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No effect of oral high frequency oscillation combined with forced expiration manoeuvres on tracheobronchial clearance in chronic bronchitis

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ABSTRACT: This study compared the effect of oral high frequency oscillation (OHFO) with the effect of the forced expiration technique (FET) on tracheobronchial clearance. Eight patients with chronic bronchitis were investigated (mean age 60±10 yrs, mean forced expiratory volume in one second (FEV_1) 68±27% predicted, mean sputum production 33±9 g·day^{-1}). OHFO was applied at the respiratory system resonant frequency of each patient (range 9.2–25 Hz) and combined with huffing. FET included breathing exercises, huffing and postural drainage. Duration of both OHFO and FET was 30 minutes. Tracheobronchial clearance was measured by means of a radio-aerosol technique. At 60 mins after start of the treatment mean tracheobronchial retention was 70±26% after OHFO, 54±26% after FET and 76±18% in the control run, which included huffing only. OHFO was not significantly different from control. FET was significantly different ($p<0.02$) from both OHFO and control. It is concluded that OHFO has no effect on tracheobronchial clearance in chronic bronchitis.
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In 1985 oral high frequency oscillation (OHFO) was reported to increase mucociliary clearance in normal man [1]. Since then it has been applied experimentally as a means of improving clearance of excessive bronchial secretion. Reports of its effectiveness in this respect show conflicting results varying from a significant increase in tracheobronchial clearance after OHFO combined with postural drainage and forced expiration [2] to no direct beneficial effect on tracheobronchial clearance but only improvement in mucus transport through stimulation of the coughing reflex [3].

The mechanism through which OHFO exerts its effect, if any, remains unclear. It has been suggested that OHFO changes the characteristics and/or production of mucus or does interact with ciliary beating. Whatever the mechanism might be it seems obvious that the effect of OHFO must be maximal when applied at respiratory system resonant frequency [1]. It is possible to determine respiratory system resonant frequency by means of the forced oscillations technique (FOT) [4].

In this study, each patient's resonant frequency was measured by means of the FOT in order to apply OHFO at his or her specific resonant frequency. The aim of the study was to evaluate the effect of OHFO at respiratory system resonant frequency when combined with forced expiration manoeuvres (huffing) on tracheobronchial clearance. This was compared with the effect of huffing in combination with breathing exercises and postural drainage (FET).

Methods

Patients

Eight patients with chronic bronchitis as defined by the Medical Research Council [5] took part in the study. Their mean age was 60 yrs (range 44–76 yrs). The mean forced expiratory volume in one second (FEV_1) was 68 (SD±27)% predicted. The mean forced vital capacity (FVC) was 92 (SD±20)% predicted. The mean FEV_1/FVC was 67 (SD±19)% predicted. The mean sputum production was 33 (range 22–47) g wet weight per day.

Study design

On three separate days with at least two days in between the effect of the following three treatments was evaluated: 1) oral high frequency oscillation (OHFO); 2) huffing combined with breathing exercises and postural drainage (FET); 3) huffing alone (control). The sequence was determined in a randomized cross-over fashion.

OHFO consisted of oscillations superimposed on tidal breathing during one period of 30 mins. Every 5 mins OHFO was interrupted to perform a few huffs (maximal forced expirations from mid-lung volume). If necessary the patients coughed. OHFO was applied at respiratory system resonant frequency. This frequency had been determined on the same day prior to radio-aerosol inhalation by means of the FOT [4] using the Oscillaire (Jones, USA). Resonant frequencies ranged from 9.2–25 Hz. Sinewave oscillations were produced by a 20 cm bass loudspeaker (Philips AD 80602 W8) connected to a waveform generator (Exar, XR-8038). Stroke volume of the oscillations ranged from 60–250 ml. Oscillations were delivered to the subject through a 50 cm semirigid tube (internal diameter 2.5 cm) attached to a mouthpiece. A side arm in the tube was connected to a humidifier (see fig. 1). The patients were sitting with the elbows resting on a table. No postural drainage was performed.

