Resection for Pulmonary Tuberculosis
in Infants and Children*

JOHN P. IGINI, M.D., F.C.C.P.,* ROBERT T. FOX, M.D., F.C.C.P.,**
and WILLIAM M. LEES, M.D., F.C.C.P.***
Chicago, Illinois

The treatment of pulmonary tuberculosis in infants and children has been, until recently, entirely medical. Prior to 1949 pulmonary resection of tuberculous lesions in children was not widely attempted, although such procedures for bronchiectasis, cystic disease, etc. have been generally accepted. The advent of better surgical technique, endotracheal anesthesia, and better understanding of pre and postoperative care have given all types of intrathoracic surgery a satisfactory margin of safety in children. The introduction and intelligent use of the specific antituberculous drugs, especially streptomycin and isonicotinic acid hydrazide, has afforded great advances in the therapy of tuberculosis in general. More specifically, these drugs have aided in the resolution and clearing of pulmonary lesions to a point where surgical excision is feasible and, together with other antibiotics, have protected these children from the majority of infectious complications during the postoperative period.

The various surgical procedures commonly used in adult tuberculous patients could not be carried over entirely to the treatment of infants and children. It is common knowledge that thoracoplasty in young patients up to the age of 16 is usually contraindicated because of the incidence of severe scoliosis and resultant embarrassment of cardiorespiratory function. Pneumothorax has never been very satisfactory in young children, although pneumoperitoneum is tolerated fairly well by older children.

The medical literature in the past few years contains several reports on excisional surgery for pulmonary tuberculosis in infants and children. In 1950 Levitan and Zelman* reported four cases of pneumonectomy for tuberculosis, the patients ranging in age from two and one half to 12 years. Three of these were successful in achieving arrest of the disease. In 1952 Rubin and Mishkin of Seton Hospital, N. Y., reported on excisional surgery in 30 tuberculous children and adolescents, ranging from seven to 16 years in age. There were two surgical deaths. A more recent report by Rubin, et al., has extended their series to 62, with four operative deaths (15 per cent).

We wish to outline our experience with resectional surgery in children at the Chicago Municipal Tuberculosis Sanitarium from 1949 through 1954. Fifteen years was arbitrarily selected as the upper age

†From the Department of Surgery, Municipal Tuberculosis Sanitarium.
*Formerly, Resident in Thoracic Surgery, Municipal Tuberculosis Sanitarium. Presently, Clinical Assistant, Department of Surgery, Stritch School of Medicine — Loyola University.
**Assistant Chief of Surgery, Municipal Tuberculosis Sanitarium and Associate in Surgery, Northwestern University Medical School.
***Chief of Surgery, Municipal Tuberculosis Sanitarium and Clinical Associate Professor in Surgery, Loyola University — Stritch School of Medicine and Mercy Hospital.
RESECTION FOR PULMONARY TUBERCULOSIS

FIGURE 1. D.W.: Film taken after 90 days of antituberculous chemotherapy. Extensive bilateral disease still present.

FIGURE 2. D.W.: After 18 months of antimicrobial drugs and 12 months of pneumoperitoneum. The right upper lobe is destroyed and contracted. The remaining disease has regressed and is remaining stable.

FIGURE 3. D.W.: Film taken 13 months after operation. No active parenchymal disease is visible.
FIGURE 4. A.M.: Shortly after admission on June 27, 1949. Note extensive cavitatory in the left apex with pneumonic infiltration beneath it and scattered nodular infiltration in left lower lung field and also in the right mid-lung field.

FIGURE 5. A.M.: Preoperative film. After 11 months of antimicrobial therapy there is still extensive residual cavitary disease in the left upper lung with a combination of nodular disease and atelectasis of the lower lobe secondary to the fibrostenosis of the bronchus.

FIGURE 6. A.M.: Chest film 2½ years after left pneumonectomy. Note elevation of left hemidiaphragm, heart in midline, and moderate retraction of superior mediastinal structures to the left. No evidence of active parenchymal disease on the right is seen.
limit for this group, and we are presenting 25 cases, with an average age of 11 years and six months. The youngest was two years and nine months of age. There were four children five years or under, one child in the six to 10 year group, and 20 in the 11 to 15 year bracket. Of these, 22 were Negro and three White. Nineteen were girls and six were boys.

