Immediate Changes in Blood-Gas Tensions During Chest Physiotherapy With Positive Expiratory Pressure and Oscillating Positive Expiratory Pressure in Patients With Cystic Fibrosis

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OBJECTIVE: To assess and compare immediate effects of chest physiotherapy with positive expiratory pressure (PEP) versus oscillating PEP on transcutaneously measured blood-gas tensions in patients with cystic fibrosis. METHODS: Fifteen patients (mean age 12.5 y, range 6.9–21.5 y) participated. The treatments were randomized and performed on 2 separate occasions, 8 weeks apart. Spirometry was conducted before and after each treatment. We transcutaneously measured oxygen tension (P_{tO_2}) and carbon dioxide tension (P_{tCO_2}) 20 min before, during, and 10 min after each treatment. RESULTS: There were no changes in spirometry values. During PEP, different trends in blood-gas tension were seen, and there were no consistent changes. During oscillating PEP, P_{tO_2} increased and P_{tCO_2} decreased. During oscillating PEP, P_{tCO_2} was lower and the intra-individual change in P_{tCO_2} was more pronounced than during PEP. The results obtained immediately after oscillating PEP showed a higher P_{tO_2} and a lower P_{tCO_2} than with PEP. CONCLUSION: PEP and oscillating PEP can both cause transitory effects on blood gases in patients with cystic fibrosis. However, oscillating PEP alters blood-gas tensions more than does PEP, and hyperventilation during oscillating PEP may reduce treatment time. *Key words: adolescent, chest physiotherapy, child, cystic fibrosis, oscillating positive expiratory pressure, positive expiratory pressure, transcutaneous blood gas tensions.* [Respir Care 2006;51(10):1154–1161.

Introduction

One of the most important symptoms in cystic fibrosis (CF) is recurrent airway infections, with expectoration of mucus.[1] To decrease the frequency of these infections, the mucus must be evacuated regularly, and it is thus important to have access to suitable chest physiotherapy methods. Traditional chest physiotherapy involves postural drainage combined with chest percussion and vibration.[2–4] Alternative techniques have been developed with the aim of improving the efficiency of the treatment and encouraging patient autonomy.[2,3,5] Positive expiratory pressure (PEP), obtained with a PEP valve,[4–12] and oscillating PEP, obtained with the Flutter device,[4,10–17] are 2 chest physiotherapy methods that do not require the assistance of a caregiver.[8,13,14,16]

The Flutter device creates an oscillating PEP, automatically regulated up to a maximum of 20 cm H_2O, and an intermittent acceleration of the expiratory airflow.[14] Oscillating PEP is thought to facilitate mucus mobilization

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Table 1. Lung-Function Measurements Before and After Chest Physiotherapy With PEP and Oscillating PEP in 14 Patients With Cystic Fibrosis*

	PEP		Oscillating PEP	
	Before	After	Before	After
FVC (% of predicted)†	96.1 ± 15.6	98.6 ± 16.2	92.5 ± 12.7	91.4 ± 10.9
FEV_1 (% of predicted)	90.6 ± 19.9	91.7 ± 19.6	87.4 ± 19.9	86.4 ± 17.7
MEF_{50} (% of predicted)	86.4 ± 39.8	84.0 ± 34.5	82.0 ± 36.1	82.5 ± 34.8
MEF_{25} (% of predicted)	76.6 ± 45.2	72.2 ± 44.3	79.1 ± 46.7	76.8 ± 42.6

*Values are mean ± SD.
†Percent-of-predicted reference values based on sex, age, and height.[21,22] None of the differences are statistically significant.
PEP = positive expiratory pressure
FVC = forced vital capacity
FEV_1 = forced expiratory volume in the first second
MEF_{50} = maximum expiratory flow at 50% of FVC
MEF_{25} = maximum expiratory flow at 25% of FVC

and clearance[13] and to decrease mucus viscoelasticity within the airways.[15] Oscillating PEP increases vital capacity and forced expiratory volume in the first second (FEV_1) in adults with bronchial asthma[14] and chronic obstructive pulmonary diseases.[17]

The expiratory pressure obtained with the PEP valve[2,6,12] is individually determined and is regulated by the inner diameter of the fixed expiratory orifice[8] and the patient's respiratory flow pattern.[12] Immediately after PEP, the functional residual capacity[7] and forced vital capacity (FVC)[6] increase in children with CF.

