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Mucus clearance with three chest physiotherapy regimes in cystic fibrosis: a comparison between postural drainage, PEP and physical exercise

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ABSTRACT: The effects of three different regimes of chest physiotherapy were compared in this cross-over study. Mucus clearance was monitored in nine clinically stable cystic fibrosis (CF) patients. The patients performed: 1) postural drainage with thoracic expansion exercises + forced expiration technique (FET) in the left decubitus position; 2) positive expiratory pressure (PEP)-mask breathing + FET; and 3) physical exercise on a bicycle ergometer + FET. All treatments had the same duration and FET was standardized. Mucus clearance was assessed using a technique based on measurement of the elimination of inhaled radiolabelled particles. Mean clearance of tracer from the right lung by postural drainage, PEP and physical exercise was 18% (range 10–29%), 20% (12–43%), 16% (8–25%), respectively, and from the left lung 20% (8–42%), 15% (5–23%) and 13% (5–17%), respectively. The differences were not statistically significant. Surprisingly, postural drainage (PD) was the most effective technique in the left, dependent lung in 7 of the 9 patients.

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Mobilization and expectoration of excess bronchial secretions is an important part of the every day treatment of patients with cystic fibrosis (CF) [1, 2].

Physical exercise is recommended [3], in order to maintain or increase cardiopulmonary fitness [4, 5], mobility of the chest, and muscle strength [6]. Physical exercise in addition to chest physiotherapy has been reported to increase the amounts of expectorated sputum [7]. Performing a comprehensive exercise programme daily, or several times a week, in addition to ordinary chest physiotherapy, requires a lot of time. A combination of physical exercise interspersed with the forced expiration technique (FET) (forced expirations and breathing controls) is, therefore, used in some CF centres [8].

Different chest physiotherapy techniques have been developed at CF centres throughout the world. In addition to the active cycle of breathing techniques based on thoracic expansion exercises, FET and postural drainage [9], various forms of physical exercise [8] and breathing with positive expiratory pressure (PEP) [10] are being used in combination with FET. Although there are several studies comparing techniques of chest physiotherapy [11], only some have been aimed at investigating the immediate effect of physiotherapy on mucus clearance [12–14], others concentrating more on its effect on lung function variables such as spirometry. In many studies, the amount of sputum expectorated has been measured in association with physiotherapy. The use of this technique is limited by the difficulties in accounting for swallowed sputum and for admixture of saliva. These problems are eliminated if mucus clearance is measured by means of inhaled radiolabelled particles. Studies of chest physiotherapy techniques based on postural drainage, physical exercise or PEP breathing have been reported, but show differing results [11].

The main purpose of the present study was to measure mucus clearance during three regimes of chest physiotherapy in patients with CF. Postural drainage with thoracic expansion exercises + FET was compared with PEP + FET and with physical exercise on a bicycle ergometer + FET. The second purpose of this study was to evaluate the effect of gravity during postural drainage.

Patients

Nine clinically stable CF patients with a mean age of 25 yrs (range 12–36 yrs) participated in the study (table 1). The patients randomly performed all three

chest physiotherapy regimes on three separate study days. All subjects produced sputum daily. Four patients produced >30 ml of sputum daily, and five <30 ml. All subjects maintained their baseline medication, including inhaled $beta_2$-agonists. The interval between the last $beta_2$-agonist inhalation and chest physiotherapy was kept constant in each patient. The study was approved by the local Research Ethics Committee and informed consent was obtained from each subject.

position whilst performing the forced expirations and breathing controls, but they were allowed to sit up whilst coughing. During PP and Ex, subjects were sitting during pauses, forced expirations, breathing controls and coughs. Vital capacity and forced expiratory volume were measured after treatment on each study day with a Vitalograph bellows spirometer. Predicted values were obtained from BERGLUND *et al.* [18].

Table 1. – Characteristics of subjects studied

Pt no.	Sex	Age yrs	SHWACHMAN* Score	FEV_1 % pred.	FVC % pred.	Sputum prodn ml
1	F	20	70	45	59	>30
2	M	36	55	37	38	<30
3	M	19	63	27	39	<30
4	M	22	94	74	95	<30
5	F	12	69	54	65	>30
6	M	28	39	20	28	>30
7	M	34	72	78	90	<30
8	F	23	72	62	70	>30
9	M	29	66	62	71	<30
Mean		25	66	51	62	
Total	3F/6M					4 >30/5 <30

FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; *: reference [15], Sputum prodn: sputum production.

Chest physiotherapy

The three regimes compared were: 1) postural drainage with thoracic expansion exercises + FET (PD); 2) PEP + FET (PP); and 3) physical exercise + FET (Ex). The study was carried out at the same time of day during three different, non-consecutive days, within 2 weeks.

