First decade's experience with thoracoscopic lobectomy in infants and children

Steven S. Rothenberg*  

The Rocky Mountain Hospital for Children, Denver, CO 80111, USA

Received 28 August 2007; accepted 2 September 2007

Index words:  
Thoracoscopy; Lung resection; Lobectomy; Children; Sequestration; Congenital adenomatoid malformation (CAM); Bronchiectasis; Congenital lobar emphysema (CLE); Children

Abstract  
Purpose: This study evaluates the safety and efficacy of thoracoscopic lobectomy in infants and children.  
Methods: From January 1995 to March 2007, 97 patients underwent video-assisted thoracoscopic lobe resection. Ages ranged from 2 days to 18 years and weights from 2.8 to 78 kg. Preoperative diagnosis included sequestration/congenital adenomatoid malformation (65), severe bronchiectasis (21), congenital lobar emphysema (9), and malignancy (2).  
Results: Of 97 procedures, 93 were completed thoracoscopically. Operative times ranged from 35 minutes to 210 minutes (average, 115 minutes). There were 19 upper, 11 middle, and 67 lower lobe resections. There were 3 intraoperative complications (3.1%) requiring conversion to an open thoracotomy. Chest tubes were left in 88 of 97 procedures for 1 to 3 days (average, 2.1 days). Hospital stay ranged from 1 to 12 days (average, 2.4 days).  
Conclusions: Thoracoscopic lung resection is a safe and efficacious technique. It avoids the inherent morbidity of a major thoracotomy incision and is associated with the same decrease in postoperative pain, recovery, and hospital stay as seen in minimally invasive procedures.

Thoracoscopy has been in use since the turn of the century when first described by Jacobeus [1] in 1910. The first significant use in children was recorded in the late 1970s by Rodgers et al [2] who reported his experience with modified cystoscopy equipment to perform evaluation of intrathoracic lesions, small biopsies, and limited pleural debridements. By the mid-1990s, thoracoscopic lung biopsy had become an accepted, and in many cases superior technique, for obtaining tissue in cases of interstitial lung disease or malignancy [3]. A thoracoscopic approach has also become common place in the treatment of empyema, mediastinal masses, and other intrathoracic processes [4,5]. However, experience with formal lobectomy has remained relatively limited.

Thoracoscopic lobectomy is one of the most technically demanding minimally invasive procedures performed in pediatric population. The complex nature of the disease process and surgical dissection, the risk of bleeding, and the unique anesthetic issues have limited the number of procedures being attempted. We described our early experience with this technique in 2003 [6]. This report details our experience with the evolution of thoracoscopic lobectomy for congenital and acquired lung disease over the last decade.
1. Patients and methods

From January 1995 to March 2007, all patients with lung pathology requiring resection were considered for a video-assisted thoracoscopic approach. The only patients excluded were those with solid mass lesions occupying more than 50% of the chest or those with extreme respiratory compromise suggesting they would not tolerate any length of single lung ventilation. Ages ranged from 2 days to 18 years of age (mean, 3.8 years) and weight from 2.8 to 78 kg (mean, 16.7 kg). Preoperative evaluation suggested upper lobe pathology in 18, middle lobe in 11, and lower lobe in 68. Presumed diagnosis included sequestration or congenital adenomatoid malformation (CAM) in 65, severe bronchiectasis in 21, congenital lobar emphysema (CLE) in 9, and malignancy in 2. Forty-two of the CAMs and sequestrations and 1 of the CLE were prenatal diagnoses. Six of the patients with bronchiectasis had cystic fibrosis; the others had chronic aspiration and recurrent pneumonia or airway obstruction. The 2 malignancies were in patients with metastatic osteogenic sarcoma.

1.1. Technique

The procedures were performed with the patient in a lateral decubitus position and single lung ventilation. In larger patients (>30 kg), a double lumen endotracheal tube or bronchial blocker was used. In infants and smaller children, single lung ventilation was obtained by mainstem intubation of the contralateral side.

The very first procedures (n = 8) were performed using a combination of a mini-thoracotomy and 2 to 3 thoracoscopic ports. The thoracotomy was generally in the fifth intercostal space, 5 to 8 cm long, and used a total muscle-sparing technique. A combination of thoracic and thoracoscopic instruments was used. Standard Linear staplers (GIA and TA; USSC, Norwalk, CT) were inserted through the thoracotomy incision to complete the fissure, and take the main pulmonary vessels and bronchus.