Thus, both PEP and oscillating PEP affect lung volumes and ventilatory properties of the lungs. However, we were interested in studying whether PEP and oscillating PEP can affect the main function of the lungs: gas exchange. After PEP, transcutaneously measured oxygen tension (P_{tO_2}) increases in patients with CF.[6] We know of no report of transcutaneous monitoring during and after oscillating PEP, nor of any comparison of how the PEP valve and Flutter device affect blood-gas tensions during treatment.

The aim of the present study was to assess the immediate effects of PEP and oscillating PEP treatment on blood-gas tensions in patients with CF and to compare the results from these 2 chest physiotherapy methods.

Methods

Patients

The study was approved by the ethics committee of the medical faculty of Göteborg University, Sweden. Informed consent was obtained from the patients, or the parents of patients who were younger than 16 years of age.

Fifteen patients with CF (6 girls, 9 boys) (mean ± SD age 12.5 ± 5.1 y, range 6.9–21.5 y) were included in the study. All the patients had a pathological sweat test confirmed with the Gibson-Cooke sweat test.[18] Six patients were chronically infected with *Pseudomonas aeruginosa* and 1 patient with *Stenotrophomonas maltofilia*. The other patients were not chronically infected with bacteria. At baseline, compared to healthy children and adolescents,[19] P_{tO_2} was < –2 SD in 7 patients, within ± 2 SD in 3 patients, and > 2 SD in 5 patients. Transcutaneously measured carbon dioxide tension (P_{tCO_2}) was < –2 SD in 2 patients, within ± 2 SD in 4 patients, and > 2 SD in 9 patients. The median Shwachman score[20] was 83 (range 58–98). When compared to individuals of the same age, all the patients were within ± 2 SD for height and weight.

Lung volumes are reported as percent-of-predicted values, based on sex, age (< 20 y and ≥ 20 y),[21,22] and height (Table 1). Problems with mucus accumulation occurred daily in 6 patients and intermittently in 9 patients. Twelve patients inhaled a β_2 agonist (albuterol, 1.3–2.5 mg) a mean of 3.6 h (range 1.5–8.5 h) before PEP therapy, and 3.8 h (range 1.5–7.8 h) before oscillating PEP. Six patients also inhaled a mucolytic agent (acetylcysteine, 200–400 mg) at the same time. Three patients did not inhale any β_2 agonist or mycolytic agent before any of the treatments. Fourteen patients had tried PEP and 9 of them were using PEP regularly before the study. None of the patients had used oscillating PEP before the study.

Equipment

The PEP valve equipment (Astra Tech, Mölndal, Sweden) consisted of a mouthpiece, a nose clip, a one-way valve, and 8 different expiratory orifices (inner-diameter range 1.5–5.0 mm). The PEP was recorded with a manometer and was set at 10–20 cm H_2O and regulated by the patient's expiratory flow and the fixed orifice. The Flutter device (Axcan Scandipharm, Birmingham, Alabama) has a mouthpiece, a circular cone, a stainless steel ball, and a perforated cover.

A respiration monitor (Pneumoscreen, Intra Medic, Bålstad, Sweden) was used for spirometry. P_{tO_2} and P_{tCO_2} were measured with transcutaneous monitors (TCM2 and TCM20, Radiometer, Copenhagen, Denmark). The temperature of the P_{tO_2} electrode was 45°C, and it was calibrated by one-point calibration in air. The temperature of the P_{tCO_2} electrode was 43°C and it was calibrated by one-point calibration in 5% carbon dioxide. All values were corrected to 37°C and for ambient pressure. Before and after each recording the results were corrected for drift. The recordings were printed on a chart recorder (Servogor 460, Goerz Electro, Vienna, Austria).

