COMMENTSARY

Ten years of rapid development of pediatric thoracic surgery in China

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China’s pediatric surgery is a specialty first established in 1954 by Prof. Jinzhe Zhang, an academician of the Chinese Academy of Engineering. During the same period, several professors (most notably Anquan Ma, Yaxiong She, Zanyao Wang, and Erchang Tong) successively established pediatric surgery specialties in Shanghai and Wuhan, as well as in Shenyang, Chengdu, Chongqing, and Guangzhou. Initially, pediatric surgery primarily focused on treatment of emergencies, such as trauma, burns, surgical infection, and acute abdomen. Subsequently, as economic conditions improved, emergency cases decreased; in contrast, cases of congenital malformation increased annually as a focus of pediatric surgery.

Establishment of the specialty of pediatric thoracic surgery

With the establishment of pediatric surgery subspecialties nationwide, as well as continuous enhancement in the diagnosis and treatment of pediatric surgery, patients’ families have begun to expect more professional diagnosis and treatment of different local and systemic conditions in pediatric surgery. Beginning from general pediatric surgery, subspecialties of pediatric surgery have been gradually established; these include orthopedics, neonatal surgery, cardiothoracic surgery, oncological surgery, and plastic surgery. Beijing Children’s Hospital affiliated to Capital Medical University established subspecialties of pediatric surgery in 1972, in the manner advocated by Dr. Jinzhe Zhang; these included thoracic surgery, which was then headed by chief physician Feng Xue and focused on treating pediatric patients with thoracic diseases. At its inception, the department had four ward beds and provided services for infectious diseases, such as empyema, lung abscess, and tuberculosis; it then gradually expanded its services to include diagnosis and treatment of mediastinal tumor, pectus excavatum, pectus carinatum, hiatal hernia, diaphragmatic hernia, congenital pulmonary cyst, as well as other diseases.

In the late 1980s, Professors Tingze Hu and Wenying Liu also established the subspecialty of pediatric thoracic surgery at West China Hospital (Sichuan University), and began to conduct some basic investigations regarding infectious diseases and pectus excavatum. At that time, in most other children’s hospitals in China, the diagnosis and treatment of pediatric thoracic diseases was performed by the cardiothoracic surgery department, or by the general surgery department. A small number of pediatric thoracic diseases were diagnosed and treated by the thoracic surgery department in adult general hospitals.

Reasons for slow development of pediatric thoracic surgery

(1) High surgical risk and a variety of complications
Pediatric thoracic surgery is not a scaled-down version of adult thoracic surgery. First, different disease spectra are involved in each type of surgery. Adults may exhibit lung cancer or esophageal cancer, which is rarely encountered in children. Malignant pulmonary tumors in children also differ from those in adults (e.g., the uncommon pleuropulmonary blastoma). Pediatric thoracic diseases primarily comprise congenital malformations of many types, some of which are unique to pediatric patients but exhibit relatively low incidence rates. Second, surgical procedures and postoperative management performed for adult patients cannot be directly applied for use in pediatric patients. For example, early pediatric thoracotomy was performed using the approach for adult thoracotomy: partial ribs were excised, and intercostal muscles were sutured after surgery to close the thoracic cavity, without the use of an indwelling closed thoracic drainage tube. Because of the thin nature of the thoracic wall, pediatric patients often died of tension pneumothorax after surgery.

Moreover, in the early period, anesthetic and life-support techniques were relatively immature and the single-lung ventilation technique was unavailable; thus, it was difficult to control respiration during surgery, and the surgical field could not be clearly exposed. In this context, postoperative care and perioperative management were insufficient. Because of the extended duration of thoracotomy, hypothermia was frequently encountered, and postoperative scleroderma often occurred after surgery, particularly among newborns. Because of the extended immobilization required after surgery, postoperative pneumonia and pulmonary atelectasis often occurred and impeded postoperative respiration; in some instances, they were life-threatening. Initially, there was no effective treatment; however, implementation of airway management enabled aspiration of sputum and oxygen delivery via positive end-expiratory pressure.

