

Physiotherapy after coronary artery surgery: are breathing exercises necessary?

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ABSTRACT One hundred and ten men undergoing coronary artery bypass grafting took part in a prospective randomised study comparing three physiotherapy protocols. All patients were taught self supported huffing and coughing by a physiotherapist and encouraged to move about. This comprised the sole treatment for the 37 control patients (group 3). Additional physiotherapy included breathing exercises for the 35 patients in group 1 and use of an incentive spirometer for the 38 patients in group 2. Functional residual capacity (FRC) was measured daily at the bedside until the fifth postoperative day and arterial blood gas tensions were measured on the second and fourth postoperative days. After surgery patients developed a severe restrictive ventilatory defect and profound arterial hypoxaemia. There were no differences between the three groups. Mean FRC on day 2 was 1.90 litres (61% of the preoperative value), increasing to 2.32 l by day 5 (76% of the preoperative value). The mean arterial oxygen tension was 7.37 kPa on day 2 and 8.58 kPa on day 4. Four patients in group 1, two in group 2, and five in group 3 developed a chest infection. It is concluded that the addition of breathing exercises or incentive spirometry to a regimen of early mobilisation and huffing and coughing confers no extra benefit after uncomplicated coronary artery bypass grafting.

Introduction

After coronary artery bypass grafting physiotherapy—consisting of breathing exercises emphasising inspiration, incentive spirometry,¹ techniques to clear bronchial secretions, and early mobilisation—is given with the aim of increasing lung ventilation and preventing chest infections.

So far all studies comparing physiotherapeutic techniques in patients who have had coronary artery bypass grafting have been carried out in the United States or Canada,²⁻⁷ and with the exception of one study⁵ have included patients undergoing cardiopulmonary bypass for other surgical procedures. The number of patients randomised to a study group has been eight or less in some cases^{5,7} and the physiotherapy techniques have on occasions differed considerably from those used in Britain.

The present study was undertaken to investigate whether the addition of breathing exercises or incentive spirometry to a regimen of early mobilisation and instruction in huffing and coughing would prove more effective in improving lung function and preventing

chest infection in men recovering from coronary artery bypass grafting. This paper describes a randomised study comparing three physiotherapy protocols in 110 such men.

Methods

PATIENTS

Consecutive white men undergoing elective coronary artery bypass grafting during one year were considered for inclusion in the study. Patients who had previously had cardiac surgery and those unable to walk the length of the ward (64 metres) for reasons other than angina were excluded. The study was approved by the hospital ethics committee and informed written consent was obtained from all patients.

LUNG FUNCTION MEASUREMENTS

Patients were first studied in the afternoon during the 48 hours before surgery. Pulmonary function was measured at the bedside with the patient sitting upright in a chair, as follows:

1 *Lung volumes* Functional residual capacity (FRC) was measured by the steady state helium dilution method with a portable spirometer (Pulmonet III, Gould Godart Ltd). Three vital capacity (VC) breaths were taken at the end of the test and the highest value was used in the calculations.

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2 Arterial oxygen (PaO_2) and carbon dioxide ($Paco_2$) tensions were measured by analysis of arterialised ear lobe capillary blood.⁸

3 Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and peak expiratory flow (PEF) were measured with a Respiradyme spirometer.⁹ The highest values from five maximal forced expirations were taken. Patients with an FEV_1 less than 50% predicted normal or a forced expiratory ratio (FER) less than 60% were excluded from the study. Stratified randomisation to balance for age and FER was used to allocate patients to one of three groups.

PHYSIOTHERAPY PROTOCOLS

All patients were seen before operation by a physiotherapist, who explained the need to move about after surgery and to expectorate excess bronchial secretions. Patients were taught huffing (forced expirations with the glottis open), coughing with sternal support and active exercises of the upper and lower limbs. When they were able they sat in a chair and walked on the second postoperative day; stair climbing was introduced on the fourth day. This was the only postoperative physiotherapy for the control patients (group 3).