Study Design

Chest physiotherapy with PEP and oscillating PEP was performed on 2 separate occasions, 8 weeks apart, in connection with a medical checkup. On the first occasion, 8 patients were randomized to use PEP and 7 patients to use oscillating PEP. On the second occasion, all the patients used the other treatment. Spirometry was performed before and after each treatment. The spirometry results before and after PEP therapy and before and after oscillating-PEP therapy were compared within each method. We also compared the changes in spirometry values induced by each treatment. Transcutaneous blood gas monitoring was conducted 20 min before, during, and until 10 min after the treatments. The blood-gas tensions before and after treatment were compared within each method. The blood-gas tensions obtained before, during, and after PEP were compared with the corresponding oscillating-PEP values. We also compared the changes in blood-gas tensions induced by each treatment.

Chest Physiotherapy With PEP

During the therapy, each patient sat on a chair with a backrest, and used a nose clip and a mouthpiece. During 2 min, the patient breathed calmly into the device, with only a small active expiration, with the aim to increase functional residual capacity. Then the patient took away the nose clip and the mouthpiece and evacuated mucus with forced expirations for 2 min. This procedure was repeated 3 times, which gave a total treatment time of 16 min. The instructions to the patient were: "You should breath calmly into the PEP valve for 2 min, with only a small active expiration. Then you should take away the nose clip and the mouthpiece for 2 min, when you should try to evacuate mucus with forced expirations. You should do this procedure for a total of 4 times."

Chest Physiotherapy With Oscillating PEP

During the therapy, each patient sat on a chair with a backrest. The Flutter device was held horizontally to start, but the patient could, if desired, tilt the device up or down from horizontal to get the maximal vibration sensation in the airways. The patient inhaled deeply, put the device into the mouth, and exhaled quickly into the device. This was repeated during 1 min. Then, during 2 min, the patient evacuated mucus with forced expirations. This procedure was repeated 3 times, which gave a total treatment time of 12 min. The instructions to the patient were: "You should hold the Flutter device horizontally and expire into the device for 1 min. To get the maximal vibration sensation into the airways, you can tilt the device up or down from the horizontal. Then you should take the device away from your mouth for 2 min, when you should try to evacuate mucus with forced expirations. You should do this procedure for a total of 4 times."

Measurement Procedures

The recordings were made with the patient in the sitting position. The P_{tO_2} and P_{tCO_2} electrodes were placed ventrally on one forearm.[23] Continuous recordings of P_{tO_2} and P_{tCO_2} were made for 46 min when using PEP and for 42 min when using oscillating PEP. After 10 min of recording and 10 min before treatment, spirometry was conducted 3 times. After 20 min, when P_{tO_2} and P_{tCO_2} had reached a steady state, PEP therapy or oscillating-PEP therapy was carried out. After the treatment, the blood-gas recording continued during rest for another 10 min, until P_{tO_2} and P_{tCO_2} had again reached a stable level. Spirometry was then conducted 3 times.

The charts from before, during, and after the treatments were analyzed. The blood-gas tensions reported are the average of a stable recording over a 2-min period before the treatment, the values immediately after the treatment, and the average over a 2-min period after the treatment, as soon as the recordings had stabilized. The means of the 4 highest P_{tO_2} and P_{tCO_2}, and the 4 lowest P_{tO_2} and P_{tCO_2}, respectively, during PEP and oscillating PEP, were called the maximal and the minimal values. The difference between the maximal and minimal values during the treatment was called the intra-individual change. From the spirometry, the charts with the highest FVC and FEV_1, one before and one after treatment, were analyzed.

Statistical Analysis

The two-tailed Student's *t* test was used to compare the means of paired data. Calculations were made with statistics software (StatView for Macintosh, StatView, Cary, North Carolina). Probability values < 0.05 were considered significant.