(2) Low incidence rate and relative difficulties in diagnosis

Compared with conditions managed by pediatric general surgery, cardiac surgery, orthopedics, and other specialties, diseases requiring pediatric thoracic surgical treatment have a relatively low incidence rate. Pediatric patients may develop the symptoms of thoracic diseases at a relatively late stage in the course of disease, and early symptoms primarily comprise cough and fever, which may not be easily differentiated from those of respiratory tract infection. In the past, when more serious symptoms (e.g., dyspnea) occurred, limited diagnostic and treatment capabilities resulted in the inability to achieve appropriate therapeutic value when medical treatment was administered. Moreover, few hospitals had access to computed tomography and ultrasound technology, so it was difficult to diagnose thoracic diseases.

(3) Few subspecialists and inadequate attention

Roughly 10 years ago, there were fewer than 10 physicians fully engaged in the diagnosis and treatment of pediatric thoracic diseases. Some departments were not yet independent from general thoracic surgery, such as the department of cardiothoracic surgery; notably, because diseases requiring cardiac surgery are more complicated, requiring hazardous operation and difficult postoperative management, greater attention was given to cardiac surgery. Because of the increased incidence of diseases requiring general surgery, relative to diseases requiring thoracic surgery, surgeons in general surgery departments primarily focused on the diagnosis and treatment of diseases requiring general surgery; therefore, very few physicians focused on treatment of pediatric thoracic diseases.

Ten years of rapid development of pediatric thoracic surgery in China

Over the past 40–50 years, pediatric thoracic surgery generally developed more slowly than other subspecialties of pediatric surgery. In the most recent decade, Chinese physicians began to focus more intently on pediatric thoracic surgery, and more physicians became involved in the diagnosis and treatment of pediatric thoracic diseases. Such rapid development was based on scientific progress, introduction of thoracoscopic surgery, and the widespread application of minimally invasive Nuss surgery for pectus excavatum.

(1) Nuss surgery for pectus excavatum propelled development of pediatric thoracic surgery

Minimally invasive Nuss surgery for pectus excavatum was a milestone in the surgical treatment of pectus excavatum; notably, this was an important factor in stimulating the development of pediatric thoracic surgery in China. Most pediatric surgical methods were developed on the basis of methods used in adult surgery; pediatric thoracic surgery used this approach. Pectus excavatum is a type of congenital disease; its unique nature required development of a corrective method in pediatric surgery, prior to its application in adult surgery. In the 1980s, the Ravitch operation was introduced into China; a number of pediatric surgeons (and very few adult thoracic surgeons) then became involved in treatment of pediatric thoracic diseases. However, because of its relatively narrow indications, relative invasiveness, and complicated operation, pediatric thoracic surgery did not subsequently develop rapidly. At the beginning of this century, Nuss surgery—a revolutionary thoracic wall surgery with no requirement for a median chest incision, osteotomy, or muscle diastasis—was introduced to China. Beijing Children’s Hospital, Peking University First Hospital, and the Second Affiliated Hospital of Xi’an Jiaotong University began to implement minimally invasive Nuss surgery in treatment of pectus excavatum.
In April 2007, the thoracic surgery department of Beijing Children’s Hospital organized the first workshop regarding minimally invasive Nuss surgery for pectus excavatum and recruited more than 150 trainees. Prof. Donald Nuss, the inventor of Nuss surgery, attended in-person to teach and demonstrate the surgery; with the participants, he discussed the procedures and his experience in Nuss surgery for pectus excavatum. Prof. Nuss also authorized Beijing Children’s Hospital to be the sole training center for minimally invasive repair of pectus excavatum (MIRPE) in China. Because Nuss surgery involves some risks, the training center serves as a platform for establishing nationwide authoritative training bases and communication platforms for pediatric thoracic surgeons, as well as for training groups of technical specialists engaged in thoracic wall corrective surgery. Thus, minimally invasive treatment of thoracic wall malformations could be performed more extensively and safely.

