

Is cough as effective as chest physiotherapy in the removal of excessive tracheobronchial secretions?

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ABSTRACT The relative value of chest physiotherapy (including cough) and cough alone for the removal of excessive tracheobronchial secretions has been assessed in six patients with stable chronic obstructive lung disease. After labelling with inhaled radioactive tracer particles, clearance of secretions from selected central and peripheral lung regions was followed with a gamma camera linked to a computer. Cough alone and chest physiotherapy (including cough) were equally effective in the enhancement of central lung clearance. Physiotherapy but not cough alone accelerated peripheral lung clearance ($p < 0.05$). Sputum yield was greater during physiotherapy than during cough ($p < 0.05$). These findings confirm the value of chest physiotherapy and high-light the limitation of cough in patients with excessive tracheobronchial secretion and impaired mucociliary clearance.

Since the description of simple manoeuvres in 1915,¹ chest physiotherapy has become established in the treatment of chronic lung conditions associated with excessive tracheobronchial secretions. Objective evidence for its value, however, is both lacking and controversial.^{2,3} Using the radioaerosol tracer technique,⁴ we were able to establish the efficacy of the various combined manoeuvres of the chest physiotherapist with cough in aiding the removal of excessive secretions from central, intermediate and peripheral lung regions. Oldenburg *et al.*,⁵ however, using similar techniques subsequently produced data suggesting that cough alone was as effective as chest physiotherapy combined with cough. We have therefore examined critically the relative roles of cough alone and chest physiotherapy with cough in enhancing regional lung clearance.

Methods

Six patients (three men and three women) with stable chronic airway obstruction and regular daily expectoration took part in the study. Written informed consent from the patients and approval of the local ethics committee were obtained. Three patients had chronic obstructive bronchitis and three

bronchiectasis. Three were non-smokers, two ex-smokers, and one a current smoker. Their physical characteristics and ventilatory function are summarised in table 1.

The labelling of tracheobronchial secretions by an aerosol containing uniform 5 μm polystyrene particles firmly tagged with ^{99m}Tc (half-life 6 h) has been fully described previously.⁶ After the controlled inhalation of radioaerosol, the clearance of particles deposited throughout the tracheobronchial tree was monitored by external gamma counting using a Nuclear Enterprises Mark III gamma camera. Counts were collected from the anterior chest over five-minute periods at half-hourly intervals from 30 to 150 minutes after

Table 1 *Physical characteristics, daily sputum production, and ventilatory function for six patients with stable chronic airways obstruction*

Characteristic	Results (mean \pm SD)
Age (yr)	60 \pm 16
Height (m)	1.63 \pm 0.09
Weight (kg)	61 \pm 10
Sputum production (ml/day)	160 \pm 100
PEFR observed (l/min)	166 \pm 38
PEFR % predicted	38 \pm 6
FEV ₁ observed (l)	0.94 \pm 0.43
FEV ₁ % predicted	37 \pm 13
FVC observed (l)	1.75 \pm 0.64
FVC % predicted	55 \pm 16
FEV ₁ /FVC observed (%)	52 \pm 6

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radioaerosol inhalation. A P-D-P 1105 computer enabled the calculation of particle clearance from selected central, intermediate and peripheral lung regions (fig 1).

For each region the data from both lungs were combined. All counts were corrected for radioactive decay and background. Clearance was expressed as a percentage of the initial radioactivity counts to compensate for unavoidable differences in radioactive lung burden between patients and studies. A radiation dose of less than 15 mrem was delivered to the lungs during each inhalation procedure.

Each patient completed a control, a chest physiotherapy, and a cough study in a random order separated by one or two days. All bronchodilator therapy was withdrawn for 12 h and simple ventilatory function assessed 1 h before each study. In all three studies the patients refrained from coughing for the first 60 minutes and, in the control study, for the first 90 minutes after radioaerosol inhalation. In the physiotherapy study a sequence of postural drainage, vibration (12 to 16 Hz), shaking (2 Hz), and percussion (5 Hz) was administered for four minutes every five minutes for a total duration of 20 minutes one hour after the inhalation of radioaerosol. The patient lay horizontally in the left and right lateral positions for equal periods of time. At the end of each four-minute sequence the patient was sat upright and was instructed by the physiotherapist to cough for a one minute period. Each

cough was preceded by a deep inspiration of air. All manoeuvres were given by hand which was held in the cupped position during percussion. The frequency of each manoeuvre was determined by the physiotherapist applying her techniques to a large ambu bag filled with air and attached to a pressure transducer (SE Laboratories type 1150) linked with an ultraviolet recorder (SE Laboratories oscillograph type 3006) via an amplifier and pre-amplifier (SE Laboratories types 4910 and 4919). Frequency was thus measured from a trace of pressure against time. During the equivalent period in the third study, the patients were instructed by the physiotherapist to cough for one-minute periods every five minutes. The total period of coughing was the same for both the physiotherapy and the cough studies. Spontaneous coughing was allowed in all three studies one and a half hours after radioaerosol inhalation. All sputum samples produced during the physiotherapy and cough periods were collected and weighed.