Results

We accomplished data-recording with 14 patients during PEP, and with 15 patients during oscillating PEP. The P_{tO_2} and P_{tCO_2} charts from one PEP recording could not be

Table 2. P_{tO_2} and P_{tCO_2} Before, During, and After PEP and Oscillating PEP Therapy in Patients With Cystic Fibrosis*

	PEP			Oscillating PEP			p (PEP vs Oscillating PEP)
	n	Mean ± SD (mm Hg)	Min/Max (mm Hg)	*n*	Mean ± SD (mm Hg)	Min/Max (mm Hg)	
P_{tO_2}							
Before	13	75.0 ± 12.8	57.8/96.0	13	77.3 ± 10.5	61.5/95.3	0.492
During (min)	12	72.0 ± 11.3	55.5/93.8	12	68.3 ± 8.3	54.0/79.5	0.265
During (max)	12	80.3 ± 12.0	66.0/101.3	12	83.3 ± 9.8	69.8/99.8	0.426
Immediately after	13	75.8 ± 12.0	58.5/99.0	13	84.0 ± 10.5	67.5/99.0	0.069
At steady state after	13	75.8 ± 11.3	59.3/94.5	13	77.3 ± 11.3	59.3/100.5	0.673
P_{tCO_2}							
Before	14	41.3 ± 5.3	33.0/48.0	14	41.3 ± 2.3	38.3/45.8	0.744
During (min)	14	39.0 ± 4.5	31.5/47.3	14	35.3 ± 3.0	30.0/41.3	0.0102
During (max)	14	42.0 ± 5.3	32.3/49.5	14	41.3 ± 3.0	36.8/48.0	0.722
Immediately after	14	39.8 ± 6.0	30.8/49.5	14	34.5 ± 3.8	29.3/40.5	0.0109
At steady state after	14	41.3 ± 5.3	29.3/48.0	14	42.0 ± 3.0	36.8/48.8	0.506

*Transcutaneously measured oxygen tension (P_{tO_2}) and carbon dioxide tension (P_{tCO_2}) before, during, immediately after, and during a stable recording over a 2-min period (steady state) after chest physiotherapy with positive expiratory pressure (PEP) or oscillating PEP in patients with cystic fibrosis. The Min and Max values are the means of the 4 lowest (Min) and 4 highest (Max) P_{tO_2} and P_{tCO_2} values, respectively. A steady-state level was defined as the average of a stable recording over a 2-min period before and after, respectively, PEP or oscillating PEP therapy.

used because the recorder was out of order. The blood-gas tensions from this patient, before, during, and after the treatment were obtained from the transcutaneous monitor during the recording. One P_{tO_2} chart was jagged during PEP treatment, and the minimal and maximal values during the treatment could not be determined. Instead, the P_{tO_2} trends and the pre-treatment and post-treatment tensions were recorded. During oscillating PEP, one P_{tO_2} chart was not recorded because of a system failure of the transcutaneous monitor.

The first patient to receive the oscillating-PEP therapy performed four 2-min sessions (with 2 min of rest between the sessions), but over the course of the sessions she had successively decreasing P_{tCO_2} and began to feel very dizzy. Therefore, we had the subsequent patients perform four 1-min oscillating-PEP sessions (with 2 min of rest between the sessions). The results of the first patient's oscillating-PEP sessions are presented separately.

PEP Treatment

During PEP we saw several trends in transcutaneous blood-gas tensions, but no consistent changes appeared. In all patients but one, the P_{tO_2} and P_{tCO_2} trends changed direction immediately after the treatment when the PEP valve was taken away from the patient's mouth. Table 2 shows the blood-gas tensions before, during, and after PEP. The immediate results showed reduced P_{tCO_2} ($p < 0.05$) (Table 3 and Fig. 1), but no change was seen in P_{tO_2} (Table 3 and Fig. 2).

Table 4 shows the intra-individual P_{tO_2} and P_{tCO_2} changes during PEP. A stable recording over a 2-min period was obtained 4.2 min (range 1.0–7.0 min) after the treatment. The results at steady state showed no changes in P_{tO_2} or P_{tCO_2} (see Table 3). After PEP, no changes in spirometry values were seen (see Table 1).

Oscillating PEP Treatment

During oscillating PEP, all the patients had increasing P_{tO_2} and decreasing P_{tCO_2}. Immediately after the treatment, when the Flutter device was taken away from the patient's mouth, the trends in P_{tO_2} and P_{tCO_2} changed directions, with decreasing P_{tO_2} and increasing P_{tCO_2}. Table 2 shows the blood-gas tensions before, during, and after oscillating PEP. The immediate results showed increased P_{tO_2} ($p < 0.001$) (see Table 3 and Fig. 2) and decreased P_{tCO_2} ($p < 0.001$) (see Table 3 and Fig. 1).