Starting in 1997, with improvement in technique and instrumentation, the mini-thoracotomy was eliminated and all procedures were done through trocars alone. The patients were still placed in a lateral decubitus position to give access to both the anterior and posterior hilum. Three to five valved endoscopic ports ranging from 3 to 12 mm were used. The EndoGIA (USSC, Norwalk, CT) was used in larger patients to complete the fissure and take the main pulmonary vessels and bronchus. In smaller patients (<15 kg), endoclips and ligatures were used as the EndoGIA is too large to fit the thoracic cavity of a small child. Over the last 7 years, the Ligasure (Valleylab, Boulder, Colo), a bipolar sealing device that comes in a 5-mm curved dissector design, was the primary mode of vessel ligation. It also proved to be useful in sealing the lung and completing the fissure.

The room setup is shown in Fig. 1. The surgeon and assistant are at the patient’s front with the monitor at the patient’s back. The chest is initially insufflated with a low-flow low pressure of carbon dioxide to help complete collapse of the lung. A flow of 1 L/min and pressure of 4 to 6 mm Hg are maintained throughout the case. The first port is placed in the mid to anterior axillary line in the fifth or sixth interspace to determine the position of the major fissure and evaluate the lung parenchyma. Position of the fissure should dictate the placement of the other ports as the most difficult dissection occurs in this plane. If the EndoGIA is to be used, a 12-mm port is placed near the anterior axillary line at the interspace aligned with the front edge of the fissure. This is usually the seventh interspace. The exact procedure varied in each case depending on the lobe resected and the pathology encountered.

For lower lobectomies, the first step is mobilization of the inferior pulmonary ligament. During this maneuver, care is taken to look for the systemic vessel coming off the aorta in cases of sequestration. When found, the vessel is ligated and divided. The inferior pulmonary vein is dissected out but not ligated at this point. Ligation before division of the pulmonary artery can lead to congestion in the lower lobe, which can create space issues especially in the smaller child and infant. The fissure is then approached going anterior to posterior. The pulmonary artery to the lower lobe is isolated and ligated at its main trunk or at the segmental level, depending on the anatomy and completeness of the fissure. The inferior pulmonary vein is then divided and the bronchus to the lower lobe isolated. The bronchus is divided with the EndoGIA in larger children or cut sharply and closed with 3-0 polydioxanone suture (PDS) in smaller patients. Five-millimeter endoclips have been used in some newborns over the last 2 years for bronchus occlusion. The specimen is then brought out through a slightly enlarged trocar site, either whole or piecemeal.

For upper lobe resections, dissection starts with division of the superior pulmonary vein. This maneuver exposes the main pulmonary artery trunk. The lobe is then stripped of the main pulmonary artery taking segmental vessels as they appear. This is generally accomplished going from the top...
down but can also be accomplished by starting in the major fissure. The bronchus is then divided after completing the major fissure.

For middle lobes, the major and minor fissures are completed and the segmental veins and arteries to the middle lobes can then easily be seen and safely divided.

A chest tube was left in all cases except extralobar sequestration.

2. Results

Of 97 lobectomies, 93 were completed endoscopically. Operative times ranged from 35 to 210 minutes (average, 115 minutes). There were 19 upper, 11 middle, and 67 lower lobectomies. Nine of the lobectomies, 8 lower and 1 upper, were extralobar sequestrations. One additional patient had a CAM, which involved the apical segment of the left lower lobe and the posterior segment of the left upper lobe with no fissure separating the two. This patient had a bi-segmentectomy. Pathology of the other specimens included sequestration/CAM in 56, severe bronchiectasis in 20, CLE in 9, and malignancy in 2. There were 3 intraoperative complications resulting in conversion to open (3.1%). Two were for bleeding and 1 for a bronchoplasty. This last case was a patient with severe bronchiectasis of the left lower lobe. The bronchus was divided with an EndoGIA and the firing resulted in compromise of the left upper lobe bronchus. The procedure was converted to open to perform a bronchoplasty on the left upper lobe bronchus. The other conversion was in a patient with metastatic osteosarcoma with a large centrally located tumor. She required a left lower lobectomy to remove the mass. The procedure was converted because of the size and location of the mass, and so as not to violate the tumor. Chest tubes were left in 88 of 97 cases and remained in 1 to 5 days postoperatively (average, 1.6 days). There were 3 postoperative complications. The first was a pneumothorax on postoperative day 7 in a patient with cystic fibrosis. A chest tube was placed with immediate expansion of the lung and no evidence of air leak. The tube was removed after 72 hours without incident. The second was a postoperative pneumonia, which resolved with antibiotics and aggressive respiratory care. The third was in a patient with a persistent air leak after a left lower lobectomy for a CAM. She was reexplored thoracoscopically on the eighth postoperative day, and a leak from a small bronchial fissure in the fissure was identified and suture ligated. The chest tube was removed 2 days later and she was discharged.