In addition to this treatment patients in groups 1 and 2 were given a rationale for taking deep breaths (group 1) or for using an incentive spirometer (group 2) and were treated according to the following protocols:

Group 1 Patients had the usual physiotherapy for patients undergoing cardiac surgery, consisting principally of localised (lateral costal and abdominal) breathing exercises.¹⁰ Three to five consecutive deep breaths were interspersed between periods of quiet breathing. Patients practised the exercises in the sitting or half lying position, but if the physiotherapist thought that it was indicated patients were treated while lying on their side with chest vibration or gentle percussion to encourage expectoration.

Group 2 Patients were taught to use an incentive spirometer (Triflo II, Sherwood Medical Industries) in the sitting or half lying position. Three to five consecutive breaths with the spirometer were interspersed between periods of quiet breathing.

Patients in groups 1 and 2 were instructed to practise self treatment exercises preoperatively and once extubated to take at least 10 deep breaths (group 1) or to use the incentive spirometer at least 10 times (group 2) in each waking hour until the end of the fifth postoperative day.

After surgery (which was performed via a median sternotomy) all patients were seen by a physiotherapist at least twice on days 1 and 2 and at least once daily on days 3–5. At the end of each treatment, instructions to

practise taking deep breaths (group 1) or to use the incentive spirometer (group 2) were given. Treatment sessions lasted on average 10–15 minutes for patients in groups 1 and 2 and somewhat less for patients in group 3. Two senior physiotherapists (JML and LCJ) were responsible for coordinating the study and for closely monitoring the practice of the other physiotherapists treating the patients. Medical and nursing personnel were not told which treatment patients were receiving.

Patients were withdrawn from the study for any of the following reasons: more than 24 hours' assisted ventilation; over 48 hours in the intensive care unit; mobilisation contraindicated; clinically important neurological complications; mental confusion.

ASSESSMENT

FRC and VC were measured at the bedside on the afternoon of the second postoperative day and at the same time each succeeding day. Arterialised ear lobe capillary blood was sampled on days 2 and 4 with the patient breathing room air. Forced vital capacity, FEV_1 , and PEF were measured on the fourth day. All measurements were made by SCJ or SAS and were not performed in patients unable to sit in a chair, within one hour of eating, or immediately after treatment by the physiotherapist.

The first chest radiograph after extubation was assessed by a radiologist unaware of the patient's treatment group, who allocated a score (0 = clear; 1 = minor collapse at one base; 2 = pronounced collapse or consolidation (or both) at one base; 3 = bilateral changes). Subsequent films, taken on day 3 or 4, were reported as improved, unchanged, or deteriorated.

The following were recorded each day:

1 Maximum oral temperature and medication received (amount of analgesia quantified according to a system of scoring¹¹).

2 Distance walked by the patient, estimated by the number of journeys to the bathroom and lengths of the ward walked.

3 Patient's perception of chest discomfort, recorded, without knowledge of previous scores, on a visual analogue scale going from "no discomfort" to "severe discomfort."

4 Number of self treatment sessions (groups 1 and 2 only) as reported by the patient (one session was 10 deep breaths or 10 breaths with the incentive spirometer).

A diagnosis of chest infection was made if a patient had a temperature of at least 38.5°C and radiological evidence of consolidation or pronounced lung collapse.

STATISTICAL ANALYSIS

Intergroup differences were tested by analysis of

variance, the Kruskal-Wallis analysis of variance being used to test for differences in data that did not show a normal distribution in the Kolmogorov-Smirnov goodness of fit test. The χ^2 test with Yates's correction and Fisher's exact test were used for qualitative data. Paired and independent *t* tests were used for within group comparisons and analysis of data on subgroups of patients and the Wilcoxon signed rank and Mann-Whitney U tests for parametric and ranked data respectively. The relation between variables was examined by calculating correlation coefficients. Probability values of less than 0.05 were regarded as significant.