Table 4 shows the intra-individual changes in P_{tO_2} and P_{tCO_2}. A stable recording over a 2-min period was obtained 5.3 min (range 2.3–7.9 min) after the treatment. The results at steady state showed no changes in P_{tO_2} or P_{tCO_2} (see Table 3). After oscillating PEP, no changes in spirometry values were seen (see Table 1).

The patient who used oscillating PEP for four 2-min sessions showed increasing P_{tO_2} and successively decreasing P_{tCO_2} during the treatment, which was associated with dizziness. The differences between her highest and lowest P_{tO_2} and P_{tCO_2} during the treatment were 28.5 mm Hg and 12.8 mm Hg, respectively. Immediately after the treatment her P_{tO_2} and P_{tCO_2} were 87.8 mm Hg and 21.0 mm Hg, respectively (Fig. 3).

Comparison of PEP and Oscillating-PEP

During oscillating PEP there was a more pronounced intra-individual change in P_{tCO_2} ($p < 0.01$) (see Table 4),

Table 3. Mean Changes in P_{tO_2} and P_{tCO_2} Induced by PEP and Oscillating PEP Therapy in Patients With Cystic Fibrosis*

	PEP				Oscillating PEP				p (PEP vs oscillating PEP)
	n	Change Mean ± SD (mm Hg)	Min/Max (mm Hg)	95% CI of mean (mm Hg)	*n*	Change Mean ± SD (mm Hg)	Min/Max (mm Hg)	95% CI of mean (mm Hg)	
P_{tO_2}									
Immediately after treatment	13	0.3 ± 6.0	−9.8/9.8	−3.8 to 3.8	13	6.8 ± 5.3	−3.8/12.0	3.8 to 9.8	0.013
At steady state after treatment	13	0.8 ± 3.8	−6.8/5.3	−1.5 to 3.0	13	−0.8 ± 3.8	−6.0/5.3	−2.3 to 1.5	0.31
P_{tCO_2}									
Immediately after treatment	14	−1.5 ± 2.3	−4.5/1.5	−3.0 to −0.3	14	−6.8 ± 3.0	−12.8/−2.3	−9.0 to −5.3	0.0001
At steady state after treatment	14	0.0 ± 2.3	−4.5/3.8	−1.5 to 0.8	14	0.8 ± 2.3	−1.5/6.0	−0.8 to 1.5	0.31

*A steady-state level was defined as the average of a stable recording over a 2-min period before treatment with positive expiratory pressure (PEP) therapy or oscillating PEP therapy and the average over a 2-min period after the treatments as soon as the recordings again were stable.
CI = confidence interval
P_{tO_2} = transcutaneously measured oxygen tension
P_{tCO_2} = transcutaneously measured carbon dioxide tension

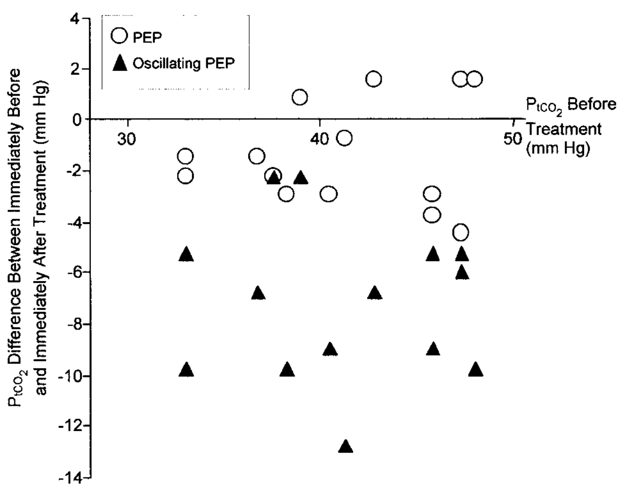

Fig. 1. Difference in transcutaneously measured carbon dioxide tension (P_{tCO_2}) measured immediately before and immediately after chest physiotherapy with positive expiratory pressure (PEP) and oscillating PEP in 14 patients with cystic fibrosis.