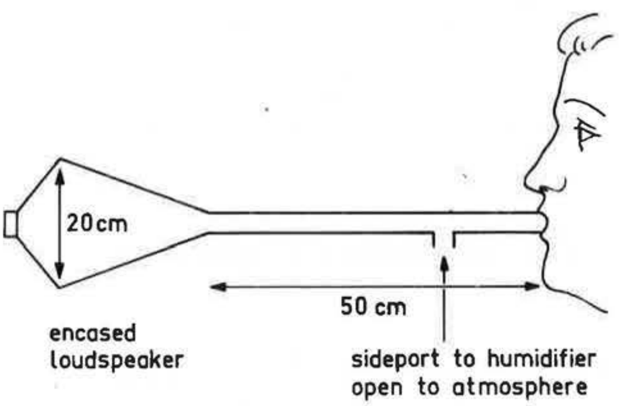

Fig. 1. – Schematic diagram of OHFO-delivery system; OHFO: oral high frequency oscillation

FET was applied according to standard procedures [6, 7]. Only two experienced physiotherapists participated in the study in order to standardize the treatment as much as possible. FET included postural drainage consisting of six positions, four lying on a tilted bed (15° head down) and two seated (leaning 45° forward and 30° backwards, respectively). In every position the patient was instructed to start with diaphragmatic breathing. When the patient had relaxed sufficiently this was followed by thoracic expansion exercises and again diaphragmatic breathing. Then followed two huffs (maximal forced expirations from mid-lung volume) with chest compression alternated with relaxed diaphragmatic breathing. If necessary the patient coughed. FET was performed without aid. Prior to the start of the study the patient had been instructed by the physiotherapist to perform the FET. The duration of the FET session was thirty minutes. During FET the patient was breathing ambient air.

The control treatment consisted of breathing humidified air for 30 mins through the mouthpiece of the switched off OHFO-generator, while sitting with the elbows resting on a table. No postural drainage was performed. Every 5 mins this was interrupted to perform a few huffs. If necessary the patient coughed.

Any medication was continued unaltered. The clinical condition of the patients as judged by lung function tests had to be stable for at least six weeks prior to and during the study period. The patients were informed about the design and the aim of the study. Written informed consent was obtained. The study was approved by the Medical Ethics Committee of the University Hospital.

Test parameters

Tracheobronchial clearance was measured using a radio-aerosol technique [8]. A monodisperse 5 μm ^{99m}Tc-labelled polystyrene particle aerosol was inhaled under standardized conditions. The radioactivity in the thorax was measured by means of two horizontally opposed scintillation detectors. One detector was placed in front of the seated subject, and the other behind the subject and centered at the spinal column. Measurements were started directly after inhalation of the radio-aerosol and repeated at regular intervals *i.e* approximately every 20 min up to 6 h after inhalation and once more at 24 h after inhalation. As described by Pavia *et al.* [9] the sum of the radioactivity count rates of the two detectors was corrected for background activity, isotope decay and 24 h retention. The latter is considered to be an estimate of the aerosol deposition in the nonciliated regions of the lung. The corrected count rate was expressed as a percentage of the count rate assessed immediately before the start of the treatment (OHFO, FET or control). These

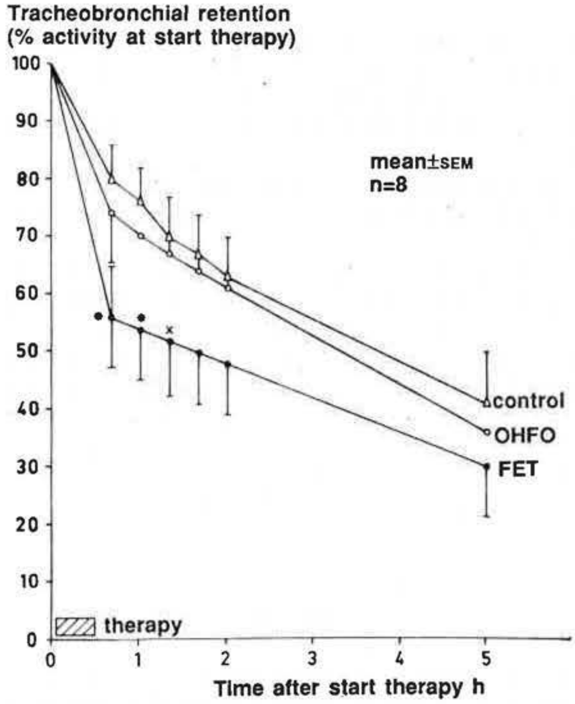

Fig. 2. – Mean tracheobronchial retention curves during and after control. OHFO and FET. *: p<0.02 FET *vs* OHFO and control; ×: p<0.05 FET *vs* OHFO; OHFO: oral high frequency oscillation; FET: forced expiration technique.