Results

One hundred and forty one patients were considered for the study. Nine patients with an FEV₁ less than 50% predicted or an FER below 60% were excluded and one patient refused consent. Twenty one patients were withdrawn after surgery: nine, four, and eight patients from groups 1, 2 and 3. The reasons for withdrawal were: ventilation for more than 24 hours or in intensive care unit (or both) more than 48 hours

(five patients), mobilisation contraindicated (four patients), neurological complications (two patients), mental confusion (five patients), lack of cooperation (five patients).

Results from 110 patients were available for analysis. There was no difference between the three groups in the patients' characteristics or preoperative lung function (table), though there was a wide range in lung function values. No patient had a PaCO₂ above 5.9 kPa and the minimum Pao₂ was 8.5 kPa. Obesity was associated with a low FRC and cigarette smoking with a low FEV₁. The groups were matched for surgeon, operation, details of cardiopulmonary bypass, transfusion requirements, and duration of postoperative ventilation (mean 11.0 (SD 4.1) hours). The internal mammary artery was used for grafting in 21 patients in group 1, 29 in group 2, and 27 in group 3 (*p* > 0.05).

POSTOPERATIVE LUNG FUNCTION

There was a substantial and persistent reduction in lung volumes and in arterial Po₂. FRC, forced expiratory volumes, PEF, and arterial blood gas tensions in the three groups are shown in figures 1-3. There were no intergroup differences (*p* > 0.3). On the

Characteristics of the 110 men completing the study (mean (SD) values except where otherwise specified)

	Group: 1		2		3	
	n: 35		38		37	
Age (y)	55	(8.5)	56	(6.9)	54	(7.6)
Height (m)	1.73	(0.07)	1.73	(0.06)	1.76	(0.08)
Weight (kg)	81.3	(11.8)	80.2	(9.0)	80.8	(10.5)
Obese* (n)	8		6		3	
Smokers† (n)	6		8		5	
Ex-smokers	21		21		25	
Non-smokers	8		9		7	
<i>Lung function and blood gas measurements‡</i>						
FEV ₁ (l)	2.97	(0.58)	2.95	(0.55)	3.09	(0.63)
(% pred)§	88.9	(13.6)	88.7	(12.6)	89.0	(17.1)
FVC (l)	3.83	(0.71)	3.82	(0.66)	4.10	(0.78)
(% pred)	91.6	(12.7)	91.4	(11.3)	94.3	(16.1)
VC (l)	4.15	(0.71)	4.17	(0.63)	4.40	(0.84)
(% pred)	99.5	(14.1)	99.8	(9.9)	102.5	(17.7)
FRC (l)	3.03	(0.68)	3.09	(0.67)	3.32	(0.73)
(% pred)	87.7	(18.4)	88.8	(17.8)	94.2	(18.9)
RV (l)	2.29	(0.59)	2.38	(0.50)	2.38	(0.46)
(% pred)	101.9	(23.1)	104.5	(20.1)	105.3	(19.6)
TLC (l)	6.44	(1.01)	6.55	(0.91)	6.78	(1.04)
(% pred)	95.9	(12.9)	96.9	(9.8)	97.6	(11.7)
RV/TLC (%)	35.4	(6.5)	36.2	(5.0)	35.3	(5.7)
PEF (l/min)	452	(97)	463	(101)	471	(95)
(% pred)	89.7	(17.1)	92.0	(18.3)	91.6	(18.7)
FER (%)	77.5	(5.9)	77.3	(6.3)	75.4	(6.4)
Pao ₂ (kPa)	10.64	(1.15)	10.46	(0.93)	10.58	(1.01)
Paco ₂ (kPa)	5.05	(0.37)	5.08	(0.42)	5.15	(0.37)

*Body mass index (kg/m²) of at least 30.0.²²

†Includes patients who stopped smoking cigarettes in the six weeks before surgery.

‡Lung function and blood gas tensions measured with the patient seated and breathing room air.