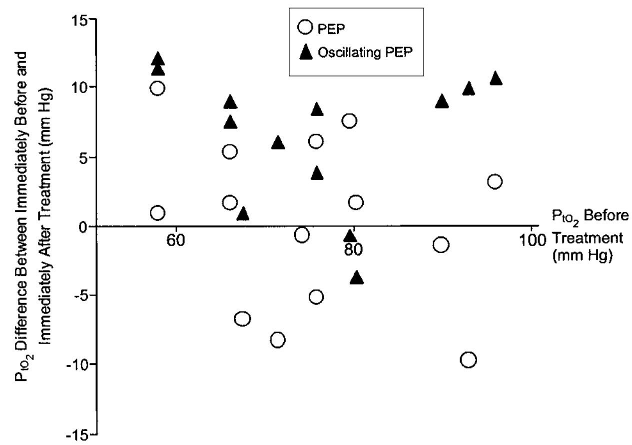

Fig. 2. Difference in transcutaneously measured oxygen tension (P_{tO_2}) measured immediately before and immediately after chest physiotherapy with positive expiratory pressure (PEP) in 14 patients with cystic fibrosis, and with oscillating PEP in 13 of those 14 patients.

and during and immediately after oscillating PEP, P_{tCO_2} was lower, compared with PEP ($p < 0.05$) (see Table 2). The immediate results after oscillating PEP showed higher P_{tO_2} ($p < 0.05$) and lower P_{tCO_2} ($p < 0.0001$), compared with PEP (see Table 3). At steady state after the treatments, all differences between methods disappeared and there was no sustained effect on blood gases. There were no differences in the spirometry values after treatment (see Table 1).

Discussion

The aims of chest physiotherapy are, among others, to evacuate airway mucus and to improve ventilation.[2] It is important to evaluate the effects of each chest physiotherapy method used, to have a possibility of choosing the most appropriate method for each patient. Many studies have used the amount of expectorated mucus to evaluate the efficacy of a chest physiotherapy method.[6,7,9,13,15] This evaluation method has been criticized by several authors,[9,24] because a patient's sputum production varies from day to day, sputum production differs between patients, and the sputum is not necessarily expectorated (some of it may be swallowed).[9,10,24] Another approach is to evaluate the effect of chest physiotherapy on gas exchange. In the present study, transcutaneous blood-gas monitoring was used because it is noninvasive and provides continuous evaluation *during* the treatment.[23]

In children and adolescents, P_{tO_2} and P_{tCO_2} follow the arterial blood-gas tensions, but P_{tO_2} is somewhat lower than P_{aO_2}, and P_{tCO_2} is somewhat higher than P_{aCO_2}.[23]

Table 4. Intra-Individual Changes in P_{tO_2} and P_{tCO_2} During PEP and Oscillating PEP Therapy in Patients With Cystic Fibrosis*

	PEP				Oscillating PEP				p (PEP vs oscillating PEP)
	n	Change Mean ± SD (mm Hg)	Min/max (mm Hg)	95% CI of mean (mm Hg)	*n*	Change Mean ± SD (mm Hg)	Min/Max (mm Hg)	95% CI of mean (mm Hg)	
P_{tO_2}	12	9.0 ± 3.8	2.3/16.5	6.0 to 11.3	12	14.3 ± 8.3	5.3/36.8	9.8 to 19.5	0.062
P_{tCO_2}	14	3.0 ± 1.5	0.8/6.8	2.3 to 4.5	14	6.0 ± 2.3	2.3/10.5	4.5 to 7.5	0.0057

*The change was defined as the difference between the means of the 4 highest and the 4 lowest P_{tO_2} and P_{tCO_2}, respectively, in each patient during positive expiratory pressure (PEP) therapy and oscillating PEP therapy.
CI = confidence interval
P_{tO_2} = transcutaneously measured oxygen tension
P_{tCO_2} = transcutaneously measured carbon dioxide tension