This workshop session was followed by six sessions in Hangzhou, Hong Kong, and other locations; these were held to discuss surgical techniques, as well as methods to prevent surgical complications, reduce surgical risks, and enhance surgical safety. The widespread application of Nuss surgery for pectus excavatum attracted a considerable number of pediatric surgeons to focus on and participate in treatment of pediatric thoracic diseases; additionally, adult thoracic surgeons gained a new understanding of pediatric thoracic surgery, and some also began to perform pediatric thoracic surgery.

(2) Development of thoracoscopic surgery stimulated the progress of pediatric thoracic surgery

The history of thoracoscopy can be traced to 1910, when Jacobeus first reported the application of thoracoscopy.\(^3\) In 1970, Rodger et al first reported the application of thoracoscopy in a pediatric patient;\(^4\) they used an improved cystoscope to observe and perform excisional biopsy of pulmonary lesions, as well as to perform local chest debridement. In the 1990s, thoracoscopy was gradually applied in the diagnosis of interstitial lung disease and pulmonary malignant tumor; moreover, thoracoscopic lung biopsy became a commonly used approach.\(^5\) Supported by further technological development, thoracoscopy has become useful for treatment of adult pulmonary diseases.\(^6,7\)

As early as in the 1970s, Prof. Gans first used the laparoscope to diagnose biliary atresia and to probe the gonads. In 1981, Prof. Jinzhe Zhang and Gans jointly performed pediatric laparoscopic bile duct exploration in Beijing Children’s Hospital. In 1990, Gotz et al\(^8\) reported the first pediatric laparoscopic appendectomy in China. Thus, 1990 is regarded as the first year in which application of and clinical treatment with pediatric laparoscopy were initiated.\(^9\)

In 1992, thoracoscopy was officially introduced to China. Under the guidance of American surgeon Michael Mack, the thoracic surgery department of Peking University First Hospital successfully performed China’s first video-assisted thoracoscopic surgery, marking the birth of thoracoscopic surgery in China.\(^10\) In 1998, endoscopic techniques were officially introduced to Beijing Children’s Hospital. During initial application, these techniques were primarily used for the treatment of abdominal diseases, such as laparoscopic appendectomy, as well as endoscopic minimally invasive treatment of hypertrophic pyloric stenosis and other diseases.

For the treatment of chest diseases, due to the unique physiological anatomy of the airway in pediatric patients, as well as the narrow airway present in younger children, it is impossible to perform double-lumen tube intubation and single-lung ventilation during operation; thus, a small thoracic cavity and intercostal space are present in pediatric patients. Exposure of the surgical field inside the thoracic cavity is a difficult problem in pediatric thoracoscopy. Early pediatric thoracoscopy was therefore limited to lung biopsy, pleural biopsy, and other simple operations; it was difficult to perform technically demanding and complicated operations, such as pulmonary lobectomy and mediastinal tumorectomy.

Pediatric thoracoscopic surgery differs from adult thoracoscopic surgery. Notably, in adult thoracoscopic surgery, double-lumen tube intubation is used to achieve single-lung ventilation, and the surgery is performed with thoracoscopic observation. In this procedure, the thoracic cavity is connected with the outside, and conventional surgical instruments are placed inside the thoracic cavity through a small incision on the thoracic wall for operation. However, it is difficult to achieve single-lung ventilation in infants and young children. Generally, only 9–10-year-old children can receive the smallest double-lumen tube intubation. To achieve single-lung ventilation in the early days of the procedure, it was common to directly insert the tube into the main bronchus of the unaffected side, which is a very difficult procedure. In younger pediatric patients, the trachea is remarkably short. Single-lung ventilation often failed due to the varying depth of intubation caused by body position and traction during the operation.