Only one postural drainage position was used during PD in this study, *i.e.* that considered to clear mainly the right middle lobe (lying on the left side, slightly backwards rotated and 15° head down). The subjects were instructed to take 3 deep breaths·min^{-1} in this position, in between relaxed lower chest breathing. No percussions, assisted thoracic compressions or vibrations were performed. PEP was performed with the patient sitting comfortably on a chair with the elbows on a table and the feet on the floor. The subjects were instructed to breathe at normal rate, with slightly active expirations, through a mask with a one-way valve and an expiratory resistance. Mid-expiratory pressure during treatment was 15–20 cmH_2O. Physical exercise was performed on a bicycle ergometer at 80% of each subjects latest measured maximum working capacity (all patients are tested annually).

The chest physiotherapy session lasted for exactly 20 min on each study day. All three regimes were performed 3×3 min with 3 pauses in between. During each pause, which lasted for 3 min, the same number of forced expirations started from mid-lung volume [16, 17] and breathing controls [9] were performed. When performing PD, the subjects stayed in the drainage

Measurement of mucus clearance

The patient was placed in front of a gamma camera (Maxicamera 400T, GEC, Milwaukee, WI, USA) and a transmission scintigram was obtained using a flood source. This scintigram was used to define regions of interest over the lungs in the data analysis.

The subjects then inhaled ^{99m}Tc-labelled colloidal albumin particles (mass median diameter 5 μm) from an air jet nebulizer. The subjects were instructed to breathe somewhat deeper than at rest until a rate of 2,000 counts·s^{-1} had been reached.

Four sets of scintigraphic images were obtained, each consisting of anterior and posterior view. Each image was acquired for 2 min.

The first set of images was obtained immediately after the inhalation, the second after a rest of 15 min in sitting position. The third set of images was obtained after 20 min of chest physiotherapy and the fourth after another 15 min of rest in sitting position.

Regions of interest enclosing each lung were defined in the transmission scintigrams and subsequently projected onto the emission scintigrams. Each lung was also divided into a hilar region comprising 25% of the total lung field and a peripheral region comprising 75%. Clearance was calculated as the reduction in count rate in the total lung fields between successive emission scintigrams. The initial distribution of the aerosol was assessed by calculating a penetration index (PI) as the ratio between the count rate in the peripheral and hilar region in the first scintigram. There were no statistically significant differences in the initial distribution between sessions.

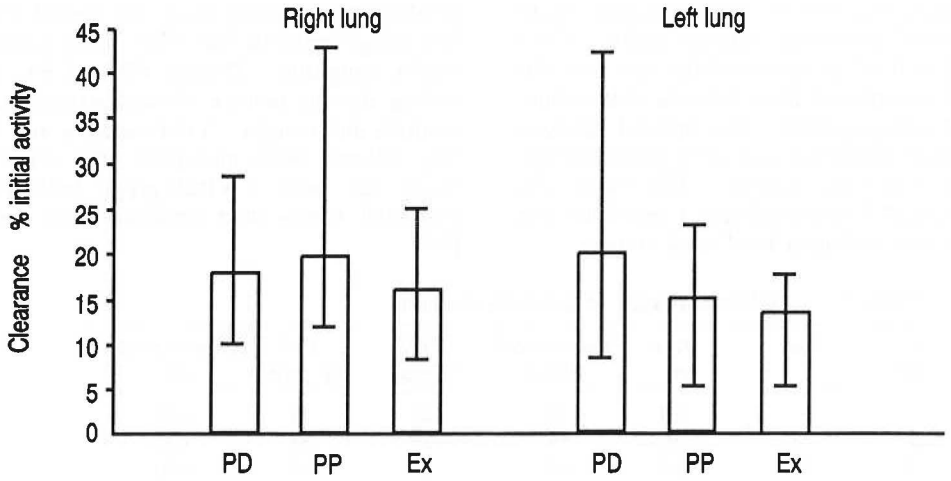

Fig. 1. – Mean effect of the different chest physiotherapy regimes on clearance of radioactive particles from the right and left lungs. The verticle lines represent range. PD: postural drainage with thoracic expansion exercises + forced expiration technique (FET); PP: positive expiratory pressure (PEP) + FET; Ex: physical exercise + FET.

