Pulmonary Functions before and After Thoracoplasty operation and Pulmonary resection*

By

H. B. DINGLEY, KULDIP SINGH & S. N. GUPTA
(Tuberculosis Hospital, Mehrauli, Delhi)

The value of an operative procedure must be judged not only on the basis of its ability to inactivate or remove a tuberculous process, but also on its function diminishing characteristics. Patients with tuberculosis for whom surgery is proposed often have little functional reserve and the choice of the type of operation may well be crucial in preventing any further progression towards respiratory insufficiency and Cor-pulmonale.

The effect of surgical removal of various amounts of lung or its collapse on the function of the remaining lung has been the subject of several other studies, the results of which have not always been in agreement; while some investigators have found a pattern consistent with developing emphysema in the remaining lung, others have reported over distension alone without any other evidence of disturbance of function.

The gradual increase of resective surgical work for pulmonary Tuberculosis in our Hospital stimulated our interest to determine the comparative effects of Thoracoplasty in contrast to resective surgery on the loss of pulmonary functions in patients surgically treated for tuberculosis. A group of tests is available to measure objectively both divisions of pulmonary functions (1) Ventilation i.e. mechanical component and (2) Respiration i.e. the physiochemical component. In the present study only the first component has been studied.

During a period of 18 months from July, 1958 to December 1959, 84 patients were studied with respiratory function tests pre-operatively. For one reason or the other it was possible to do post-operative studies only in 47 patients. Hence observations have been made and conclusions derived only in 47 patients, studied both pre and post operatively. Posterior staged thoracoplasties were done in 32 cases. Of these, 18 cases had this operation as primary form of surgical therapy, while the remaining 13 cases had Pneumoperitoneum for a period of 12—24 months and one had empyema and non expandible lung following Pneumothorax treatment for nearly 3 years prior to surgical interference. In the resection group, 11 cases had lobectomy and 4 had pneumonectomies. Of the 4 cases who had pneumonectomy, 2 had Pneumoperitoneum and 2 had A. P. as the treatment prior to the operation.

Method of Study

Of the patients studied, 33 were men and the rest 14 were women. The average age of the group under review was 32 years with the youngest being 18 years and the eldest to be operated being 60 years old. All the patients were with

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moderately or far advanced tuberculosis which was not always unilateral in distri-
bution but all were with rather relatively stable tuberculous lesions. All the patients
were ambulatory and in good physical condition. The operations included pleural
pneumonectomy, pneumonectomy, Lobectomy, Lobectomy with a segment or a
Wedge and Thoracoplasty.

Preliminary observations of Vital Capacity, maximal breathing capacity, bron-
chospirometry, Bronchascopy and fluoroscopy were obtained in all patients.

Function determinations were made within a period of 14 to 30 days before
surgery particularly in a phase when the amount of secretions was less and were
repeated post surgery, the average interval being 82 days.

A collins respirometer (with nine litre bell and tubing with 3/4 inches in
diameter) was employed to measure pulmonary volumina and maximum breathing
capacity. Courmand’s Regression formula was used to calculate Predicted Vital
Capacity and maximum breathing capacity.

Bronchospirometry was performed using a standard Zavods double lumen-
catheter introduced under direct Laryngoscopy under topical Laryngotraceobron-
chial anaesthesia with 1 % xylocaine solution. Preliminary seduction included a
barbiturate (Sodium Sonreyl 3 grs.) plus Atropine sulphate gr. 1/100. Correct posi-
tion of the Catheter in the left main bronchus was verified fluoroscopically, the Cuff
balloons were inflated and the proximal Catheter Channels were attached to double
recording Spirometers, containing 100 per cent, oxygen and Soda lime Cannisters.
Records of oxygen consumption, tidal air, respiratory minute volume, inspiratory
and expiratory reserve volume and Vital Capacity were obtained. The Broncho-
spirogrammes were graded as to its appearance and quality. Tracings which were
satisfactory in every way were used for comparative study.

Surgical Procedure adopted :— Graph I shows the various surgical measures
done in the group under review.

The trend in the choice of the operation was Thoracoplasty while resection was reserved for very definite indications including strictly localized unilateral disease, a giant or a Lower lobe Cavity or a destroyed lung.

Results

Ventilatory function profile of the Entire Group:— Graph II indicates the pre-operative Ventilatory functions of every patient with maximum breathing capacity on the ordinate and the vital capacity on the abscissa, as the per cent, of the predicted normal.

