Chapter 14
Surgery for Pulmonary Tuberculosis and Its Indications

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14.1 History of Surgery for Pulmonary Tuberculosis patients

It has been almost 200 years since the development of pneumosurgery (Waldhausen et al. 1996). In 1821, Milton Anthony completed the first lung resectional surgery in the world without anesthesia (Brewer 1982). Pulmonary tuberculosis (PTB) surgery started in the late nineteenth century, during a mass outbreak of PTB and before the advent of antibacterial agents. At that time, the only way to cure PTB was to prescribe rest and nutrition, which meant conservative therapy such as sunbathing on the beach and taking vitamins. It is believed that the reason for the failure of this approach was that the lung continued working without break, complicating the healing from PTB. In surgery, the burden of the lung could be diminished and PTB might be cured. In 1822, Carson first proposed artificial pneumothorax technology. In 1873, Wilms (1913) reported paravertebral thoracoplasty. In 1879, Estlander first cured tuberculous empyema by cutting the costal bone and causing chest wall collapse (Krassas et al. 2010). In 1911, Stuertz performed phreniclasia with collapse treatment for curing PTB. It was a simple operation that making a small incision in

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the neck, crushing a section of the phrenic nerve with a ring clamp, and causing a short time paralysis. But permanent phrenic nerve paralysis was a serious risk that could interfere with lung function, so this procedure was abandoned. Since 1935, thoracoplasty became an increasingly performed operation. Alexander (1937) proposed aboral lateral thoracoplasty, which could reduce the death rate to 2 % or lower after the operation. As a result, he is credited as the father of modern thoracoplasty.

In 1937, Wang Datong from Peking Union Medical College Hospital completed a pulmonary resection for a bronchiectasis patient, which was the first case in China. Then this surgery was extended to PTB patients (Li 2006). In 1943, investigators for the first time made a detailed description of the blood vessels and bronchi of all lung lobes and named them, which provided the foundation for lung surgery anatomy (Pomerantz and Mault 2000).

In the 1940s and 1950s, it was learned that collapse treatment led to pathological changes in patients' bodies. As a result, fewer patients opted for collapse treatment. Finally, it was replaced by lung resection in conjunction with chemotherapy (Xin and Ge 1964). Even now, lung resection therapy remains the main method for PTB surgery. In the 1950s, PTB surgery constituted 82 % of all the lung resection operations at Shanghai Second Tuberculosis Hospital in China (Wu et al. 1959; Special Study Group for Tuberculosis in Shanghai 1960).

14.1.1 PTB Surgery and Chemotherapy

As new anti-tuberculosis (TB) drugs are developed, more reasonable chemotherapeutic programs are implemented. As a result, most PTB patients can be healed by chemotherapeutic treatment. In the 1970s, most patients with initial treatment could be cured through a reasonable chemotherapeutic program with rifampin. Fox et al. (1999) proposed that surgery was unnecessary except for patients suffering from complications beyond PTB. This suggested that medical treatment could take the place of surgery. However, the lack of new chemotherapy drugs over time combined with incomplete chemotherapy and/or patient compliance has led to an increased number of patients with drug-resistant and Multidrug-resistant TB (MDR-TB).

Drug-resistant and MDR-TB has become a growing problem. The challenges of MDR-TB treatment include long-term treatment, high cost, serious side effects, ineffective chemotherapy, low rate of healing, and a high rate of relapse, illness, and death. Because of the emergence of MDR-TB, curing PTB surgically became an option again. Surgery for PTB can not only reduce the bacteria quantity and shorten the time for medication treatment but also eliminate the source of TB immediately by reducing its spread. Lalloo et al. (2006) suggested that surgery for curing MDR-TB could prevent the bacterial spread and protect the healthy lung issue. In 2005, Takeda et al. reported that 17.6 % of 199 operations on PTB patients were MDR-TB related. The PTB surgery patients ranged in age from 2 years to 78 years; 60–70 % were male and 20–40 % were female (Pomerantz et al. 2001; Takeda et al. 2005). MDR-TB patients especially may benefit from surgery. According to the statistical analysis, 2–5 % of PTB patients need surgery today (Sung et al. 1999).