Fourteen of the 25 children had a history of immediate family contact and their disease was diagnosed by follow-up x-ray films of such contacts. Six of the 25 were asymptomatic, and of the remaining 19 with symptoms, 15 had an acute onset. The remaining four had an insidious beginning.

On reviewing the records, it was of interest to note the long period of time between the initiation of treatment and the performance of surgery. The shortest period between diagnosis and resection was 11 months, and the longest was five years, with an average of 27½ months. It is obvious that every effort was made to provide for maximum clearing of the disease prior to considering resectional surgery. In our earlier experience it was felt that surgery was to be reserved for the salvage type of case, but as satisfactory results were achieved a much more aggressive definitive attitude was taken.

The indications for resection in children are not as clear-cut as they are in adults. In addition to the universally recognized indications as applied to children, there are the cases of progressive unilateral disease and the progressive primary complex. These are cases where, because of insufficient host resistance, intercurrent infection or nutritional deficiency spread of the lesion occurs. This progression occurs in the patients who fail to form a fibrous wall or capsule about the primary focus of infection. The spread occurs by contiguity or aspiration and soon the entire lobe or segment may become involved (Fig. 7). With continued progression liquefaction and cavitation appear (Fig. 4). From this progressive lesion, aspiration with rapidly progressing generalized tuber-

FIGURE 7
FIGURE 8


crosis of the lungs may develop. While this type of lesion may arise in any portion of the lung, the lower lung fields are more frequently involved. These areas are, therefore, permanently and irrevocably damaged and constitute a continued hazard to the patient who harbors them. We, therefore, agree with Boyd and Wilkinson that resection is to be advocated when such permanent damage seems inevitable.

Of the 25 patients, 19 had detectable disease on one side only, whereas six had bilateral involvement. In these latter cases, criteria for surgical consideration included evidence of stability of the contralateral lesions as demonstrated by serial x-ray films and, occasionally, by laminographic study. Fourteen of the total number had roentgenographic evidence of cavitation, three with associated atelectasis, one had a destroyed lung and one a tuberculoma. Four of the children had progressive primary disease.

Because the period of this study goes back to 1949, and since the presurgical treatment in these children ranged from 11 months to five years, the program of antibiotic and inflation collapse therapy was quite varied. Early in this period, short courses of chemotherapy consisting of streptomycin with or without PAS was given. The more recent group had long periods of treatment with dihydrostreptomycin (DHSM), para aminosalicylic acid (PAS), and isoniazid (INH). In all, six of the children had six months or less of chemotherapy, 10 from six months to a year, and nine had more than one year of chemotherapy. Nine of the 25 children had pneumoperitoneum for varying lengths of time, four had pneumothorax, three had temporary phrenic nerve interruptions, and one had had a extrapleural pneumothorax. It was felt that pneumoperitoneum had been of appreciable value in most of those cases in which it was used, whereas, the benefit from the other ancillary measures mentioned was doubtful. Extra-pulmonary tuberculosis was significant in one patient, a child who had had tuberculous meningitis and Pott's disease. These lesions were controlled before pulmonary surgery was considered.

A tracheobronchial tree grossly free of any tuberculous endobronchi- tis was a prerequisite for resection. All patients were bronchosoped preoperatively. Six had endobronchitis necessitating postponement of surgery. These responded to increased dosage of streptomycin augmented with periods of aerosol inhalation of pencillin and streptomycin, so that subsequent bronchoscopic inspection demonstrated complete clearing of the endobronchitis. At the present time, streptomycin is used in place of dihydrostreptomycin.