For a considerable period of time, the method most frequently employed has been to infuse CO\(_2\) into the thoracic cavity to create an artificial pneumothorax and facilitate thoracoscopic surgery after pulmonary collapse. Because the pressure of artificial pneumothorax was controlled within 4–6 mm Hg in the early days of the procedure, it could not be used to perform complicated operations, and was limited to some simple procedures, such as empyema and lung biopsy. As experience has accumulated, physicians have more closely controlled the flow rate. With no serious respiratory or
hemicardiac malformations, most child patients can endure approximately 10–12 mm Hg of pressure; during this process, a trocar with a valve is needed. This method can also be applied to pediatric patients who cannot tolerate single-lung ventilation. Pulmonary collapse can be achieved successfully through low tidal volume, low pressure peak, and increased respiratory rate, to prepare for subsequent operation.\(^{11}\)

In 2007, the thoracic surgery department of Beijing Children’s Hospital published a clinical study paper entitled “Application of Video-assisted Thoracoscopy in Pediatric Thoracic Surgery” in the Chinese Journal of Pediatric Surgery, comprising a summary of 556 thoracoscopic surgeries since 1998.\(^{12}\) These surgeries included diagnostic surgeries (e.g., mediastinal biopsy, pleural biopsy, and lung biopsy) and therapeutic surgeries (e.g., mediastinal tumorectomy, empyema removal, chylothorax, pectus excavatum, pericardial fenestration, cardiac achalasia, and cystic lung disease). The primary anesthetic technique in use during that period was single-lumen tube incubation; artificial pneumothorax was used during the operation for assistance in flow control, to expose the surgery field of thoracic cavity.

(3) Scientific progress promoted development of pediatric thoracic surgery

Continuous scientific progress and the invention of thinner fiber bronchoscope enabled regulation of single-sided tube intubation during operation. The invention of the bronchial catheter plug provided a new method for single-lung ventilation in pediatric patients. Recently, application of the Arndt endobronchial blocker has facilitated the use of single-lung ventilation in pediatric thoracoscopic surgery.

Four-dimensional color Doppler ultrasound has enabled identification of additional malformations of the thoracic cavity in the fetal period; thus, pediatric patients can be diagnosed at an early stage, facilitating more appropriate timing for surgery to increase surgical success and reduce mortality.

Minimally invasive thoracoscopic surgery has been widely used in the treatment of various thoracic diseases, on the basis of its advantages, including minimal invasiveness, good intraoperative surgical field, reduced postoperative complications, and short hospital stay. With the progress of anesthetic technique, mastery of thoracoscopy operating skills has enabled further development of thoracoscopic surgery. Thus far, thoracoscopy can be used for pulmonary lobectomy, mediastinal tumorectomy, diaphragmatic hernia repair, diaphragmatic plication, and esophageal atresia.

**Current state of pediatric thoracic surgery in China**

Due to demographic factors, pediatric surgery departments in western nations typically include the following specialties: orthopedics, urinary surgery, cardiac surgery, neurosurgery, and plastic surgery. Additional diseases are generally diagnosed and treated in the pediatric surgery department, including those of the general surgery, general thoracic surgery, and neonatal surgery subspecialties, but there are no independent pediatric thoracic surgery departments. China is a country with a large population. Concomitant with its economic development and technological progress, pediatric thoracic diseases have increased annually. Some hospitals have realized that a special team is needed for pediatric thoracic surgery, to ensure appropriate diagnosis and treatment of pediatric thoracic diseases. Throughout the history of pediatric thoracic surgery, in addition to Beijing Children’s Hospital in the early 1970s and West China Hospital (Sichuan University) in the 1980s, several independent units specializing in the diagnosis and treatment of pediatric thoracic diseases have appeared in the most recent decade (e.g., The Children’s Hospital, Zhejiang University School of Medicine). Others include two subspecialties (e.g., Jinan Children’s Hospital and Children’s Hospital of Capital Institute of Pediatrics), which generally comprise tumor and general thoracic surgery. In most other children’s hospitals, general thoracic surgery is still included in the cardiac surgery or general surgery departments; some of these hospitals have acquired specialists for advanced studies, to pursue or emphasize general thoracic surgery. A number of adult hospitals have specialist physicians who focus on the diagnosis and treatment of pediatric thoracic diseases.