The regression equation for calculation of the predicted normal values have a standard error of about 20 per cent, therefore a performance of 80 per cent, or better must be regarded as possibly being within the normal limits of the whole group.

Points falling on a line drawn at fortyfive degrees to the Coordinate axes show equal impairment of M. B. C. and V. C. That is, the fraction per cent. Of Predicted M.B.C. (air velocity index) is equal to 1.0 per cent. Of Predicted V.C.

As is evident from the graph, none of the patients had normal M.B.C. and V.C.

Almost all patients had moderate impairment of Ventilatory functions. Most patients had air Velocity indices within the normal limits of 0.8 to 1.2 suggesting that a Ventilatory defect demonstrable was of restrictive type.
Graphs III & IV show comparison of the average Vital Capacity and maximum breathing capacity observed with the expected average in the 47 cases under review.

The average observed Vital Capacity was 2.14 litres as compared with 3.96 litres expected Vital Capacity. Similarly the observed Maximum Breathing Capacity was 98.2 litres as compared with the average 121.5 litres expected Maximum Breathing Capacity.

A. Thoracoplasty Group:

Graph V shows the results of comparative study of the total Vital Capacity, maximum breathing capacity and Vital Capacity of the individual lung, oxygen intake per minute and C.C. per breath.

<table>
<thead>
<tr>
<th></th>
<th>Average before Operation</th>
<th>Average after Operation</th>
<th>Total number of cases studied</th>
<th>Functional Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vital Capacity</td>
<td>2.14 Liters</td>
<td>2 Liters</td>
<td>25</td>
<td>0.14 Liters</td>
</tr>
<tr>
<td>Vital Capacity (R)</td>
<td>1.2 Liters</td>
<td>0.7 Liters</td>
<td>15</td>
<td>0.3 Liters</td>
</tr>
<tr>
<td>Vital Capacity (L)</td>
<td>1.2 Liters</td>
<td>0.9 Liters</td>
<td>15</td>
<td>0.3 Liters</td>
</tr>
<tr>
<td>Maximum Breathing Capacity</td>
<td>60.3 Liters</td>
<td>48.1 Liters</td>
<td>25</td>
<td>12.2 Liters</td>
</tr>
<tr>
<td>Ventilation (R)</td>
<td>5.9 Liters per mt.</td>
<td>5.2 Liters per mt.</td>
<td>15</td>
<td>0.7 Liters</td>
</tr>
<tr>
<td>Ventilation (L)</td>
<td>5.3 Liters per mt.</td>
<td>5.1 Liters per mt.</td>
<td>15</td>
<td>0.2 Liters</td>
</tr>
<tr>
<td>Oxygen Intake per Minute (R)</td>
<td>334.4 c.c.</td>
<td>262.7 c.c.</td>
<td>6</td>
<td>71 c.c.</td>
</tr>
<tr>
<td>Oxygen Intake per Minute (L)</td>
<td>368 c.c.</td>
<td>224 c.c.</td>
<td>5</td>
<td>144 c.c.</td>
</tr>
<tr>
<td>C.C. per Breath (R)</td>
<td>22.6</td>
<td>17.3</td>
<td>6</td>
<td>5.33</td>
</tr>
<tr>
<td>C.C. per Breath (L)</td>
<td>29.6</td>
<td>29.5</td>
<td>5</td>
<td>0.1</td>
</tr>
</tbody>
</table>
B. Resection Group:

(i) Lobectomy Group:— Graph VI shows the results of comparative study of the total Vital Capacity, Maximum Breathing Capacity, Vital Capacity of the individual lung, oxygen intake per minute and C. C. per breath.

