

## Pulmonary gas transfer 20 years after pneumonectomy for pulmonary tuberculosis

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**Gimeno, F., Kraan, J. K., Orie, N. G. M., and Peset, R. (1977). Thorax, 32, 80-83. Pulmonary gas transfer 20 years after pneumonectomy for pulmonary tuberculosis.** The changes in pulmonary function after pneumonectomy in 13 patients with pulmonary tuberculosis have been studied. The data at the time of two follow-up studies are compared with those obtained before the pneumonectomy. The first follow-up was carried out between 5 and 30 months postoperatively and the second between 20 and 24 years later. The results of this second follow-up show a relatively normal arterial oxygen saturation and gas transfer factor but an increased residual volume which cannot be explained by increasing age alone.

The influence of thoracic surgery and pulmonary resection on pulmonary function in tuberculosis patients has been extensively studied in the past (Cournand *et al.*, 1950; Geelen, 1953; Laros, 1956; Larmi *et al.*, 1959; Dietiker *et al.*, 1960; Pianetto *et al.*, 1967). Changes in lung function after pneumonectomy were evaluated by comparing pre- and post-operative results in the same patients and by comparing these results with the predicted values. These published data described the influence of this operation on pulmonary function during the immediate postoperative period. Some publications compared the values for gas transfer factor preoperatively and one to 10 months postoperatively (Dietiker *et al.*, 1960), but few are available on lung function many years after the operation. Laros studied lung volumes soon after pneumonectomy (Laros, 1956; Tammeling and Laros, 1959) and again 20 years after the operation (Laros, 1973). In the present paper, the lung volumes, blood gas values, and gas transfer factors of a group of 13 patients who underwent pneumonectomy about 20 years ago are presented.

### Patients

The present study concerns 13 patients, four women and nine men, who underwent pneumonectomy for tuberculosis between 1947 and 1954. Ventilatory tests were performed before

and again shortly after the operation. The time between operation and the last lung function assessment, including the determination of gas transfer factor, ranged from 20 to 24 (mean 21.4) years. The age of the patients at the time of this last investigation ranged from 42 to 60 (mean 51.2) years, height from 156 to 190 (mean 176.2) cm, and weight from 57 to 95 (mean 78.9) kg. Full details concerning the individual patients may be obtained from the authors on request.

### Methods

The following pulmonary function studies were carried out in the sitting position:

**Spirometry** The slow inspiratory vital capacity and forced expiratory volume in one second measured with a water-sealed spirometer.

**Lung volumes** Residual volume was determined by the closed-circuit helium dilution method (Tammeling, 1958). Predicted values were obtained from Tammeling (1961). In 10 patients, preoperative bronchospirometry was also carried out (Tammeling, 1958).

**Arterial blood gases** In three cases arterial oxygen saturation at discharge after pneumonectomy was measured with the reflection method according to Zijlstra (1951). Twenty years after pneumonectomy arterial blood gases were measured using glass and membrane electrodes

The arterial oxygen saturation was calculated from the pH and  $P_{aO_2}$  in blood (Severinghaus, 1966). In our experience, both methods, the reflection and the calculated saturation, give comparable values for arterial oxygen saturation (Gimeno, 1969).

**Pulmonary diffusing capacity** The pulmonary diffusing capacity was measured at rest by the carbon monoxide single breath method according to Ogilvie *et al.* (1957) with some modifications (Peset and Gimeno, 1974). Predicted values were obtained from Cotes (1965).

## Results and discussion

A summary of the results is given in Table 1. After pneumonectomy the vital capacity decreased to a greater extent than the residual volume. The mean forced expiratory volume in the first second after a maximal inspiration was reduced to about the same extent as the vital capacity. The residual volume increased with the

years to postoperative values which are larger than the preoperative ones. These observations are in agreement with those of Laros (1956) and Burrows *et al.* (1960).

It is of interest that the arterial blood oxygen saturation increased in the three patients tested before and 20 years after pneumonectomy. Arterial blood carbon dioxide tension values did not change (mean value 4.5 kPa, range 3.7–5.3).

Table 2 gives the values for gas transfer. About 20 years after operation the mean gas transfer factor represents about 78% (range 47 to 104) of the predicted value for two lungs, and the mean Krogh's permeability coefficient about 110% of the predicted value (range 60 to 143).