The main categories of diseases that are treated in pediatric thoracic surgery departments include: (1) Malformations of the thoracic wall, such as pectus excavatum and pectus carinatum; (2) Congenital cystic lung diseases, such as congenital pulmonary airway malformations, sequestration of the lung, and bullae of the lung; (3) Thoracic neoplasms, such as mediastinal tumors (neurogenic tumor, teratoma, lymphangioma), tumors of the thoracic wall (e.g., primitive neuroectodermal tumor), and pulmonary tumors (pleuropulmonary blastoma, inflammatory myofibroblastic tumor, and pulmonary metastasis); (4) Esophageal diaphragmatic diseases, such as esophageal atresia, hiatal hernia, posterolateral diaphragmatic hernia, retrosternal hernia, diaphragmatic evagination, and esophageal stenosis (tracheal cartilage ectopia, achalasia of cardia, chemical burns of esophagus); (5) Others, including chest trauma, empyema, chylothorax, and pneumothorax.

The history of Nuss surgery for pectus excavatum in China is a microcosm of the development of pediatric thoracic surgery in China. Along with the application of Nuss surgery for pectus excavatum, an increasing number of children’s hospitals focus on the diagnosis and treatment of pediatric thoracic diseases; they support this approach by sending physicians to the thoracic surgery department.
of Beijing Children’s Hospital for visiting or continuing professional development. Thus far, the thoracic surgery department of Beijing Children’s Hospital has received approximately 100 training physicians from throughout China.

To support the development of pediatric thoracic surgery, the Cooperative Group of Pediatric Thoracic Surgery was established under the Cardiothoracic Surgery Group, Pediatric Surgery Branch, of the Chinese Medical Association in 2015. In 2017, the Pediatric Thoracic Minimally Invasive Surgery Group was established under the Minimal Invasive Committee of Maternal and Child Health Care of Chinese Maternal and Child Health Association.

Upcoming decade, a golden age for pediatric thoracic surgery

By adapting to the general trend of growth in the pediatric thoracic surgery specialty, and supporting clinical application of thoracoscopic surgery, robotic surgery, and use of virtual reality techniques, pediatric thoracic surgery will enter an advanced age.

Thus far, China’s major children’s hospitals and general hospitals with children’s medical centers have mastered pediatric thoracoscopic surgery. However, from a nationwide perspective, unbalanced development remains. Diagnosis and treatment of pediatric thoracic diseases can be further improved. Under the direction of medical associations and medical oversight groups, increased understanding is expected; this will lead to further efforts to standardize pediatric thoracic surgery; cultivate young physicians who aspire to become involved in pediatric thoracic surgery; formulate relevant expert consensuses and clinical guidelines; and enhance diagnosis and treatment level. These changes will support development of pediatric thoracic surgery. In the future, pediatric thoracic surgery is expected to receive greater attention; moreover, closer cooperation among children’s hospitals is needed to perform multidisciplinary and multi-centered prospective studies, which will enhance nationwide diagnosis and treatment of pediatric thoracic diseases.

Overall, pediatric thoracic surgery is an integral part of the pediatric surgery system, with features distinct from those of other pediatric subspecialties. As the health-for-all plan and universal two-child policy have been launched, both the national government and the broader society will more closely monitor children’s health. Children are the country’s future. With strong national support, societal interest, and the guidance of medical associations and medical oversight groups, China’s pediatric thoracic surgery infrastructure will become increasingly stronger; thus, diagnosis and treatment will be continuously enhanced, stimulating the arrival of the next golden age.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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