**Graph VI:—LOBECTOMY GROUP**

<table>
<thead>
<tr>
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<th>Average after Operation</th>
<th>Total number of cases studied</th>
<th>Functional loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Vital Capacity</td>
<td>2.1 Liters</td>
<td>2.0 Liters</td>
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<td>0.1 Liters</td>
</tr>
<tr>
<td>Vital Capacity (R)</td>
<td>1.2 Liters</td>
<td>1.1 Liters</td>
<td>6</td>
<td>0.1 Liters</td>
</tr>
<tr>
<td>Vital Capacity (L)</td>
<td>1.1 Liters</td>
<td>0.9 Liters</td>
<td>5</td>
<td>0.2 Liters</td>
</tr>
<tr>
<td>Maximum Breathing Capacity</td>
<td>61.6 Liters</td>
<td>49.0 Liters</td>
<td>II</td>
<td>12.6 Liters</td>
</tr>
<tr>
<td>Ventilation (R)</td>
<td>7.4 Liters per mt.</td>
<td>5.7 Liters per mt.</td>
<td>6</td>
<td>1.7 Liters</td>
</tr>
<tr>
<td>Ventilation (L)</td>
<td>10.1 Liters per mt.</td>
<td>5.5 Liters per mt.</td>
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<td>4.6 Liters</td>
</tr>
<tr>
<td>Oxygen Intake per Minute (R)</td>
<td>334.4 c.c.</td>
<td>262.7 c.c.</td>
<td>6</td>
<td>71 c.c.</td>
</tr>
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<td>29.5</td>
<td>5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

(ii) Pneumonectomy Group:— Graph VIII shows the results of comparative study of the total Vital Capacity, maximum breathing capacity, vital capacity of the individual lung, oxygen intake and c. c. per breath.

![Graph VIII:—PNEUMONECTOMY GROUP](image-url)
Discussion

Pre-operatively the Vital Capacity was abnormally low and immediately after operation there was further reduction in most of the cases.

In every case the preoperative values for the maximum breathing capacity were low. The reduction was frequently very marked and quite out of proportion to the extent of the lesion. Following operation there was a fall in the maximum Breathing Capacity.

Previous experience with bronchspirometry in the measurement of functional loss due to thoracoplasty are relatively few. The main purpose of the Bronchspirometry was to measure oxygen consumption and Vital Capacity of the operated lung.

Pinner and associates carried out Bronchspirometry post-operatively in 11 patients who had Thoracoplasty operation. The operation varied in extent. The oxygen uptake of the operated side ranged from 23-46 per cent of the bilateral value (mean of 32%).

Leinner investigated twenty six cases with resection of 4-8 ribs. He found a slight decrease of oxygen uptake, minute volume, tidal air and Ventilation equivalent.

Gaensler and Watson studied 22 cases of right sided six rib apical thoracoplasty. The study showed that right lung’s participation in the total oxygen uptake diminished from a pre-operative value of 56 per cent to a post operative value of 22 per cent. The right lung’s vital capacity portion of the total went down from 38 to 22 per cent.

The results of consecutive bronchspirometry in 23 cases by the same workers are presented from one to thirty days pre-operatively, immediately pre-operatively, immediately post-operatively and 3 months post-operatively. It was shown that the mean pre-operative change in per cent of oxygen uptake is slight.

The total loss during surgery of oxygen uptake may vary from 3 to 100 per cent subject chiefly to the technical factors involved and the extent of the disease. An occasional patient may even show a gain in oxygen uptake. Mean loss was 20 per cent.

Although the post-operative gain was striking in numerous cases this was not always so, some patients showing a continuous loss, the mean post-operative gain from 1—3 months post operatively was 6 per cent.

Kaltrieder found a greater reduction in Vital Capacity than is to be expected from the extent of lung tissue compressed. He noted a reduction of 50 per cent in the Predicted normal value of Vital Capacity (This being due to interference with the mechanics of respiration by reducing the lateral expansion of the chest excursion of the diaphragm and rib rotation).

Leinner noted that following thoracoplasty, there is diminution of total pulmonary volume, reserve air showing the greatest reduction.

Warring noted lowering of the maximum breathing capacity.

Cournand and Richards noted a constant co-relationship between the number of ribs resected and the decrease in maximum breathing capacity. The important factors disturbing such a co-relation in individual cases were the development of scoliosis, further disturbance in diaphragmatic function or collapse of valuable amounts of normal lung tissue.

At variance with these opinions Wright and Woodruff concluded that when collapse is confined to diseased lung tissue no significant reduction in respiratory Capacity on the surgical side occurs. They stated that after sufficient time had elapsed for return of mobility and comfort, the maximum breathing capacity is increased often by as much as 50 per cent. This increment being due to strengthening of respiratory muscles in an exercising patient compared to his former status as a bed patient.

In the present series under review despite the poor functions preoperatively, the reduction in the vital capacity and maximum breathing capacity was there, though there was slight decrease of oxygen uptake, minute volume, tidal air and the ventilation equivalent.