There were 24 resections completed in the 25 children (Table 1). There were five pneumonectomies, four on the left, one on the right; 15 lobectomies, and four segmental resections. There is no case of bilateral resection. In one instance, resection was not completed. This was in a 15 year old girl who developed cardiac arrest during the hilar dissection for a contemplated pneumonectomy. Resuscitative measures, including rhythmic manual systole, were successful in re-establishing apparently normal cardiac action and the chest was promptly closed. The child expired about one hour later however, despite all further efforts. There was one other death. This occurred on the seventh postoperative day.
TABLE 1 OPERATIVE PROCEDURES IN 25 PATIENTS

<table>
<thead>
<tr>
<th>Segmental Resection</th>
<th>No. of Cases</th>
<th>No. of Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apico-posterior of Left Upper Lobe</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Basal of Left Lower Lobe</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lobectomies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Upper</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Right Upper and Superior Segment of Right Lower Lobe</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right Middle and Lower</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Right Middle</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Right Lower</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Left Upper</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Pneumonectomies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Left</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Thoracotomy, No resection</td>
<td></td>
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</tr>
</tbody>
</table>

following left pneumonectomy in a 12 year old girl. Death was due to massive spread of the tuberculous infection into the contralateral lung. In this girl all sputum specimens were positive for tubercle bacilli despite seven months of dihydrostreptomycin.

Postoperative Complications

There were surprisingly few complications postoperatively. As reported in the literature previously, these young patients sometimes have a fear of deep breathing and coughing. Consequently, retained bronchial secretions may become a major problem. Our patients were cooperative. Preoperatively they were instructed to breathe deeply and cough, and they were even rehearsed. This proved beneficial in alleviating some of their fears. Tracheal aspiration was used on two or three occasions, and bronchoscopic aspiration of retained secretions was not necessary in any case.

As seen in Table II, there were two cases of contralateral spread. One ended in death, being very fulminating in nature. The other case was controlled by continuation of chemotherapy in the form of streptomycin and PAS. This second case of contralateral spread occurred in a 12 year old girl who had left pneumonectomy for large cavitary disease with scattered disease also in the right lung. She had positive sputum preoperatively and received just four months of streptomycin preoperatively. Her sputum was quickly converted and the disease came under control. She was discharged arrested 26 months postoperatively.

There was one case of tuberculous empyema following left basilar segmentectomy. This quickly cleared with repeated aspiration and chemotherapy. As noted, there was no bronchopleural fistula, wound infection, or other complication.

TABLE II POSTOPERATIVE COMPLICATIONS

<table>
<thead>
<tr>
<th>Complication</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchopleural Fistula</td>
<td>0</td>
</tr>
<tr>
<td>Empyema (closed) Tuberculous</td>
<td>1</td>
</tr>
<tr>
<td>Contralateral Spread</td>
<td>2</td>
</tr>
<tr>
<td>Wound Infection</td>
<td>0</td>
</tr>
</tbody>
</table>

(One fulminating resulting in death 7 days postoperatively)
Pathology

1. Preoperatively an attempt was made to predict the pathologic changes to be found in the diseased lung. This was based on the chronologic history of the patients, disease, and roentgenographic interpretation. The resected specimens were carefully studied and found to substantiate our preoperative impression in 21 of the 25 cases. (The autopsy specimen of the case of cardiac arrest was included). In the four cases in which our prediction was in error, instead of the expected cavitation, the specimen showed bronchiectasis or fibrocaceous disease alone. One specimen showed a thin-walled, cystic lesion with fibrous lining, showing no signs of gross or microscopic tuberculous disease. This was either an example of so-called "open healing," or else a cystic dilatation distal to tuberculous endobronchial disease. The above has shown that the preoperative impression may be expected to correlate closely with the disease demonstrated in the surgical specimen.

2. Essentially, the disease found in the surgical specimens may be classified as follows:

<table>
<thead>
<tr>
<th>Disease Description</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrocaceous Tuberculosis with cavitation</td>
<td>11</td>
</tr>
<tr>
<td>Fibrocaceous Tuberculosis with calcification</td>
<td>5</td>
</tr>
<tr>
<td>Fibrocaceous Tuberculous foci</td>
<td>6</td>
</tr>
<tr>
<td>Tuberculous Bronchiectasis</td>
<td>1</td>
</tr>
<tr>
<td>Fibrosis with Cystic Formation</td>
<td>1</td>
</tr>
<tr>
<td>Fibrosis</td>
<td>1</td>
</tr>
</tbody>
</table>

In addition to the major changes described above, there was found varying degrees of involvement with bronchiectasis, atelectasis, fibrosis and endobronchitis.