14.2 Indications for PTB Surgery

The primary requirement for PTB surgery is that the patient's condition is stable after medical treatment, with unresolved infection but absence of active and diffuse bacteria (Yan and Duanmu 2003). The indications for PTB surgery treatment are:

- After normal anti-TB chemotherapy, sputum bacteriological examination remains positive or is intermittently positive and the lung lesion is localized.
- Though sputum bacteriological examination is negative, there are irreversible changes such as tuberculous cavity, destroyed lung, atelectasis, or large bullae. Respiratory function could be improved by removing nonfunctioning lung tissue and balancing the ventilation-perfusion ratio.
- TB has been resolved or incompletely resolved, but there are some complications such as bronchiectasis, recurrent hemoptysis, tuberculous empyema, or cancer.
- The most important condition for PTB surgery is that the bacteria are sensitive to two or more anti-TB drugs. Surgery can remove infected tissue, but it cannot eliminate all the TB bacteria. That is why effective anti-TB treatment after surgery is essential. If the bacterial strain in the patient is not sensitive to two or more of the anti-TB drugs, surgery alone may be very dangerous. For MDR-TB and extensively drug-resistant (XDR) TB patients who responded poorly to anti-TB chemotherapy, surgery could be performed if conditions permit. The surgical success rate is very low for MDR-TB and XDR-TB patients, so performing surgery before the bacteria becomes MDR or XDR is important.
- It is important to make sure patients understand and accept the surgical risks and treatment program. PTB patients who need surgery do not need to have their TB confined to one lobe or one side of the lung. It does not impact the operation effect if the rest of the lung is under control. Shiraishi et al. (2004) have reported that of 30 MDR-TB patients, only 6 had no significant lesions in the other side of the lung. If the rest of the lung or contralateral lung lesion is stable, or fibrous or cord-like lesions change, it will not affect the surgical treatment of lung resection.

14.3 Contraindications for PTB Surgery

- Patients with poor cardiopulmonary function who cannot tolerate surgery.
- After surgery, there will still be active TB in the rest of the lung or the contralateral lung.
- There is active bronchial TB in the opening where the lobe is to be resected.
- The bacterial strain in the patient is completely resistant to first-line and second-line anti-TB drugs.
- The patient refuses surgery.

14.4 Preoperative Preparation

Like other thoracic surgeries, TB patients receiving a lung resection need preoperative cardiopulmonary function tests to ascertain whether surgery can be tolerated. In addition, bronchoscopy must be carried out before surgery to make sure that there is no bronchial TB in the opening where the lung will be resected. Bronchial TB is one of the most serious risks causing bronchial stump fistulas after surgery. If possible, surgery should be carried out after the bacterial culture and drug susceptibility test, in order to guide the postoperative anti-TB treatment. The most important preoperative requirement is regular anti-TB treatment for 3–6 months before surgery. Preoperative anti-TB treatment is directly related to postoperative mortality and complication rates. In general, surgery should be performed when the level of TB bacteria is lowest in the body. Shiraishi et al. (2004) reviewed 30 MDR-TB cases. Patient infections were resistant to a range of 2–9 drugs. Preoperative chemotherapy was given for 3 months with 3–6 drugs (including fluoroquinolones for 80 % of the patients) as appropriate given sensitivity testing results. Naidoo and Reddi (2005) reported 23 patients using second-line anti-TB drugs for at least 3 months prior to surgery. Orki et al. (2009) reported 55 patients receiving a range of 3–6 anti-TB drugs for 2–8 months before surgery. Mohsen et al. (2007) reported 23 MDR-TB patients receiving 4–6 drugs (according to their drug susceptibility test) for at least 3 months. Tang and Xiao (2003) believed that MDR-TB patients should take anti-TB chemotherapy for at least 2 months prior to surgery. TB patients, especially MDR-TB patients, may be malnourished because of their prolonged course and long-term consumption. Addressing the nutritional needs has also become an important part of preoperative preparation. If necessary, provide enteral or parenteral nutrition to patients 2–4 weeks before surgery to reduce complications.

14.5 Methods of PTB Surgery

There are two types of methods used in TB surgery: collapse therapy and the removal of primary lesions (Waldhausen et al. 1996; Yan and Duanmu 2003). The aim of the first type is to collapse the lung and chest by removing part of the ribs to change the thoracic shape and promote the cavity closure. The effects of collapse therapy are not stable, because it is an indirect treatment. What's more, postoperative thoracic deformation is particularly noticeable, leading patients to reject this operation and prefer lesion removal instead. Different procedures are used to remove lesions according to their size and the area of the lung affected. The different types of excisions are wedge resection, lung segment resection, lobectomy, composite resection (resection of one or two lobes of the lung and a lung segment, mainly referring to the right middle and right upper lobe resection, or right lower and right middle lobectomy, or right upper and right lower lobe tip resection, or left upper and left lower lobe tip resection), pneumonectomy, and pleural pneumonectomy.