Table 1. – Area under the curve 0–2.5 h after start of therapy (AUC–2.5) (%hours) of each patient for FET, OHFO and control, respectively

Patient No.	FET	OHFO	Control
1	207	222	228
2	66	103	184
3	129	140	173
4	162	185	189
5	193	236	198
6	109	229	194
7	79	101	103
8	209	213	220
Mean	144	179	186
SD	58	56	38

FET: forced expiration technique; OHFO: oral high frequency oscillation.

tion after OHFO, FET and control are presented in figure 2. At 40 and 60 min there is a significant difference between FET and both OHFO and control ($p<0.02$). At 80 min there is a significant difference between FET and OHFO only ($p<0.05$). In table 1 the results of the area under the curve up to 2.5 h after the start of therapy (AUC–2.5) are presented. In all patients the AUC–2.5 was smallest after FET as compared with both OHFO and control ($p<0.02$). There appeared to be no significant difference in AUC–2.5 between OHFO and control. In table 2 the results of the measurement of lung function are presented. There appeared to be no consistent effect of any of the three therapies. The results of the measurement of the collected sputum are presented in table 3. Sputum production during FET was significantly ($p<0.02$) larger than during both OHFO and control.

Table 2. – Lung function data before and after therapy (n=8, mean±SD)

	before	after	before	after	before	after
	FET		OHFO		Control	
FEV_1 *l*	2.3±1.0	2.2±1.0	2.2±1.0	2.1±1.0	2.3±1.0	2.2±1.0
FVC *l*	4.0±1.1	3.8±1.1	3.9±1.0	3.6±1.0	3.9±1.1	3.8±1.1
MEF_{50} $l \cdot sec^{-1}$	1.5±1.0	1.5±1.1	1.6±1.2	1.5±1.2	1.5±1.0	1.6±1.1
sGaw $l \cdot sec^{-1} \cdot kPa$	0.77±0.36	0.76±0.44	0.69±0.25	0.72±0.39	0.85±0.38	0.76±0.43

FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; MEF_{50}: mean expiratory flow rate at 50% of forced vital capacity; sGaw: specific airways conductance; for other abbreviations see legend to table 1.

percentages were plotted against time after start of the treatment thus resulting in tracheobronchial retention curves. The area under the retention curves of each individual measurement was calculated using nonfitted data.

The area under the retention curve up to 2.5 h after start of the treatment (AUC–2.5) was used to evaluate the effect of the treatment [10].

Lung function was measured just before inhalation of the radio-aerosol and at about 1 h after physiotherapy, including a flow volume curve and specific airways conductance (sGaw) by means of a body plethysmograph (Jaeger Bodyscreen II). Sputum was collected during the therapy and during the rest of the day. Sputum wet weight was measured. In addition sputum was dried for 72 h at 50°C to determine sputum dry weight. The Wilcoxon test for paired data was used to evaluate the significance of any differences observed.

Results

No significant difference between the values of 24 h retention after OHFO, FET or control treatment was found. The mean 24 h retention which stands for alveolar deposition was 34 (SD±18)%, 36 (SD±21)% and 35 (SD±18)%. The mean curves of tracheobronchial reten-

Table 3. – Sputum production (n=8, mean±SD)

	FET	OHFO	Control
During therapy	201±145*	43±62	29±42 mg dry weight
24 h production	36±12	31±10	32±9 g wet weight

*: $p<0.02$ as compared with OHFO and control; for other abbreviations see legend to table 1.