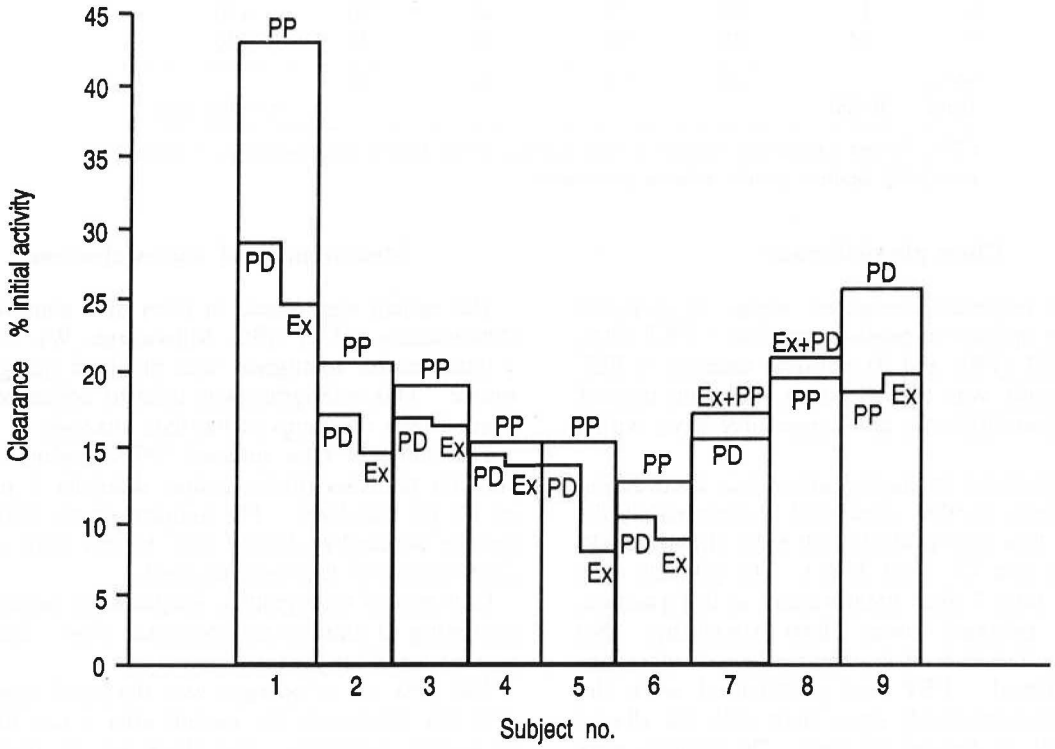

Fig. 2. – Effect of the different chest physiotherapy regimes on the right lung. For abbreviations see legend to figure 1.

Friedman's non-parametric test was used for comparison between regimes and Wilcoxon's signed-rank test was used for comparison between right and left lungs.

Results

The set of images obtained immediately after the inhalation showed prominent deposition of particles in the central airways.

Mean mucus clearance during the first 15 min of rest in sitting position before treatment was higher from the right lung ($p<0.05$) than from the left in 21 of the 27 measurements (9 patients × 3 measurements). There was a close correlation between mucus clearance from the right and left lung at rest ($r=0.80$, $p=0.01$). Mean mucus clearance was also higher from the right than from the left lung before treatment when only the studies of PD were considered ($p<0.05$).

Since PD was performed only in the position to clear the right middle lobe, the effects of the chest physiotherapy were analysed separately for the two lungs. There were small differences between the three regimes (fig. 1), and statistical significance was not reached in either lung. Highest clearance from the right lung was seen with PP, and highest from the left lung with PD.