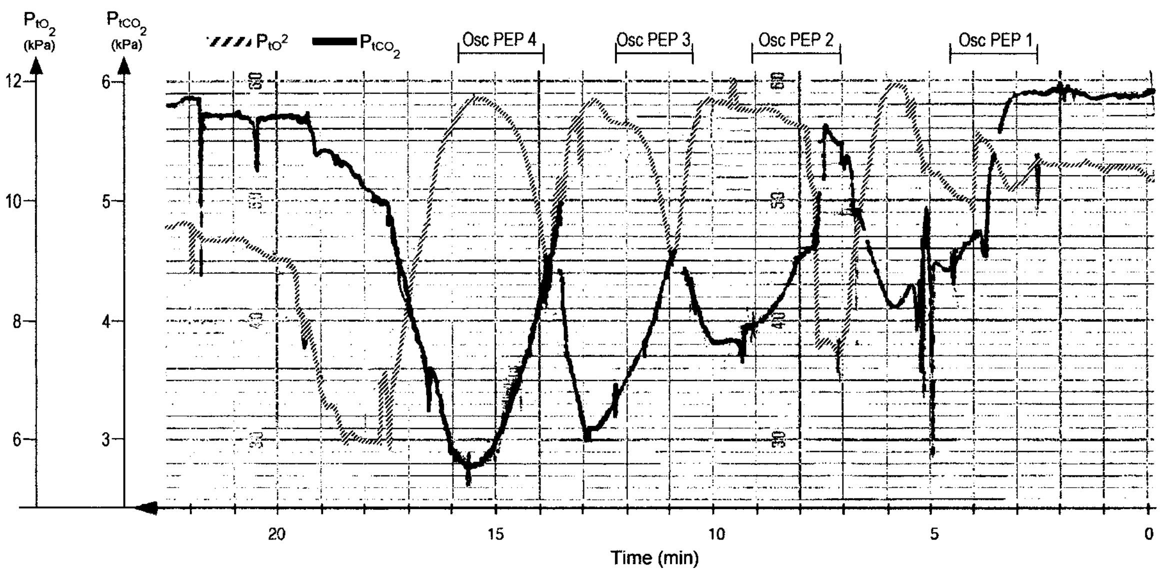

Fig. 3. Transcutaneously measured oxygen tension (P_{tO_2}) and carbon dioxide tension (P_{tCO_2}) curves during chest physiotherapy with oscillating positive expiratory pressure (Osc PEP) for four 2-min sessions, with 2 min of rest between each session, from a patient with cystic fibrosis. During the treatment, P_{tCO_2} successively decreased. This graph is read from right to left.

Some investigators have used transcutaneous monitoring to describe blood-gas tensions during PEP,[6,25,26] but none during oscillating PEP. Instead, oxygen saturation values obtained *after* PEP[10] and oscillating PEP[10,16] have been reported. However, in the upper part of the oxygen-dissociation curve, even large changes in P_{O_2} yield small changes in oxygen saturation.

It was impossible to blind the patients or physiotherapist to the treatments, because the PEP valve is of a different design than the Flutter device, and the immediate effects obtained when using the 2 devices are different. The PEP valve creates a consistent resistance to expiration, whereas the Flutter causes an oscillating resistance. However, we had no preference for one of the 2 methods and wanted only to examine if and how the methods had any effect on P_{tO_2} and/or P_{tCO_2}. We therefore concluded that blinding the methods was not essential.

It was planned that the patients would use PEP and oscillating PEP for 2 min, 4 times each. At the first recording with oscillating PEP, the patient had successively decreasing P_{tCO_2} and dizziness. This showed that chest physiotherapy can profoundly affect blood-gas tensions and that it may be important to gain knowledge about this matter. Because of that patient's reaction, we decreased the oscillating PEP sessions to 1 min, 4 times. Hyperventilation during oscillating PEP has also been described by van Winden et al[10] and Konstan et al.[13]

Our results show that both PEP and oscillating PEP can influence blood-gas tensions, but only oscillating PEP gave a homogeneous result in all patients, with increasing P_{tO_2} and decreasing P_{tCO_2} for as long as the treatment lasted. The immediate results showed a higher P_{tO_2} and a lower P_{tCO_2} with oscillating PEP, and the intra-individual change in P_{tCO_2} was higher during oscillating PEP, all compared to