Results

All patients to date have been discharged as arrested in the postoperative period which has varied from three to 24 months. All 23 surviving resectional surgery are living and well, and are free of any signs of active tuberculosis. All are pursuing normal physical activity.

These patients have been followed in the Clinic Division with repeated roentgenograms, sputum and gastric lavage cultures and have been found to be free of acid-fast organisms.

Case Reports

D. W. An 11½ year old colored girl admitted to M.T.S. on February 11, 1953, had insidious onset of disease. The admission x-ray film showed extensive bilateral disease; sputum was positive. After 90 days of chemotherapy in the form of streptomycin, isoniazid and PAS, she showed remarkable improvement, and pneumoperitoneum was initiated.

After 14 months therapy, cultures became negative; there was further contraction of disease in the right apex. After 12 months of chemotherapy, she was reviewed at the Surgical Conference. She had atelectatic right upper lobe with some scattered lesions throughout both lung fields. On October 5, 1954 right upper lobectomy and superior segmentectomy was performed.

The pathologic report showed the right upper lobe to be the seat of many discrete and confluent fibrocaceous nodules measuring up to 1 cm. in diameter. In the superior segment of the lower lobe complete replacement by large fibrocaceous foci up to 2 cm. in diameter was noted. The caseous content could be easily evaluated.
RESSECTION FOR PULMONARY TUBERCULOSIS

She made an uneventful recovery and was given chemotherapy for 3½ months following surgery, and was discharged on January 29, 1955, being classified as inactive for the past 10 months. Follow-up questionnaire indicates she is well and free of active disease.

A. M. A 12 year old colored girl admitted to sanitarium on June 27, 1949 after insidious onset of disease dating to March 1949, with diagnosis of primary tuberculosis. X-ray film showed dense pneumonic infiltration in the upper half of the left lung. She had 20 days of streptomycin before admission. This was continued for 60 days starting November 7, 1949. Bronchoscopic examination on July 13, 1949 was essentially negative. The surgical section reviewed the case and recommended left pneumonectomy on the basis of increased disease in the left lung, with the upper lobe entirely excavated and the lower lobe demonstrating consolidation. The right lung was free of demonstrable disease. Preoperative bronchoscopy showed no contraindication to surgery; however, a narrowing of the left main stem bronchus was noted. On June 2, 1950 left pneumonectomy was performed. This was complicated by contralateral spread in the right upper lobe. After this she was treated with dihydrostreptomycin and PAS, 12 gms. daily. After 90 days this lesion showed improvement. Chemotherapy was continued for 210 days. There was complete resolution of the right upper lobe spread by this time.

The resected lung showed a 3.5 cm. cavity in the upper portion surrounded by dense scar. The remaining portion of the lung showed numerous scattered caseous foci. A second cavity in the right upper lobe was 1.8 cm. in diameter and was filled with inspissated material.

Weight gain continued and sputum and stomach wash cultures were persistently negative. Last positive sputum was on April 9, 1951. On July 3, 1952 she was discharged as pulmonary tuberculosis, far advanced, inactive. She has been followed since discharge in the clinic division and found free of active disease, and carrying on normal school activities.

M. A. Admitted to the sanitarium in March 1952 at age of 19 months, by transfer from a private general hospital. He had an acute pneumonic onset in November 1951 with fever, chills and convulsions. Primary tuberculosis was diagnosed and he was treated with streptomycin and promizale at the private hospital. Figure VII shows the chest X-ray film in March 1952. Treatment at M.T.S. consisted of isoniazid, August 1952 to May 1954; PAS, May 1953 to May 1954; and streptomycin, January 1954 to March 1954. On treatment the infiltrate on the right resolved and the lesion on the left slowly shrank to a circumscribed mass 3 cm. in diameter in the left upper lobe. This mass showed stippled calcification (Fig. VIII). All gastric and bronchial cultures were negative for acid-fast bacilli.