Discussion

The aim of this study was to evaluate the effect of OHFO on tracheobronchial clearance in patients with chronic bronchitis and abundant sputum production. In the study by GEORGE *et al.* [1] resonant frequency was determined by the subjects themselves on the basis of their sensation of shaking within the chest. This frequency ranged from 8–12 Hz. In our study OHFO was applied at a predetermined frequency identical to respiratory system resonant frequency as measured by means of FOT. This ranged from 9.2–25 Hz. Apart from the frequency of the oscillations, the volume thereof could be varied individually as well. The latter was adjusted in such a manner that it was possible to feel the oscillations by hand over the thorax of the patients or to hear them by stethoscope over the lungs without the oscillations causing too much discomfort to the patients. Apart from the oscillations, OHFO in this study consisted of forced expiration manoeuvres at 5 min intervals. George *et al.* [1] suggest that the mechanism by which OHFO is effective in promoting mucus clearance is by altering the viscoelastic properties of airway mucus. King [11] has reported that high frequency oscillation reduces the apparent viscosity of sputum *in vitro*. In the same study it has been demonstrated that a decrease in mechanical impedance (*i.e.* the vectorial sum of elasticity and viscosity) of mucus appears to have a positive effect on clearance induced by *in vitro* simulated cough. Assuming that these results are also valid for forced expirations it seems logical to combine OHFO with forced expiration manoeuvres as performed in our study. However, the results reported by King have been questioned by Hachenberg *et al.* [12]. The latter reported a slight but significant increase in viscosity under high-frequency vibration. There appeared to be no significant difference in any of the parameters between OHFO and a control measurement, which consisted only of forced expiration manoeuvres at 5 min intervals for 30 min. FET including forced expiration manoeuvres, breathing exercises and postural drainage appeared to be significantly more effective than both OHFO and control (see fig. 2 and tables 1 and 3). Probably the most essential difference between FET and OHFO is postural drainage. In this respect it is important to realize that George *et al.* [2] reported a significant enhancement of tracheobronchial clearance in cystic fibrosis patients only when OHFO was combined with physiotherapy including postural drainage.

Although in our study essentially different equipment to generate oscillations has been used, our results of OHFO are in agreement with those reported by Ravez *et al.* [3]. The fact that George *et al.* [1] found an enhancement in tracheobronchial clearance caused by OHFO in normal subjects might suggest that OHFO can be beneficial only in the presence of normally effective mucociliary clearance and not in the presence of excessive bronchial secretions and/or failing mucociliary transport. The suggestion by the same authors that OHFO exerts its effect mainly in distal airways is not supported by the results in our study (fig. 2). The difference between the study of George *et al.* [1] and our study with regard to the time during which OHFO has been applied could provide an explanation for the contradictory results. Several authors have described the effect of nonsymmetrical flow on mucus transport *in vitro* [13–15]. This effect of oscillatory flow has been seen in an animal study in which dogs were ventilated by means of chest wall oscillation [16]. The oscillations delivered to the subjects in our study were symmetrical. Furthermore, these oscillations were superimposed on spontaneous tidal breathing. Therefore the described mechanism [13–15] by which nonsymmetrical flow causes mucus transport does not seem to be applicable to our results.

On the basis of the results of our study it must be concluded that OHFO as applied in this study in combination with forced expiration manoeuvres does not improve tracheobronchial clearance of excessive bronchial secretions in patients with chronic bronchitis.

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Absence d'effet des oscillations buccales à haute fréquence combinées avec des manoeuvres d'expiration forcée sur la clearance trachéo-bronchique chez les bronchitiques chroniques.
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RÉSUMÉ: Cette étude compare les effets des oscillations buccales à haute fréquence (OHFO) avec ceux de la technique d'expiration forcée (FET) sur la clearance trachéo-bronchique. Huit patients atteints de bronchite chronique ont fait l'objet de cette investigation (âge moyen 60±10 ans, VEMS moyen 68±27% des valeurs prédites, production moyenne d'expectoration 33±9 g·jour^{-1}). OHFO a été appliqué à la fréquence de résonance du système respiratoire de chaque patient (limite: 9.2–25 Hz) et a été combiné avec une manoeuvre d'halètement. FET a compris des exercises respiratoires, du halètement et du drainage postural. La durée de OHFO et de FET a été de 30 minutes. La clearance trachéo-bronchique a été mesurée par une technique de radio-aérosol. 60 minutes après le début du traitement, la rétention trachéo-bronchique moyenne était de 70±26% après OHFO, de 54±26% après FET, et de 76±18% dans le groupe contrôle, qui ne comportait que du halètement. OHFO ne s'avère pas significativement différent du contrôle. FET est significativement différent ($p<0.02$) à la fois de OHFO et du contrôle. Nous concluons que OHFO n'a pas d'effet sur la clearance trachéo-bronchique chez les bronchitiques chroniques.

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