As the number of patients studied was small and the results do not follow a normal distribution, non-parametric methods have been used in the statistical analysis.⁷

Results

Ventilatory function was similar for all three study days, confirming the stability of airway obstruction. The initial group mean distribution of radioaerosol across the three selected lung regions was also similar (fig 2). The group mean retention of deposited

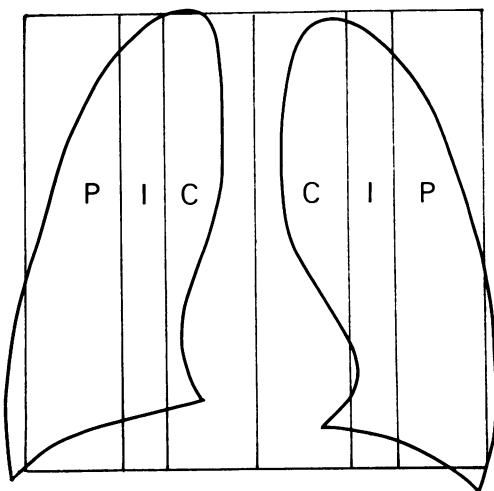


Fig 1 The computer-selected lung regions: central (C), intermediate (I), and peripheral (P), related by area in the ratio 2:1:2.

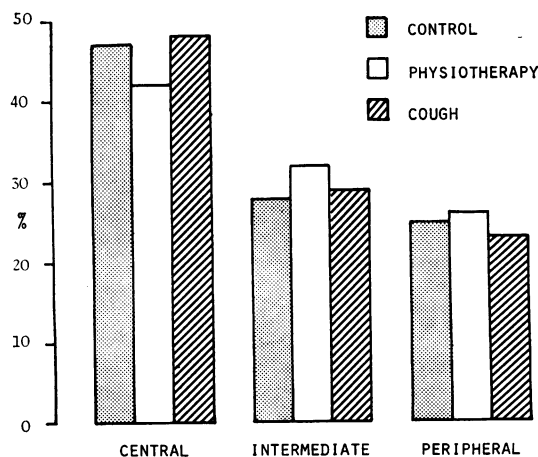


Fig 2 Initial group (six patients) mean distribution of deposited radioaerosol 30 min after particle inhalation across the three selected regions. The results from right and left lungs have been combined and expressed as a percentage of the combined total lung count.

radioaerosol for the three selected regions and the total lung fields is shown in fig 3. All the curves from 30 to 60 minutes are similar. After chest physiotherapy there was a marked fall in deposited radioaerosol in all regions and in the total lung fields. The fall after cough alone was similar to that following physiotherapy in the central lung region but less in the intermediate region and total lung fields. In the peripheral lung region, however, the fall after cough alone was similar to that during the equivalent control period.

The group mean clearance of deposited radioaerosol for each region and the total lung fields during the physiotherapy, cough, and respective control periods is shown in table 2. For the total lung fields and central and intermediate regions, clearance was significantly more ($p < 0.05$) for both physiotherapy and cough studies than for the respective control period. Only chest physiotherapy produced a significant increase in peripheral lung clearance ($p < 0.05$).

No sputum samples were produced during the first 90 minutes of the control study. The group mean weight of sputum collected during physiotherapy was significantly more than that during the cough study (physiotherapy 19 ± 5 (SE)g; cough alone 11 ± 3 (SE)g; $p < 0.05$).

Discussion

Lung mucociliary clearance has been found to be impaired in chronic bronchitis,⁸ bronchiectasis,⁹ and cystic fibrosis,¹⁰ leading to an excess of tracheobronchial secretions partly cleared by cough, a major symptom. Chest percussion, shaking, vibration, and postural drainage are manoeuvres used by the physiotherapist to move tenacious peripheral bronchial secretions to more central airways for expectoration by coughing. In the present study, chest physiotherapy with cough accelerated both central and peripheral lung clearance, whereas cough alone enhanced central lung clearance but was ineffective in peripheral lung regions and, furthermore, yielded less sputum. These findings confirm that cough only partially compensates for impaired mucociliary clearance and that chest physiotherapy is a necessary adjunct for the enhancement of impaired peripheral lung clearance.