In January 1954 (age 3½ years) the residual lesion was removed by resection of the apico-posterior segment of the left upper lobe. The pathologist reported a 2 cm. caseous focus surrounded by dence scar and showing early calcification.

He was discharged as Inactive Primary Tuberculosis in June 1954 after a smooth convalescence.

Discussion

It is important to realize that both deaths and all but one of the complications occurred in the group of seven patients operated prior to 1953. This, of course, is attributed to the inadequate or interrupted chemotherapy in common usage at that time. In the 17 patients resected in 1953 and 1954, there was no mortality and only one complication, an empyema which responded promptly. There is no doubt that the determining factor in reducing the postoperative complications was the benefit obtained from adequate, long-term uninterrupted chemotherapy.

Children withstand surgery well and make rapid recoveries. They are more alert and less sensitive to pain; therefore, they cough and handle secretions better than adults. Their tolerance of anesthesia is better, they are soon ambulatory and the recovery period is shorter. Also, the resiliency of the lung tissue in children reduces the tendency to bronchial insufficiency of the remaining lung as is often the problem encountered in adults. Children also withstand a greater loss of pulmonary tissue.

In review of this series it is obvious that the indication for pulmonary resection in children is essentially similar to that in adults, i.e., presence of significant fibro-caseous foci, with or without cavitation, persisting after an adequate period of uninterrupted chemotherapy.

SUMMARY

1. Twenty-five children ranging in age from two years and nine months to 15 years had excisional surgery for pulmonary tuberculosis.

2. There was one operative death, a cardiac arrest, and three postoperative complications, one resulting in death. This represents 8 per cent mortality.

3. All surviving patients are living and well, pursuing normal activity. No sign of active pulmonary disease was present within a 15 to 36 month follow-up period.

4. It has been demonstrated that pulmonary resection is a safe and effective mode of therapy for selected children with pulmonary tuberculosis.
Addendum: Since the end of 1954, 10 additional children in this age group have successfully undergone pulmonary resection without complication. There was no death. Therefore, the mortality figures may be revised as of this time to 2.9 per cent. A follow-up report from the out-patient clinic states that no difficulty has arisen in any of these children as of July 1, 1957.

RESUMEN
1. Se realizó cirugía de excisión en 25 niños de edades desde 2 años y 9 meses hasta 15 años, por tuberculosis pulmonar.
2. No hubo muertes operatorias, hubo un paro cardíaco y tres complicaciones post-operatorias, una de ellas motivo un fallecimiento.
3. Todos los que sobreviven están bien con actividad normal. No ha aparecido signo alguno de enfermedad activa dentro de un periodo de seguimiento de 15 a 26 meses.
4. Se ha demostrado que la resección pulmonar es un procedimiento seguro y efectivo en el tratamiento de casos escogidos de tuberculosis pulmonar en los niños.

RESUMÉ
1. Choisit 25 enfants âges de 2 ans et 9 mois à 15 ans, on pratiqua une exérèse chirurgicale pour tuberculose pulmonaire.
2. Il y eut une mort opératoire, par arrêt cardiaque, et trois complications post-opératoires, dont l’une se termina par la mort. Ceci représente un taux de mortalité de 8%.
3. Tous les malades survivants sont en bonne santé, poursuivant une activité normale. Il n’y eut aucun signe d’affection pulmonaire active pendant la période de contrôle allant de 15 à 36 mois.
4. Il est ainsi démontré que la résection pulmonaire est un moyen sans danger et efficace pour certains enfants atteints de tuberculose pulmonaire.

ZUSAMMENFASSUNG
1. Es wurden 25 Kinder im Alter zwischen 2 Jahren und 9 Monaten bis zu 15 Jahren wegen Lungentuberkulose mit Resektion behandelt. 2. Es kam zu einem operativen Todesfall, einem Herzstillstand und 3 postoperativen Komplikationen, davon eine mit tödlichem Ausgang. Somit betrug die Mortalität 8%.
4. Es liess sich zeigen, dass die Lungensektion in ausgedehnten Fällen ein sicheres und wirksames Behandlungsverfahren darstellt für Kinder mit Lungentuberkulose.

REFERENCES