Hospital stays ranged from 1 to 10 days (average, 2.4 days) in the 87 patients whose surgery was completed successfully thoracoscopically. There was one prolonged hospitalization, 12 days in the patient who required a bronchoplasty; this was primarily to treat a postoperative pneumonia.

3. Discussion

Over the last decade, thoracoscopy has become an increasingly important tool in the armamentarium of the pediatric surgeon. The limited explorations, biopsies, and debridements described by Rodgers in the mid- to late-1970s have become replaced by extensive, technically demanding resections and reconstructive procedures. Thoracoscopic lung biopsy, decortication, and bleb resection for pneumothorax have been shown to be so safe and effective that in many centers, it has completely replaced open thoracotomy as the treatment of choice. Reports of more technically demanding procedures such as resection of mediastinal masses, patent ductus arteriosus ligation [7], thymectomy [8], and other intrathoracic procedures [9] have also shown extremely promising results. Even one of the most technically demanding thoracic procedures, repair of a tracheoesophageal fistula, has now been accomplished and is the primary mode of treatment in a number of centers [10]. The obvious driving force behind this is to avoid the short- and long-term morbidity of a thoracotomy in an infant or child [11].

The application of thoracoscopic techniques in performing a formal lobectomy presents a number of unique and difficult problems. In our first report of more than 40 patients, we delineated the anesthetic considerations, primarily the importance of obtaining single lung ventilation. For most cases, it is necessary to obtain single lung ventilation primarily to create space for adequate visualization and dissection. We have found that most infants and children, even with significant parenchymal disease, can tolerate this for the length of the procedure without significant compromise. The greatest aid to the surgeon in maintaining full lung collapse is the use of valved ports and a creation of a mild tension pneumothorax using carbon dioxide insufflation.

Many of the patients with large CAMs or with CLE present with large space-occupying lesions that are not decompressed with single lung ventilation. This expanded series continues to show the success of decompressing or involuting these cysts (Fig. 2), using a tissue-sealing device to compress the cysts and create adequate space for visualization and manipulation (Fig. 3).

The major hurdle continues to be safe control of the major vascular structures. The key to success in this area remains a clear understanding of the anatomical relationships and meticulous dissection. Devices such as the endoscopic stapler in larger patients and the Ligasure in the smaller infants have aided in this greatly. They eliminate the need to suture ligate these vessels or use clips that might dislodge during the dissection. However, the stapler still requires a 12-mm port for access and at least 5 cm of intrathoracic space to fully open, making it difficult or impossible to use in infants and smaller children. The Ligasure, which provides a safe and effective way of sealing vessels up to 7 mm, is still limited to a 5-mm device and is
somewhat awkward in small neonates. Even with these size limitations, it has significantly enhanced the ability to perform complete lobectomies, even in newborn infants. The device has also proven to be effective in sealing lung tissue and is now the technique of choice for sealing and dividing incomplete fissures.

Because of these advances, more centers are undertaking lobectomies in infants who are diagnosed prenatally with either CAM or sequestration [12]. Our current algorithm is to now have these patients delivered at our institution and then perform the resection in the first few days of life if the prenatal findings are confirmed. Five of the cases in this series were done by the author in institutions on 3 different continents performing their first thoracoscopic lobectomy. These centers have all gone on to perform resections independently, proving the adoptability of this technique [13].

This series shows that thoracoscopic lobectomy is feasible, safe, and effective. Recent technological advancements have made the procedures technically easier with operative times similar to, or in some cases, faster than that associated with an open thoracotomy. The surgeon must have a clear understanding of the regional anatomy and 3-dimensional relationships to safely perform these procedure as the thoracoscopic approach provides only a 2-dimensional picture and limits the tactile feedback. Although a thoracoscopic approach appears to result in decreased postoperative pain, a shorter hospital stay, and a superior cosmetic result (Fig. 4), the greatest advantage is the avoidance of a formal thoracotomy with its inherent long-term morbidity of scoliosis, shoulder muscle girdle weakness, and chest wall deformity.