The essential component of the cough mechanism is the generation of a linear velocity of air flow within a given airway high enough to shear secretions from its walls.¹¹ The relevant linear flow is the post-peak sustained flow¹² and approximates to half the PEFR.¹³ In the chronic bronchitic, the PEFR may be very low and the post-peak flow even lower

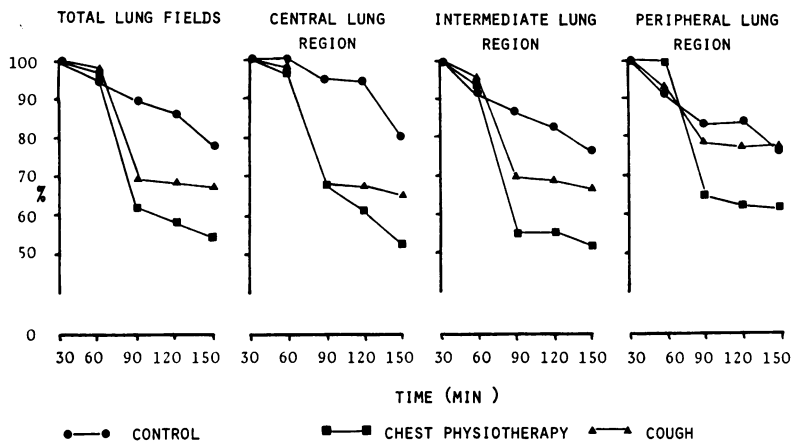


Fig 3 The group (six patients) mean retention of deposited radioaerosol for the three selected regions and total lung fields. The results from right and left lungs have been combined and expressed as a percentage of the count at 30 min post particle inhalation.

Table 2 Group mean (\pm SE) clearance of deposited radioaerosol (six patients) expressed as a percentage of each regional lung count 30 min after particle inhalation during chest physiotherapy, cough, and equivalent control periods. *Statistical differences from control period $p < 0.05$

	Total lung fields	Central lung region	Intermediate lung region	Peripheral lung region
Chest physiotherapy	$34.0 \pm 3.5^*$	$30.5 \pm 9.5^*$	$39.5 \pm 4.5^*$	$34.5 \pm 2.5^*$
Cough	$26.0 \pm 5.0^*$	$31.0 \pm 6.5^*$	$24.5 \pm 4.5^*$	14.0 ± 3.0
Control	5.5 ± 4.0	5.0 ± 4.5	5.0 ± 4.0	8.0 ± 3.0

because of extreme airway narrowing. Thus the shearing of secretions by cough may well be limited to the trachea and first two airways generations,¹³ resulting in retention of secretions in peripheral airways. The group mean PEFr in our patients was greatly reduced (38 ± 6 SD % predicted value). Shearing of secretions by cough would therefore be expected to be limited to central airways.

Both the quality—for example, viscosity and elasticity—and quantity of tracheobronchial secretions may modify the efficacy of a given cough.¹¹ The interaction of elasticity and viscosity is complex and difficult to study in man, the effect on clearance being largely unknown. The quantity of bronchial secretion is more easily investigated. The lung has been compared to a ketchup bottle³—the bottle must contain some ketchup before it can be emptied. Excessive secretions must be present in the lung before they can be removed either by cough or physiotherapy. Camner *et al*,¹⁴ using a radioaerosol tracer method, found that cough enhanced total lung clearance in six patients with lung disease and sputum, but proved ineffective in normal subjects and in two patients with no sputum. Previous negative studies evaluating chest physiotherapy^{15–20} may have resulted in part from the patients lacking increased secretions. The group mean daily sputum production in our study was 160 ml, confirming the presence of excessive lung secretion. In health, bronchial secretions removed by mucociliary clearance amount to about 30 ml/day.

Our results differ from those of Oldenburg *et al*.⁵ Using a radioaerosol method, these workers found cough to be an effective manoeuvre for accelerating peripheral lung clearance in patients with chronic bronchitis. The studies differ in several ways. Firstly, in our patients sputum volume was greater (50–300 ml versus 10–120 ml) and airways obstruction more severe ($FEV_1 = 37 \pm 13$ (SD)% versus 58 ± 21 (SD)% predicted value). Their coughs were perhaps less efficient. Secondly, the initial distribution of radioaerosol tracer particles in Oldenburg's study was predominantly central, whereas our particles were deposited more uniformly throughout the lung. Furthermore, the computer-selected lung regions are not directly comparable. It is possible, therefore, that we were monitoring clearance from more peripheral airways.

Chest physiotherapy consists of postural drainage, vibration, shaking, and percussion. The effect of postural drainage has been evaluated by several workers^{16 21–23} with conflicting results, while neither vibration, shaking nor percussion alone has been examined. The present study confirms the value of chest physiotherapy as a whole in accelerating the clearance of excessive bronchial secretions from all

lung regions in patients with stable chronic airways obstruction and highlights the limitation of coughing alone.

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