§% pred—percentage of predicted normal value.²³

FEV₁—forced expiratory volume in one second; FVC—forced vital capacity; VC—vital capacity; FRC—functional residual capacity; RV—residual volume; TLC—total lung capacity; PEF—peak expiratory flow; FER—forced expiratory ratio; Pao₂, Paco₂—arterial oxygen and carbon dioxide tensions.

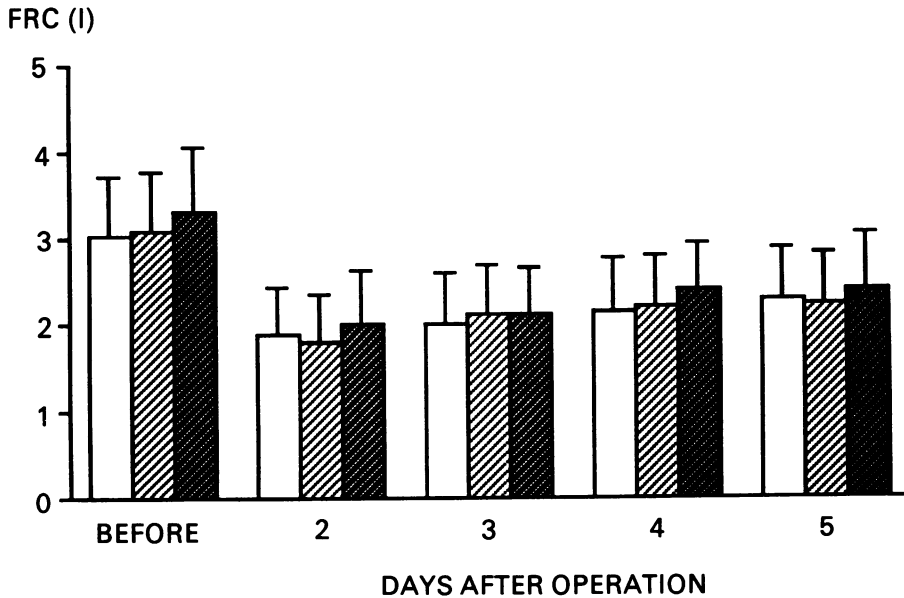


Fig 1 Mean (SD) functional residual capacity (FRC) measured before operation and on days 2, 3, 4, and 5 after coronary artery bypass grafting. The numbers in each group before operation and on days 2, 3, 4, and 5 were: group 1 (□) 35, 28, 35, 34, and 31; group 2 (▨) 38, 29, 37, 38, and 28; and group 3 (■) 37, 25, 35, 36, and 29.

second day mean (SD) FRC was 1.90 (0.60) litres, VC 1.66 (0.53) l, and total lung capacity (TLC) 3.17 (0.83) l (n = 82), increasing to 2.32 (0.65), 2.63 (0.63), and 4.39 (0.91) l by day 5 (n = 88). (Mean data for the groups are available from the author on request.) Internal mammary artery grafting was associated with a more severe reduction in lung volumes than saphenous vein grafting and has been reported separately.¹¹ Twenty patients were transferred to hospitals close to their homes on the fifth day and this accounts for some of the missing data. The mean (SD) Pao₂ was 7.37 (1.07) kPa on day 2 and 8.58 (1.15) kPa on day 4. At the time of capillary blood sampling all patients had a systolic blood pressure greater than 95 mm Hg.

CHEST RADIOGRAPHS

Radiographs taken on the first day showed areas of partial collapse or consolidation, mainly affecting the left lower lobe, in 74%, 74%, and 75% of patients in groups 1, 2, and 3. Subsequent radiographs had improved in 24%, 16%, and 12% and were unchanged in 52%, 48%, and 52% of patients in the three groups (p = 0.17).