PEP. The instructions for how to perform the PEP and oscillating PEP treatment were, however, not exactly the same. The PEP method used was that described by Falk et al, using diaphragmatic breathing with only a slightly active expiration.[6] When using oscillating PEP, the patient inhaled deeply and exhaled quickly into the device.[10] Oberwaldner et al described a method of high-pressure PEP in which the patient actively exhales into the PEP valve.[27] If this method had been used in the present study, the results of the PEP treatment might have been more similar to those obtained with oscillating PEP.

Our definition of the steady-state level as a stable recording of P_{tO_2} and P_{tCO_2} over a 2-min period was jointly agreed by all the authors. The records were then analyzed by one of the authors, which may have created an opportunity for observer bias. However, our definition of steady-state level implied that the graphs should be horizontal, which was not difficult to determine. We therefore considered it unlikely that bias would be introduced from the determination of the steady-state level.

Compared to baseline, P_{tO_2} is higher immediately after PEP in patients with CF[6] and respiratory insufficiency.[25] Also compared to baseline, P_{tCO_2} is lower immediately after PEP in adults with respiratory insufficiency[25] and chronic obstructive pulmonary disease.[26] In the present study, both PEP and oscillating PEP reduced P_{tCO_2} during the treatment period. A stable recording occurred relatively quickly after either PEP or oscillating PEP, but no differences in blood gases were seen, compared to before the treatments. The present study confirms the finding of Herala et al,[26] that PEP has no sustained effect on P_{CO_2}.

van Winden et al found no changes in blood oxygen saturation in patients with CF after PEP or oscillating PEP. They suggested that their results could be due to the relatively high baseline oxygen-saturation values of the patients in their study.[10] In the present study, also, patients with a normal baseline P_{tCO_2} and P_{tO_2}[19] showed changed P_{tCO_2} and P_{tO_2} values immediately after the treatments. These results indicate that PEP and oscillating PEP can also affect blood gases within the normal range. The differences between our results and those of van Winden et al[10] may be because, in the upper part of the oxygen-dissociation curve, P_{O_2} changes more than oxygen saturation does.

In the present study there were no changes in spirometry values after PEP or oscillating PEP. This is in contrast to the results of Falk et al, who found increased FVC after PEP.[6] Gondor et al found better improvements in FVC and FEV_1 after a week of oscillating PEP treatments than after traditional chest physiotherapy in children and young adults with CF and pulmonary exacerbation.[28] In contrast, McIlwaine et al found lower FVC in children with CF who regularly had used oscillating PEP for a year, compared with PEP. They tried to explain this result by suggesting that some airway closure may occur, resulting in air trapping after using oscillating PEP, thus decreasing FVC.[11] This shows that different results can be obtained when studying patients with CF. One explanation for the different results reported from the present study and the study by McIlwaine et al may be that the present study reported the immediate effects after oscillating PEP, whereas McIlwaine et al reported long-term effects of oscillating PEP.[11]

In the present study, both treatments induced hyperventilation, though oscillating PEP induced hyperventilation more than did PEP. This may explain both the decreased P_{tCO_2} and the increased P_{tO_2} after oscillating PEP. The previously reported mucus-evacuating effects of PEP and oscillating PEP[6,13] were not addressed in the present study, but might be explained by increased ventilation and high airflow produced by the treatments.[29] The physiologic mechanism of the mucus-evacuating effects, and whether PEP or oscillating PEP cause any changes in ventilation-perfusion ratio, remain to be studied.

Summary

Both PEP and oscillating PEP can cause transitory effects on blood gases in patients with CF. Oscillating PEP causes greater changes than PEP. However, hyperventilation during oscillating PEP can cause immediate discomfort (dizziness) and cause treatment time to be reduced. Spirometry values were not affected by PEP or oscillating PEP. The long-term effects and physiologic mechanisms of the previously reported improved mucus-evacuation with PEP and oscillating PEP[6,13] were not addressed in this study and remain to be studied.

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