Wedge Resection is suitable for peripheral pulmonary lesions that are very focused, especially when it is difficult to distinguish the lesions from lung cancer. This procedure will be used when doing a biopsy for cancer confirmation, and small resections can be done via minimally invasive thoracoscopic surgery.

Lung Segment Resection or segmentectomy is a normal surgical procedure for TB treatment. It is widely used for resection of the left upper lobe segment, the tongue segment of left upper lobe, or the bilateral lower lobe tip segment. Treatment in surgery for the surface sections should be separated along the lung segment, and, for best results, the segment surface should not be sutured. If there is serious air leakage, a bioglue or surgical sealant can be sprayed at the point of the leak. Segment surfaces must not be handled with the stapler, for sutures make lung resections meaningless. The advantages are less removal of lung tissue, and lower impact on patients' lung function. Unfortunately, there are few patients whose lung lesions are limited to a segment and thus good candidates for lung segment resection.

Lobectomy is, generally speaking, the best procedure in surgical treatment of PTB. It has less effect on a patient's cardiopulmonary function and any complications can be more easily remedied. This procedure is particularly appropriate for patients with cavitary TB, where lesions are mainly focused on the upper lobe. As with wedge and lung segment resections, the procedure is only applicable in a small number of cases as TB is not often confined to one part of the lung. There are often some big lesions around the main lesions, especially in patients with incomplete lung fissures. This can lead to adjacent lung tissue being compromised. For complete clearing of lesions, compound removal is often necessary. For patients with lung lesions limited to one side, pneumonectomy should be adopted for its broader effect.

Pneumonectomy is often used in severe TB, including drug-resistant TB. The surgery removes the entire nonfunctioning lung of one side. In the short run, this not only removes the lesions, but also increases the blood oxygen saturation by cutting off the affected lung which blocked the supply of oxygen to the blood. However, long-term negative consequences cannot be avoided. Twenty years after pneumonectomy, the ligation of lung arteries can cause increased blood flow to the intact lung, which can lead to pulmonary hypertension or pulmonary heart disease.

Generally speaking, surgery for TB is more difficult than surgery for lung cancer. Due to long-term inflammation caused by TB, there are often extensive and closely located pleural adhesions. This can typically cause bleeding when separation is attempted. When parts are closely adhered, extrapleural separation should be used to reduce the bleeding and any damage to the surface of the lung. This can reduce excessive contamination and the need for a blood transfusion. Additionally, TB patients have a greater chance than cancer patients of having the hilar lymph node infected and inflamed by TB. Therefore, the adhesion with the surrounding lymph nodes is sometimes very close, leading to separation difficulty. For these reasons, lung excision surgery of TB patients (especially for MDR-TB patients) requires the use of a thoracoscope, which is difficult in surgery. Currently, thoracotomy is still recommended for TB surgery.

Thoracoscopic surgery has been widely used. It has been the routine treatment for many patients with mild illness (Wang and Yang 2006). However, some patients with more serious illness such as ones with extensive pleural adhesions cannot receive thoracoscopic surgery, due to its restrictions.

14.5.1 Surgical Anesthesia

General anesthesia uses double lumen intubation and one-lung ventilation to prevent the bacteria spread to the contralateral lung, and the classic surgical approach is to open the chest. Going into the chest through the posterior lateral incision in order to expose the chest fully is often used. With the rapid development of surgery in recent years, thoracoscopic lung resection has been widely used, both in China and abroad.

14.5.2 Laboratory Tests for Specimens after Surgery

In order to aid in anti-TB treatment after surgery, tests of resection specimens include not only additional pathological tests, but also routine bacteriological examinations, with some specimens taken for Lowenstein–Jensen culture and drug sensitivity tests. Culture susceptibility results can guide postoperative anti-TB treatment programs to improve their success rate.

14.6 The Complications and Treatment after Surgery

Due to the strict selection of cases, anesthesia technology development, and effective postoperative antituberculous therapy, the postoperative mortality and complication rates of lung resection for PTB patients have gradually decreased. Because general surgery in treatment of PTB in recent years has become a routine operation, specialized reports about its complications are rare. Comparatively, there are more reports on drug-resistant TB operations; the postoperative mortality and complication rates for surgery of drug-resistant PTB are higher than those of lung cancer (Kim et al. 2008; Yu and Fu 2009).