CHEST INFECTION

The incidence of chest infection was 10% and occurred in four patients in group 1, two in group 2, and five

patients in group 3 (p > 0.5). The patients all smoked or had only recently given up cigarettes. Mean pre-operative residual volume (RV) and RV/TLC% were higher and FER lower in these patients. After surgery FRC and Pao₂ improved more slowly in patients with a chest infection.

ADDITIONAL PHYSIOTHERAPY TREATMENT

Chest physiotherapy was given to the five patients in group 3 who developed a chest infection. Preoperative FEV₁ was lower in these five patients than in the remaining 32 patients in group 3 (mean (SD) FEV₁ as % predicted 74.6 (7.8) v 91.3 (17.0); p < 0.05). The results of analysis for treatment differences were not influenced by exclusion of the results of these five patients. The number of self treatment sessions reported by patients in group 1 and group 2 did not differ.

No intergroup differences occurred in any of the other measures recorded.

Discussion

This study shows that a severe and persistent restrictive ventilatory defect and arterial hypoxaemia occurred after coronary artery bypass grafting. The addition of breathing exercises or incentive spirometry to a

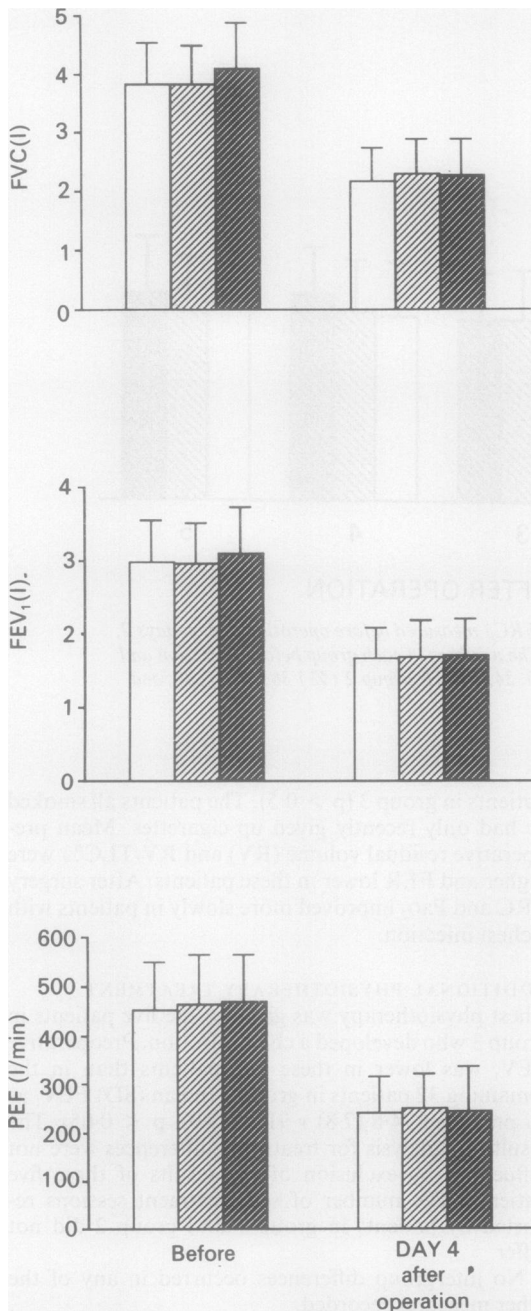


Fig 2 Mean (SD) values of forced vital capacity (FVC), FEV₁, and peak expiratory flow (PEF) before and on the fourth day after coronary artery bypass grafting with the patient seated. The numbers before and after coronary artery bypass grafting in each group were: group 1 (□) 35 and 33; group 2 (▨) 38 and 36; group 3 (■) 37 and 36.