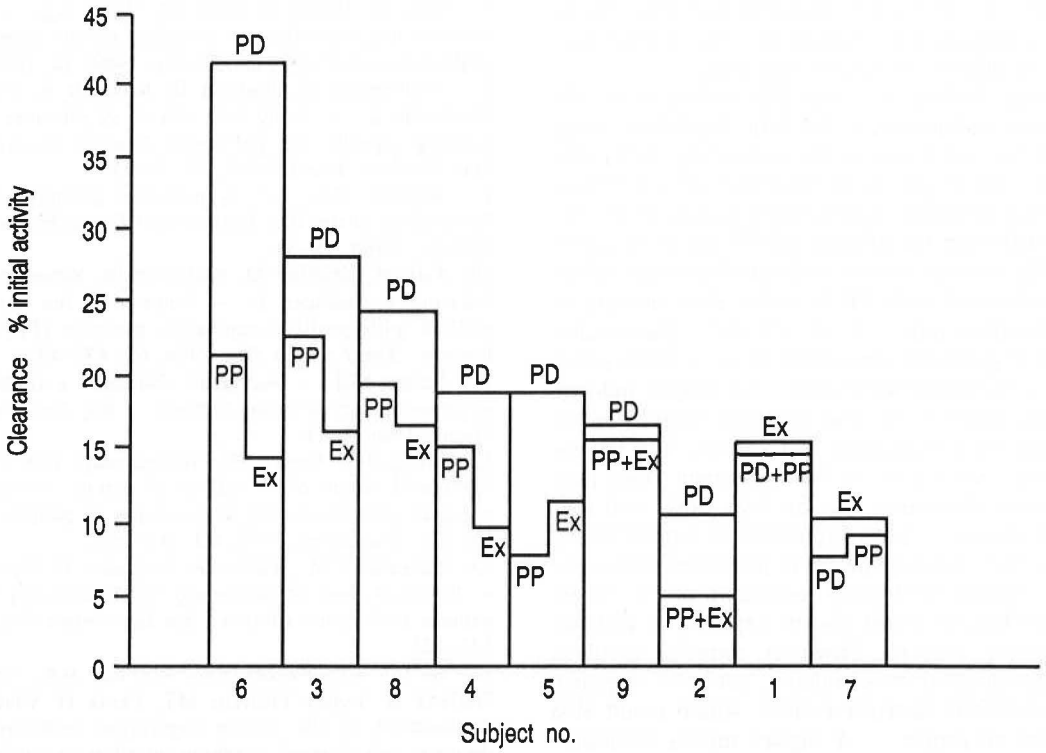

Fig. 3. – Effect of the different chest physiotherapy regimes on the left lung. For abbreviations see legend to figure 1.

In both lungs, Ex was associated with the lowest clearance. On an individual basis, PP gave the highest clearance from the right lung in 6 out of the 9 patients and PD the highest clearance from the left lung in 7 out of the 9 patients (figs 2 and 3). There was no significant difference in clearance from right and left lung during any treatment. Five out of the 9 patients cleared their left side better than their right during PD (NS).

During the second 15 min rest in sitting position, mucus clearance was best after the PP treatment in 5 patients (NS). No difference in mucus clearance between right and left lungs was found during this period of rest.

Discussion

The purpose of this study was to evaluate the effect on mucus clearance of three different chest physiotherapy regimes and to evaluate the influence of gravity on mucus during postural drainage. We wanted to study differences in mobilization rather than expectoration between the different regimes. The duration of the different chest physiotherapy sessions was exactly the same, as was the number and time of pauses for FET, including performance of the same number of forced expirations. Measures promoting expectoration were, thus, standardized.

No comparison was made with spontaneous mucociliary clearance or clearance by FET alone. There is evidence that chest physiotherapy improves expectoration in CF [2, 13, 14]. Although FET is considered a major component of chest physiotherapy, addition of postural drainage or PEP has been shown to increase the efficiency of the treatment [9, 10, 14, 16, 17, 19]. We therefore chose to include standardized FET in all treatments.

The three chest physiotherapy regimes studied are the three used most commonly in Sweden. The main reason for performing physical exercise in patients with CF is for maintainance of cardiopulmonary fitness, chest and spine mobility and muscle strength. If mucus could be mobilized at the same time, patients would save time. There is, however, limited and conflicting information about the effects of exercise on mucus clearance [20–23].

The main reason for performing PD in one drainage position only was to study the influence of gravity on mucus mobilization. One position, in which gravity influenced the two lungs as differently as possible was chosen. During the PEP treatment the subjects were instructed to use the PEP-mask in a way that would increase their functional residual capacity (FRC) during treatment [24], in order to open up clogged or collapsed airways.

On the whole, only small differences were found between the three regimes, but Ex on a bicycle ergometer proved to be the least efficient technique. This finding is supported by OLSÉNI and co-workers [22], who studied physical exercise on a bicycle ergometer in healthy men, and in patients with chronic bronchitis [23], and also by FALK *et al.* [25], who found cycling on a bicycle ergometer less effective than PEP in

patients with CF. It remains possible that other forms of physical exercise, *e.g.* jogging or "circuit training", have different effects on mucus clearance.

A surprising finding was that PD tended to be the most effective technique in the left, dependent lung. This cannot be attributed to an underlying difference between the two lungs, since clearance at rest before treatment was actually significantly higher from the right lung. Although the efficacy of PD has been questioned [9, 10], several studies indicate that chest physiotherapy performed with PD is better than therapy in the sitting position only [14, 17, 19, 26]. The mechanism of PD is generally considered to be a direct effect of gravity on bronchial secretions. Our results indicate that other mechanisms are also involved. Gravity influences regional lung ventilation and volume. The increased breathing excursions in the dependent lung may augment mucus clearance, *e.g.* by high flows and mechanical squeezing. This hypothesis is supported by the finding that hyperventilation increases clearance [20]. If increased ventilation augments mucus clearance, this mechanism might also be expected to increase clearance during exercise. However, exercise involves several physiological mechanisms, such as response from the autonomic nervous system, which could also effect mucus clearance. A higher mucus clearance from the dependent than from the non-dependent lung may help to explain the findings of KRUHLAK *et al.* [27], who observed that most trapped air was found in the apices of patients with CF at rest, and of HOLSCLAW [3], who observed that pathological abnormalities of CF seen on X-ray are seen first and most severely in the apical regions.

In conclusion, we found small differences in mucus clearance during chest physiotherapy with PD, PEP and Ex, all combined with standardized FET. Clearance during PD was greatest from the dependent lung, suggesting factors other than gravitational effects on mucus to be important.

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