14.6.1 The Postoperative Mortality

In 1970s, before rifampicin was discovered, it was reported that the mortality rate from TB surgery was 2–5 %, and the complications rate was about 10–20 % (Jones 1957). In recent years, with the rapid developments in surgery and anesthesiology,

mortality and complications from general PTB surgery have been significantly reduced, but there is no evidence-based medical statistics report. The data published today mainly focuses on drug-resistant TB, especially MDR-TB.

Mohsen et al. (2007) reviewed 23 surgeries for MDR-TB. Of the 11 patients who underwent pneumonectomies, two developed postoperative empyema; of these, one developed additional complications including a bronchopleural fistula and died in hospital, yielding a mortality rate of 4.3 % (1/23). Yu and Fu (2009) reviewed 133 surgeries for MDR-TB and reported a postoperative mortality of 2.3 % (3/133), with 2 cases dying from postoperative respiratory failure and 1 other case caused by postoperative thoracic aortic rupture. Most of the postoperative deaths reported were pneumonectomy patients. Therefore, pneumonectomy should be taken into careful consideration.

14.6.2 Common Complications and Treatments

Bleeding is the most common complication in the surgical operation for PTB. This is common knowledge, but why is the risk of bleeding so much higher than other general surgical operations? The pleural cavity is under negative pressure, making it more susceptible to bleeding. After lung resection, pressure of the pleural cavity should be negative for patient's breathing. Thus, the surgical wound surface in the pleural cavity is completely exposed to negative pressure, which can turn small-scale intrathoracic bleeding into more significant bleeding or even a huge hemorrhage. Therefore, hemostatic requirements are more stringent in lung surgery than in general surgery.

Bronchopleural fistula (BPF) and empyema are the most difficult complications following PTB surgery, with high incidence and lasting effects on patients (Gu et al. 1964). Patients with endobronchial TB have a significant risk for developing BPF. The resection stump and its anatomical features can inherently create conditions for BPF. Normally, cartilage will support the bronchi, but after resection, the sutured stump will have some tension. Additionally, the optimal condition for surgical wound healing is contact between like tissues. After bronchial resection, the stump cannot contact similar tissue, and this affects healing. As a result, the development of a stump fistula has become one of the most common complications of PTB surgery. In order to solve the problem of postoperative bronchopleural fistula, intraoperative stump embedding after treatment has become an essential step in surgery. The stumps are usually embedded by a pedicled pleural valve, whereas a pedicled muscle flap could be better. From the early twentieth century on, much research has been focused on the bronchial stump suture methods. Xin Yuling, Hu Qibang, and Zhao Zhiwen from Beijing Tuberculosis and Thoracic Tumor Research Institute (now the Beijing Chest Hospital) improved the bronchial stump suture technique after lung resection by removing bronchial stump cartilage and suturing the stump layer to layer (Xin and Ge 1964). It significantly reduced postoperative bronchopleural fistula incidence, but has not been widely used because of its degree

of difficulty. With the development of surgical instruments, fasteners are usually used to treat the stump, but it is not yet known whether fasteners are better than sutures. In Yu and Fu's report of 133 cases of MDR-TB patients (2009), nine developed bronchial stump fistulas postoperatively. BPF was positively correlated with a preoperative sputum positive result, especially preoperative bronchial TB. Wang et al. (2008) reviewed 56 MDR-TB surgeries and also found that endobronchial TB was significantly correlated to the development of BPF. Bronchial stump reinforcement significantly reduced the incidence of BPF.

Fistula of the lung surface often occurs after pneumonectomy. Pulmonary surface damage is inevitable because of the operation trauma. But if it prolongs, it may cause serious complications such as thoracic cavity infection. There is no standard for the postoperative air leaks extent and time, but generally speaking, more than a week is considered abnormal. It can be fixed by glue or some other treatments.

A postoperative residual cavity after pulmonary resection is apparent. All the tissue above and around the chest cavity is bony. Only the diaphragmatic surface is soft. After the lung is resected, the original space is occupied by the remaining lung. The remaining lung cannot inflate to the exact shape as the one removed, so a residual cavity is inevitable. Usually, the stump will disappear completely after half a year, and a longer time is needed for the cavity to recover if one side of the lung has been completely resected.