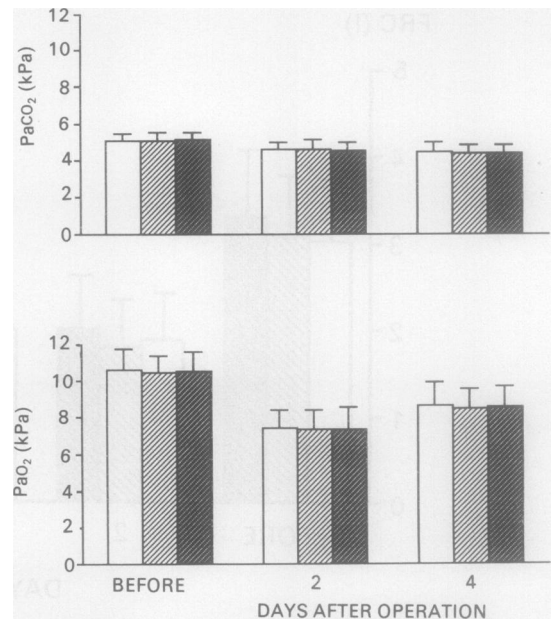


Fig 3 Mean (SD) arterial oxygen (PaO₂) and carbon dioxide (PaCO₂) tensions before and on days 2 and 4 after coronary artery bypass grafting with the patient seated and breathing room air. The numbers before operation and on days 2 and 4 were: group 1 (□) 35, 29, and 30; group 2 (▨) 38, 32, and 34; and group 3 (■) 37, 30, and 32.

regimen of early mobilisation and huffing and coughing did not make postoperative lung function improve more rapidly.

We included only men in our study, to avoid the need to transport the spirometer. Differences in outcome related to gender have not been reported in other studies of postoperative physiotherapy.^{2,6,7} Patients with severely abnormal preoperative lung function are selected infrequently for coronary artery bypass grafting and for this reason were not included in the study groups. As differences in pain tolerance related to race may influence analgesic requirements and assessment of pain, we limited our study to white people.¹²

The magnitude of the postoperative decrease in lung volumes and the blood gas abnormalities confirms and extends the findings of others.^{7,13,14} The incidence of radiological abnormalities and their failure to improve in the early postoperative period are also in agreement with previous findings.¹⁵⁻¹⁷ Measurements were not made after the fifth day because in most hospitals physiotherapy is given for five days only and in our hospital many patients are transferred to other hospitals on the fifth day. Recovery of lung function is likely to be incomplete at the time of discharge from hospital and for some time after.^{13,18}

Practical considerations prevented the simultaneous study of patients who were not seen at all by a physiotherapist, which would be desirable for assessing the importance of physiotherapy treatment. Patients who received only encouragement to move about and instruction in huffing and coughing recovered at the same rate as those who in addition performed breathing exercises or used an incentive spirometer. One benefit of early mobilisation is the greater increase in FRC in the erect than in the sitting posture.¹⁹ The low incidence of infection in the present study does not enable valid conclusions to be made about which physiotherapy treatment is most likely to prevent infection. Patients at increased risk can be identified on the basis of smoking history and pre-operative lung function.

Our findings have important implications for the management by physiotherapists of patients undergoing coronary artery bypass grafting. Incentive spirometry and deep breathing exercises have been shown to be superior to mobilisation alone after upper abdominal surgery,^{20,21} and our results should not be extrapolated to this group of patients or to the treatment of patients undergoing thoracotomy. We recommend that patients admitted for coronary artery bypass grafting are assessed by a physiotherapist before and after operation, taught to huff and cough effectively and encouraged to move about as soon as possible after operation. Additional physiotherapy should be considered only if the respiratory condition deteriorates or mobilisation is impossible.