The forced expiratory volume in the first second decreased to the same extent as the vital capacity so that the percentage of the vital capacity which can be expired in one second was not affected by pneumonectomy. The small changes observed can be explained by the increasing age of the group (Greifenstein *et al.*, 1952). The volume

Table 1 Average function studies before and after pneumonectomy in 13 patients

	Before operation	At discharge (5 to 30 mth postop.)	Follow-up (20–24 yr postop.)
Vital capacity (litres BTPS)	3.45 (0.93)	2.44 (0.69)	2.37 (0.60)
Vital capacity (% of predicted)	68.0 (13.7)	48.0 (13.0)	50.0 (9.9)
Residual volume (litres BTPS)	1.20 (0.32)	1.17 (0.50)	1.86 (0.81)
Residual volume (% of predicted)	91.5 (15.3)	89.0 (21.5)	93.8 (33.5)
Total lung capacity (% of predicted)	70.5 (11.1)	55.0 (9.9)	64.2 (15.6)
Forced expiratory volume in one second (litres BTPS)	2.27 (0.56)	1.54 (0.40)	1.39 (0.29)
Forced expiratory volume in one second (% of predicted)	73.2 (15.9)	50.3 (11.7)	46.4 (12.2)
Arterial oxygen saturation (%)	—	95.0 (3.6)	96.2 (1.2)

Figures in parentheses represent standard deviations.

Table 2 Pulmonary diffusing capacity data in 13 patients 20 years after left pneumonectomy

Subject	Diffusing capacity ( $\text{mmol min}^{-1} \text{kPa}^{-1}$ )	Diffusing capacity (% of predicted for both lungs)	Krogh's coefficient ( $\text{mmol min}^{-1} \text{kPa}^{-1} \text{l}^{-1}$ )	Krogh's coefficient (% of predicted for both lungs)
AvL	10.3	100	1.43	99
JLK	6.0	78	1.36	81
JM	5.7	55	1.86	120
LSW	7.5	104	2.03	115
AMH	4.0	47	1.68	99
JO	8.7	93	2.13	140
RK	7.0	71	2.02	143
HM	8.5	76	2.23	143
JK	8.3	84	2.25	136
JH	8.4	83	1.85	120
BB	8.3	80	1.87	126
KG	6.5	57	0.95	60
ABW	6.9	90	2.45	140
Mean	7.4	78.3	1.85	117.0
Standard deviation	1.6	17.3	0.41	25.9

Conversion: SI to traditional units:

Diffusing capacity  $1 \text{ mmol min}^{-1} \text{kPa}^{-1} \approx 2.99 \text{ ml min}^{-1} \text{ torr}^{-1}$ .

Krogh's coefficient  $1 \text{ mmol min}^{-1} \text{kPa}^{-1} \text{l}^{-1} \approx 2.99 \text{ ml min}^{-1} \text{ torr}^{-1} \text{l}^{-1}$ .

expired in one second in relation to the total lung capacity was significantly decreased, which is in accordance with the observations of Hirdes and Bosch (1955), Laros (1956), Tammeling and Laros (1959), and Burrows *et al.* (1960).

After pneumonectomy the residual volume decreased only slightly and not as much as the vital capacity. In the follow-up studies the residual volume was found to increase from 89 to 94% of the predicted values for both lungs. Tammeling and Laros (1959) and Burrows *et al.* (1960) recorded a progressive increase in residual volume after pneumonectomy for tuberculosis: and this was of greater degree than that observed in the present study.

The arterial blood gases measured 20 years after pneumonectomy are of interest. Arterial oxygen tension values were higher (mean 11.7 kPa) than those given by Ulmer and Reichel (1963) and Sorbini *et al.* (1968) for healthy adults of the same age (mean 10.8 kPa), while arterial carbon dioxide tension values were normal. When arterial oxygen saturation was calculated using the data provided by the electrodes in the three patients whose arterial saturation was measured after discharge with a haemoreflexor, it was seen that 20 years later oxygen saturation was higher. That in these three patients oxygen saturation did not change with age can be explained by assuming that the progressive increasing inequality of ventilation/perfusion ratios with age, responsible for the reported decreased arterial tension in elderly patients (Holland *et al.*, 1968) did not take place.

Dietiker *et al.* (1960) found in patients who underwent pneumonectomy for tuberculosis that six months after the operation the decrease in gas transfer factor, measured by the single breath method, was identical with the decrease in total lung capacity. This close relationship between volume and diffusion does not seem to apply many years after operation. In our patients, the total lung capacity expressed as percentage of the predicted values changed from 70% before the operation to about 55% about 10 months after pneumonectomy, and to 64% about 20 years after pneumonectomy. And at this time, 20 years after operation, we found that the mean gas transfer factor is almost 80% of the predicted value for both lungs, and not 64% as would be expected from Dietiker's data.

This suggests that the remaining lung can partially take over the function of the removed lung, and that the decrease in transfer factor due to aging, as shown by Forster (1957), might be

compensated by the physiological changes which follow pneumonectomy. Unfortunately, no transfer factor determinations were performed before or shortly after the operation since at that time (1947 to 1955) facilities for measuring it were not available. However, the normal arterial oxygen tension, the high pulmonary transfer factor as well as the high Krogh's diffusion coefficient can be explained by a relative increase in diffusing surface. This is in keeping with the findings of Ogilvie *et al.* (1963), who reported that the transfer factor was well sustained 10 years after pneumonectomy for carcinoma. Possibly this is achieved by perfusing the remaining lung with the total cardiac output, thus keeping the ventilation/perfusion ratio at an optimal level.

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