14.7 Postoperative Treatment and Prognosis

Because PTB is a systemic disease, and surgery cannot completely resect lesions, postoperative antituberculous therapy has become one of the key points for a cure. It is suggested that anti-TB chemotherapy should continue for 1 year after surgery, especially for the patients who cannot be excluded from lung cancer. If performing surgery directly without preoperative chemotherapy, postoperative antituberculous therapy should always continue for at least 1 year. Postoperative chemotherapy recommendations range from a minimum of 6 months to a maximum of 84 months, with the longer treatment times suggested for patients with MDR-TB (Tang and Xiao 2003; Takeda et al. 2005; Mohsen et al. 2007; Shiraishi et al. 2009; Yu and Fu 2009). Specific antituberculous programs can refer to what was administered before surgery or can be implemented according to the bacterial culture and drug sensitivity results of the specimens obtained from the operation. Generally speaking, if regular postoperative anti-TB drug therapy is implemented, PTB patients, including MDR-TB patients, can gain satisfactory prognosis with surgical treatment.

In the last 10 years, with the increased number of MDR-TB patients, the number of patients who require surgery has also increased. However, it must be emphasized that surgery is not the final treatment for PTB, especially for the MDR-TB patients. The factors for an effective surgery include the properly indicated patients, patients' understanding and cooperation, adequate preoperative preparation, proper operation time, an experienced operation team, and regular postoperative treatment.

Surgical treatment of TB can not only effectively reduce the patient's suffering, but it can also effectively eliminate an infectious source. Surgery is an indispensable method in the TB control process.

References

Alexander, J. (1937). *The collapse therapy of pulmonary tuberculosis*. Springfield, IL: Charles C Thomas.

Brewer, L. A., III. (1982). Historical notes on lung cancer before and after Graham's successful pneumonectomy in 1933. *American Journal of Surgery, 143*(6), 650–659.

Carson, J. (1822). *Essays, physiological and practical*. Liverpool: F.B. Wright.

Fox, W., Ellard, G. A., & Mitchison, D. A. (1999). Studies on the treatment of tuberculosis undertaken by the British Medical Research Council tuberculosis units, 1946-1986, with relevant subsequent publications. *International Journal of Tuberculosis and Lung Disease, 3*(10s2), S231–S279.

Gu, K. S., Huang, O. L., Wu, S. C., Cao, Q. H., & Qiu, Z. K. (1964). Surgical treatment for bronchopleural fistula after resectional surgery of pulmonary tuberculosis. *Chinese Journal of Antituberculosis, 2*, 434–437.

Jones, J. C. (1957). Early experience with pulmonary tuberculosis in the surgical management of pulmonary tuberculosis. In J. D. Steele (Ed.), *The surgical management of pulmonary tuberculosis*. Springfield, IL: Charles C Thomas.

Kim, D. H., Kim, H. J., Park, S. K., Kong, S. J., Kim, Y. S., Kim, T. H., et al. (2008). Treatment outcomes and long-term survival in patients with extensively drug-resistant tuberculosis. *American Journal of Respiratory and Critical Care Medicine, 178*(10), 1075–1082. doi:10.1164/rccm.200801-132OC.

Krassas, A., Grima, R., Bagan, P., Badia, A., Arame, A., Barthes, F. L. P., et al. (2010). Current indications and results for thoracoplasty and intrathoracic muscle transposition. *European Journal of Cardio-Thoracic Surgery, 37*(5), 1215–1220.

Lalloo, U. G., Naidoo, R., & Ambaram, A. (2006). Recent advances in the medical and surgical treatment of multi-drug resistant tuberculosis. *Current Opinion in Pulmonary Medicine, 12*(3), 179–185.

Li, Z. J. (2006). The development and prospect of surgery of the chest in our country. *Chinese Journal of Surgery, 41*(14), 937–939.

Mohsen, T., Zeid, A. A., & Haj-Yahia, S. (2007). Lobectomy or pneumonectomy for multidrug-resistant pulmonary tuberculosis can be performed with acceptable morbidity and mortality: A seven-year review of a single institution's experience. *The Journal of Thoracic and Cardiovascular Surgery, 134*(1), 194–198. doi:10.1016/j.jtcvs.2007.03.022.

Naidoo, R., & Reddi, A. (2005). Lung resection for multidrug-resistant tuberculosis. *Asian Cardiovascular and Thoracic Annals, 13*(2), 172–174.