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References

- Jenkins SC, Soutar SA. A survey into the use of incentive spirometry following coronary artery bypass graft surgery. *Physiotherapy* 1986;**72**:492-3.
- Vraciu JK, Vraciu RA. Effectiveness of breathing exercises in preventing pulmonary complications following open heart surgery. *Phys Ther* 1977;**57**:1367-71.
- Iverson LIG, Ecker RR, Fox HE, May IA. A comparative study of IPPB, the incentive spirometer, and blow bottles: the prevention of atelectasis following cardiac surgery. *Ann Thorac Surg* 1978;**25**:197-200.
- Gale GD, Sanders DE. Incentive spirometry: its value after cardiac surgery. *Can Anaesthesiol Soc J* 1980;**27**:475-80.
- Oulton JL, Hobbs GM, Hicken P. Incentive breathing devices and chest physiotherapy: a controlled trial. *Can J Surg* 1981;**24**:638-40.
- Dull JL, Dull WL. Are maximal inspiratory breathing exercises or incentive spirometry better than early mobilisation after cardiopulmonary bypass? *Phys Ther* 1983;**63**:655-9.
- Stock MC, Downs JB, Cooper RB, et al. Comparison of continuous positive airway pressure, incentive spirometry, and conservative therapy after cardiac operations. *Crit Care Med* 1984;**12**:969-72.
- Spiro SG, Dowdeswell IRG. Arterialized ear lobe blood samples for blood gas tensions. *Br J Dis Chest* 1976;**70**:263-8.
- Jenkins SC, Barnes NC, Moxham J. Evaluation of a hand-held spirometer, the Respiradyne, for the measurement of forced expiratory volume in the first second (FEV₁) forced vital capacity (FVC) and peak expiratory flow rate (PEFR). *Br J Dis Chest* 1988;**82**:70-5.
- Gaskell DV, Webber BA. *The Brompton Hospital guide to chest physiotherapy*. 4th ed. Oxford: Blackwell, 1980: 14-7.
- Jenkins SC, Soutar SA, Moxham J. Lung function after coronary artery surgery using the internal mammary artery and the saphenous vein. *Thorax* 1989;**44**:209-11.
- Woodrow KM, Friedman GD, Siegelau MS, Collen MF. Pain tolerance: Differences according to age, sex and race. *Psychosom Med* 1972;**34**:548-56.
- Braun SR, Birnbaum ML, Chopra PS. Pre- and post-operative pulmonary function abnormalities in coronary artery revascularization surgery. *Chest* 1978;**73**:316-20.
- Rea HH, Harris EA, Seelye ER, Whitlock RML, Withy SJ. The effects of cardiopulmonary bypass upon gas exchange. *J Thorac Cardiovasc Surg* 1978;**75**:104-20.
- Good JT, Wolz JF, Anderson JT, Dreisin RB, Petty TL. The routine use of positive end-expiratory pressure after open heart surgery. *Chest* 1979;**76**:397-400.
- Carter AR, Sostman HD, Curtis AM, Swett HA. Thoracic alterations after cardiac surgery. *AJR* 1983;**140**:475-81.
- Wilcox P, Baile EM, Hards J, et al. Phrenic nerve function and its relationship to atelectasis after coronary artery bypass surgery. *Chest* 1988;**93**:693-6.
- Estenne M, Yernault JC, De Smet JM, De Troyer A. Phrenic and diaphragm function after coronary artery bypass grafting. *Thorax* 1985;**40**:293-9.
- Blair E, Hickam JB. The effect of change in body position on lung volume and intrapulmonary gas mixing in normal subjects. *J Clin Invest* 1955;**34**:383-9.
- Morran CG, Finlay IG, Mathieson M, McKay AJ, Wilson N, McArdie CS. Randomized controlled trial of physiotherapy for postoperative pulmonary complications. *Br J Anaesth* 1983;**55**:1113-6.
- Celli BR, Rodriguez KS, Snider GL. A controlled trial of intermittent positive pressure breathing incentive spirometry, and deep breathing exercises in preventing pulmonary complications after abdominal surgery. *Am Rev Respir Dis* 1984;**130**:12-5.
- Royal College of Physicians. Report of obesity. *J R Coll Physicians Lond* 1983;**17**:6-65.
- European Community for Coal and Steel Working Party. Standardization of lung function tests. *Bull Eur Physiopathol Respir Clin Respir* 1983;**19**(suppl 5):9.