The total oxygen uptake diminished by 2% on an average from its pre-operative value to its post operative value. Similarly the vital capacity diminished by 33% from its pre-operative to post operative value. The maximum breathing capacity showed a loss of 20%.

Knowledge of the amount of the functional loss resulting from different types of resection for Pulmonary Tuberculosis is limited but Ventilatory functions lost as a result of resection, co-relate well with the extent of lung tissue removed.

Although the Bilateral Pulmonary function is of interest in this problem, the changes in function on the operated side obtainable from Bronchspirometery is even more pertinent.
Hirdes found a depression following lobectomy to the extent that the operated lung decreased its participation in the bilateral function by mean value of 12 per cent for oxygen and 9 per cent for Vital Capacity in a series of 36 cases.

Vander Drift in selected group of upper Lobectomies (6 right and 6 left) all of which were considered to be perfectly successful the mean decrease in percentage of the bilateral oxygen uptake for the right sided procedure was from 47 percent preoperatively to 40 percent post operatively and for the left sided operation group the unilateral function was 40 percent before and 25 percent after operation.

Gaensler in a series of 29 lobectomies found a decrease of oxygen consumption from a mean of 47 percent of the bilateral function preoperatively to 35 percent post operatively. The corresponding figures for Ventilation were 51 percent before and 41 percent after operation.

Limburg in a group of 14 patients who had undergone right upper lobectomy, the right lung suffered a mean loss of 47 percent of its normal value for oxygen uptake and 35 percent of its normal Vital Capacity.

In five patients with right sided lower lobectomy, the right lung lost a mean of 51 percent of its normal oxygen uptake and 49 percent of its Vital Capacity.

2 additional patients who had both right middle and Lower lobes removed resulting in a mean loss to the right lung of 67 percent of its oxygen uptake and 61 percent of its normal Vital Capacity.

Taylor and associates studied 35 cases of segmental resection and 39 patients with tailoring thoracoplasty. All patients suffered a loss of 20 percent of total vital capacity, the variations between the individual groups being remarkably few in this respect. The only group which had a larger Vital Capacity loss was that, undergoing pneumonectomy. In the group under Review there was reduction in Total Vital Capacity from 2.1 liters preoperatively to 2.0 liters postoperatively. Similarly the M.B.C. showed a loss of 12.6 liters from its preoperative value of 61.6 liters to 49.0 liters.

The total oxygen uptake showed a diminution of 71 c.c. and 144 c.c. respectively on the operated side.

**Conclusion** — The mean loss of Pulmonary functions resulting after Lobectomy is less than after thoracoplasty. Moreover the loss encountered in thoracoplasty increases steadily with the number of ribs removed after operation.

Several authors have pointed out that the amount of functioning lung removed determines the degree of impairment of function and have stressed the importance of preserving as much normally, functioning pulmonary parenchyma as possible in various chronic conditions.

**SUMMARY**

1. The Results of Pulmonary function studies in a group of 47 patients before and after Thoracoplasty operations have been reviewed.

2. The mean loss of Pulmonary function resulting after Lobectomy is less than after Thoracoplasty.

3. The loss encountered in thoracoplasty increases steadily with the number of ribs removed after operation.

Of the measures associated with the best clinical and functional results, the following are stressed:

A. Preoperative measures

1. Energetic efforts to reduce the amount and bacterial content of the sputum and to avoid bacterial resistance by using combined chemotherapy controlled by drug susceptibility studies.

2. Encouraging light to moderate amounts of physical activity as well as diaphragmatic breathing exercises before operation.

B. Intraoperative measures

1. Lysis of all the pleural adhesions including the inferior pulmonary ligament.

2. Thorough decortication including freely ‘Curl’d Under’ edges of the lower lobe resulting from previous pneumothorax and removing the soft fibrin strands so often seen, the immediate gain in pulmonary expansibility is always striking.

3. Pleurizations of as much lung surface as possible after the completion of resection.

4. Saline irrigation of the entire pleural cavity prior to closure to wash out pleural irritants.

5. Pleural drainage with two large catheters; one directed apicoposteriorly, the other Ventrally.

C. Postoperative measures.

1. Immediate and continued use of breathing exercises, coupled with the use of the Contra-lateral recumbent (non-operated side down) position.

2. In the presence of good expansion, early removal of drainage tubes (third to fourth post operative day) in order to minimise pleural reaction.

3. Early re-thoracotomy in case of extensive clothing even though the general condition of the patient appears satisfactory.

Acknowledgement

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References