Orki, A., Kosar, A., Demirhan, R., Saygi, A., & Arman, B. (2009). The value of surgical resection in patients with multidrug resistant tuberculosis. *The Thoracic and Cardiovascular Surgeon, 57*(4), 222–225. doi:10.1055/s-0029-1185458.

Pomerantz, B. J., Cleveland, J. C., Jr., Olson, H. K., & Pomerantz, M. (2001). Pulmonary resection for multi-drug resistant tuberculosis. *The Journal of Thoracic and Cardiovascular Surgery, 121*(3), 448–453. doi:10.1067/mtc.2001.112339.

Pomerantz, M., & Mault, J. R. (2000). History of resectional surgery for tuberculosis and other mycobacterial infections. *Chest Surgery Clinics of North America, 10*(1), 131–133.

Shiraishi, Y., Katsuragi, N., Kita, H., Tominaga, Y., Kariatsumari, K., & Onda, T. (2009). Aggressive surgical treatment of multidrug-resistant tuberculosis. *The Journal of Thoracic and Cardiovascular Surgery, 138*(5), 1180–1184. doi:10.1016/j.jtcvs.2009.07.018.

Shiraishi, Y., Nakajima, Y., Katsuragi, N., Kurai, M., & Takahashi, N. (2004). Resectional surgery combined with chemotherapy remains the treatment of choice for multidrug-resistant tuberculosis. *The Journal of Thoracic and Cardiovascular Surgery, 128*(4), 523–528. doi:10.1016/j.jtcvs.2004.06.012.

Special Study Group for Tuberculosis in Shanghai. (1960). Comprehensive report on surgical treatment for tuberculosis in Shanghai (General Assembly to speak). *Chinese Journal of Antituberculosis, 4*, 194–196.

Stuertz, E. (1911). Kunstliche zwerchfellahmung bei schweren chronischen elnseitigen lungenerkrankungen. *Deutsche Medizinische Wochenschrift, 37*, 22–24.

Sung, S. W., Kang, C. H., Kim, Y. T., Han, S. K., Shim, Y. S., & Kim, J. H. (1999). Surgery increased the chance of cure in multi-drug resistant pulmonary tuberculosis. *European Journal of Cardio-Thoracic Surgery, 16*(2), 187–193.

Takeda, S. I., Maeda, H., Hayakawa, M., Sawabata, N., & Maekura, R. (2005). Current surgical intervention for pulmonary tuberculosis. *The Annals of Thoracic Surgery, 79*(3), 959–963.

Tang, S. J., & Xiao, H. P. (2003). Combined therapy for multi-drug resistant tuberculosis. *Chinese Journal of Tuberculosis and Respiratory Diseases, 26*(11), 715–718.

Waldhausen, J. A., Pierce, W. S., & Campbell, D. B. (1996). *Surgery of the chest* (6th ed.). St. Louis: Mosby.

Wang, H., Lin, H., & Jiang, G. (2008). Pulmonary resection in the treatment of multidrug-resistant tuberculosis: A retrospective study of 56 cases. *The Annals of Thoracic Surgery, 86*(5), 1640–1645. doi:10.1016/j.athoracsur.2008.07.056.

Wang, J., & Yang, F. (2006). Current development and direction of minimally invasive chest surgery in China. *National Medical Journal of China, 86*(33), 2305–2306.

Wilms, M. (1913). Dis pfilerresektion der rippen zur verengerung des thorax bei lunggentuberkulose. *Therapie der Gegenwart, 54*, 17–24.

Wu, Y. K., Zhu, Z. K., Shao, L. F., & Huang, X. M. (1959). The ten years achievements on surgery treatment against tuberculosis in our country. *Chinese Journal of Antituberculosis, 4*, 6–10.

Xin, Y. L., & Ge, B. S. (1964). The application of thoracoplasty in the surgical treatment for pulmonary tuberculosis—A 100 cases study. *Chinese Journal of Antituberculosis,* (2), 438–440, 465–466.

Yan, B. Y., & Duanmu, H. J. (2003). *Phthisiology*. Beijing: Beijing Publishing House.

Yu, D. P., & Fu, Y. (2009). Surgical treatment of 133 cases of multi-drug-resistant pulmonary tuberculosis. *Chinese Journal of Tuberculosis and Respiratory Diseases, 31*(6), 450–453.