antibiotic use were 15.9 ± 14.4 and 14.3 ± 15.7 ($P = 0.83$) for the IPV and CPT groups, respectively, and number of hospital days were 3.9 ± 4.5 for the IPV group and 5.6 ± 6.1 for the CPT group ($P = 0.55$). No specific criteria for hospitalization or initiation of antibiotic use were utilized

TABLE 2—Spirometry and Anthropometrics at Start and End of IPV and STD Therapy Trial

	IPV group			CPT Group		
	30 Days	180 Days	*P* value	30 Days	180 Days	*P* value
FVC[1]	90 ± 11[2]	90 ± 12	0.99	80 ± 8	79 ± 16	0.88
FEV_1[1]	69 ± 9	69 ± 14	0.88	59 ± 14	59 ± 14	0.99
FEF_{25-75}[1]	37 ± 12	40 ± 19	0.71	31 ± 13	34 ± 20	0.73
BMI[3]	17.6 ± 2.2	17.6 ± 2.1	0.99	15.1 ± 1.5	15.0 ± 1.8	0.91
weight (kg)	38.0 ± 17.1	37.9 ± 16.8	0.99	28.9 ± 11.9	29.4 ± 12.5	0.94

[1]Percent predicted.
[2]Mean ± SD.
[3]BMI, body mass index (wt/ht^2).

TABLE 3—Responses to Patient Satisfaction Survey

	Response at 60 days	Response at 160 days
Does the IPV make you do chest physiotherapy more or less than other methods that you have used?		
Less	1	1
Same	2	1
More	4	6
The IPV is more or less time consuming than other methods that you have used.		
Less	6	7
Same	0	1
More	2	0
The IPV makes me rely on other people more or less for my chest physiotherapy.		
Less	7	7
Same	1	1
More	0	0
The IPV is more or less uncomfortable to use than other chest physiotherapy methods that I have used.		
Less	7	5
Same	0	1
More	1	2

in the study. Intravenous antibiotic use included both outpatient and inpatient treatments.

The IPV group completed the patient satisfaction surveys and returned them at each 30 day clinic visit, starting with the 60 day visit (30 days after starting the IPV treatments) and ending with the 180 day visit (end of study). Responses to questions used to evaluate patient satisfaction were based on a numerical scale of 1–10, with 10 representing more satisfaction, 0 less satisfaction, and 5 the same satisfaction for IPV therapy and CPT therapy. These were generally positive in each category of inquiry and results are shown in Table 3. The eight patients in the IPV group stated that they would continue to use the IPV if given the opportunity, both at 60 and 180 days.

One possible complication occurred during the trial. A 9-year-old male child experienced acute, minor hemoptysis during the fourth week of using the IPV device. This was accompanied by the usual signs of an acute exacerbation of *P. aeruginosa* bronchitis and the patient was started on intravenous antibiotics. The IPV treatments were stopped for 10 days until all gross hemoptysis had resolved. The patient was restarted on IPV therapy and completed the trial without additional hemoptysis. No episodes of acute pulmonary air leak or other complications occurred during the study.

DISCUSSION

The management of cystic fibrosis aims to optimize mucociliary clearance. Treatments range from manual external chest percussion to loosen secretions from the airway wall to chemical means to decrease sputum viscosity and alterations in ion transport to produce more clearable mucus.[13,14] A decrease in mucostasis and reduced airway bacterial load is thought to help preserve pulmonary function.[5] Many devices and techniques have been developed to achieve effective airway clearance. These include physical exercise, mechanical vibratory

percussors, chest percussion vests or backpacks, forced expiratory techniques, autogenic drainage, flutter valves, and positive expiratory pressure (PEP) masks.[15–21] In many cases it may be difficult or impossible to stimultaneously administer acrosol therapy while undergoing percussion, and prolonged, extended treatments are required and consume excessive time. Consequently, compliance may be compromised. Positive pressure techniques have been found to be advantageous (PEP mask) when combined with forced expiratory techniques. The positive pressures achieved with the PEP technique are similar to those preset with the IPV and are about 10–20 cm H_2O. Traditionally, positive pressure has been avoided in treatment of cystic fibrosis due to the fear of pulmonary air leak or development of hemoptysis. However, there is no literature to support this claim and a previous evaluation of intermittent positive pressure breathing (IPPB) in CF did not show complications.[22] It was uncertain whether our single case with minor hemoptysis was related to an acute infection or to use of the IPV device, since the patient continued the trial without further episodes of hemoptysis after a short period without IPV and after treatment with intravenous antibiotics. It would, however, seem prudent to use positive pressure cautiously in patients with recurrent hemoptysis or pneumothorax until more information is gathered in long-term trials of positive pressure airway clearance techniques.

There are few published studies that have looked objectively at the technology utilized in the IPV device in adults or children with pulmonary disease and there is only one in patients with cystic fibrosis.[7] In this study a single administration of standard aerosol and manual CPT was compared to standard manual CPT with high dose aerosol (through the IPV device without the percussive component activated) and IPV therapy. No difference in quantity, viscosity, or clearability of sputum could be detected at 4 or 24 hr after each type of treatment and no complications occurred during the IPV treatments. Spirometric values were similar after each therapy. Ravez et al. studied the IPV in a small group of adults with chronic bronchitis. They found that total lung clearance of radioaerosol was enhanced with IPV therapy, but it was unclear how much IPV-stimulated cough contributed to the observed benefit.[23] Small pilot studies with the IPV device have shown it to be useful for relief of lobar atelectasis and for increased sputum production in patients with chronic obstructive pulmonary disease.[24,25] The high frequency percussive ventilator with its sliding venturi flow interruptor technology has shown promising results in adult patients with adult respiratory distress syndrome, thermal inhalation injury, and increased intracranial pressure, and in neonates who failed conventional mechanical ventilation.[26–29]

The IPV appears to be an acceptable alternative to standard aerosol and CPT in the patient with CF, especially when the patient has no helper to assist with CPT. The portability of the device, relatively low cost compared to some percussive devices, and the ability to simultaneously administer aerosol and CPT make it attractive. However, optimum frequency of oscillatory pulses, inspiratory to expiratory ratio of oscillations, and optimal peak pressures need to be determined. Radioaerosol distribution studies should be undertaken to assess deposition of aerosols under high frequency positive pressure conditions to determine whether the device may offer some advantage over standard aerosol therapy techniques. Larger and longer term studies comparing IPV to other therapies or combining it with other methods such as forced expiratory techniques or mucolytic agents (dornase alpha) will be necessary to further define its usefulness.

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