References


Fig. 3  Collapsed upper lobe allows exposure of superior pulmonary artery.

Fig. 4  Skin incisions 2 weeks after a thoracoscopic surgery on the left lower lobe.

Discussion

**Doctor**: Steve, that is a very nice series. I have had some experience with this now and my biggest problem is dealing with fused fissures, and I wonder if you have any special tricks with the truly fused fissure where you do not have lobar anatomy.

**Dr Rothenberg (response)**: I just did a case a couple of months ago where we thought it was a left upper lobe CCAM, but at the time of operation, there was no fissure between the upper and lower lobe. The CCAM seemed to incorporate the apical segment of the lower lobe and the posterior segment of the upper lobe. I used a Ligasure to create a plane and basically did a bi-segmentectomy. I think these new energy sources really help with this. In this child, I left the chest tube in but had no air leak postoperatively and he went home on the third postoperative day. If you are doing a segment or something that is not clearly anatomic, I think that some of the new devices really are extremely useful and I suspect that within a few years we will be doing wedge biopsies not with a stapler or endoloops but simply by wedging lung tissue out with these sealing devices.

**Doctor**: Steve, that is a very impressive series. I have one question about the group with congenital lobar emphysema or overinflation as we call it. Some of those babies are in significant respiratory distress during the period of induction and sometimes you have to perform a very quick thoracotomy to permit that overinflated lobe to come out of the pleural cavity so that the venous return is reestablished and the baby stabilizes. When you are doing one of those thoracoscopically, have you run into that problem? And, if you did, how did you deal with it?

**Dr Rothenberg (response)**: A couple of these were older neonates who developed it later but that was the final diagnosis made by pathology, but they do have some respiratory difficulty. In a lot of these cases, like the chest x-ray I showed today, we actually have a catheter in the bronchus to try and limit the ventilation to that side, inducing single lung ventilation. The key is to get in and then compress the emphysematous lobe as quickly as possible to create space. It is a little dicey for the first few minutes but they seem to tolerate it well. Obviously, the sickest babies have not had this procedure.

**Dr Holcomb, MD (Kansas City, Mo)**: I think the upper lobes are the most difficult. Again, I think it is a matter of being comfortable with the anatomy, kind of having a picture in your mind where exactly it is. If there are large cyst-occupying lesions, compress them to create space and make it easier to visualize the structures. Then, usually what I will do is work from front to back. I will find the branches of the superior pulmonary vein, isolate those, ligate them and divide them, and you simply strip the upper lobe off the pulmonary artery. You then ligate the segmental vessels as you come across them. Occasionally, you are able to proceed backwards from the fissure up but usually that works the best. It is really just being comfortable with where the anatomy is and hopefully the lung tissue is not too friable when you manipulate it. What many of us did during open was to keep flipping the lung back and forth, looking front, looking back, working in the fissure. If you try to do that thoracoscopically you will end up with a bloody mess so you really need to do it like a book. You need to start at the front and just work your way through to the back, and the more manipulation you do to the lung and the tissues, the greater problem you will create for yourself.

**Doctor**: It appeared to me in your series you have some CCAMs that you did very early. We know that some of these lesions will regress over time. What was your indication for surgery and what was the advantage of doing that early?

**Dr Rothenberg (response)**: We follow all these cases prenatally and certainly there are some that regress with serial prenatal ultrasound studies. In those cases where we see evidence of regression, we evaluate the baby, and if there is any question at all, we hold off and will repeat the CT scan. However, I have not seen a baby that had a significant CAM at birth that has then completely regressed over time.

The other reason that we do them early is because of where we live, a lot of the mothers travel quite a distance to be delivered in our hospital and so if the baby has a CCAM, and now with the techniques that we have available, we give the parents the option of taking care of the resection at the time of delivery so that mother and baby can go home together and do not
need to travel quite some distances to return to Denver. If the CCAM has regressed in utero then obviously we do not do anything, but the ones we have seen have been fairly significant.

Doctor (moderator): I would just add that I think they regress, but they do not disappear if they are truly CCAMs. If it truly disappears, then it probably was not a CCAM to begin with.