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# The first 100 infant thoracoscopic lobectomies: Observations through the learning curve and comparison to open lobectomy

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ABSTRACT

*Objective:* The objective of the study is to describe our initial 100 attempted infant thoracoscopic lobectomies for asymptomatic, prenatally diagnosed lung lesions, and compare the results to contemporaneous age-matched patients undergoing open lobectomy.

*Background:* Infant thoracoscopic lobectomy is a technically challenging procedure, which has only gained acceptance worldwide in recent years.

*Methods:* This is a retrospective review of all patients undergoing thoracoscopic or open lung lobectomy between March 2005 and January 2014. Included were all asymptomatic infants younger than 4 months. Excluded were patients undergoing emergent lobectomy and patients with isolated extralobar bronchopulmonary sequestrations.

*Results:* A total of 100 attempted thoracoscopic lobectomies were compared with 188 open lobectomies. In the thoracoscopic group, mean age and weight at surgery were 7.3 weeks and 4.8 kg, mean operative time was 185 minutes, and mean hospital stay was 3 days. Twelve cases were converted to open (12%). Ten conversions occurred within the first third of the series and none in the last third. There were no mortalities. There were no differences between the thoracoscopic and open groups in perioperative complications or hospital stay. There was a significant difference in the operative time: 111 minutes vs. 185 minutes (open vs. thoracoscopic; $p < 0.001$). There was a higher mean end-tidal carbon dioxide ($ETCO_2$) and lower mean peripheral capillary oxygen saturation ($SpO_2$) in the thoracoscopic group versus the open group (51.7 versus 38.6 mmHg and 97.5 versus 99.1%, respectively).

*Conclusion:* In high volume centers, the learning curve of thoracoscopic lobectomy can be overcome and the procedure can be performed with equivalent outcomes and, in our opinion, superior cosmetic results to open lobectomy.



Thoracoscopic lung lobectomy in infants and children was described more than 15 years ago, and has gradually gained acceptance worldwide [1]. While there have been many reports published on thoracoscopic lobectomy in children, most are relatively small series that cover a broad range of ages and pathologies. In fact, Rothenberg, who first described the procedure in children, has published the only large experience with infant thoracoscopic lobectomy [2]. As a large prenatal referral center, we have had the opportunity to evaluate and subsequently treat an unusually large number of congenital lung lesions [3]. In 2005, one surgeon (AWF) initiated a program of thoracoscopic lobectomies and every prenatally diagnosed asymptomatic lung lesion operated on by that surgeon was attempted thoracoscopically. During the same period, two other surgeons (NSA and HLH) performed their procedures open. This dichotomy of operative approaches provided the opportunity to review our experience with the first 100 consecutive infant thoracoscopic lobectomies, and compare the outcomes to those of a contemporaneous series of age-matched open lobectomies.

## 1. Materials and methods

After obtaining institutional review board approval, we retrospectively reviewed the medical records of all patients with prenatally diagnosed lung lesions (congenital pulmonary airway malformations [CPAM], intralobar bronchopulmonary sequestrations [iBPS], bronchial atresias [BA], and hybrid lesions) who underwent open or thoracoscopic lung lobectomy between March 2005 and January 2014. We excluded symptomatic patients who underwent urgent or emergent lobectomy, patients older than 4 months at the time of operation, and patients with isolated extralobar pulmonary sequestrations. As above, the type of operation was determined by the operating surgeon. The distribution of patients was determined by which surgeon counseled the patient prenatally as assigned by a three way call schedule. Anesthesia data were retrieved from the anesthesia information management system (Philips, Andover, MA), and consisted of vital signs and ventilator parameters captured at 15-second intervals. The anesthetic data auditing,

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visualization, and analyses were performed using visual analytic (Quikview, Radnor, PA) and spreadsheet software (Microsoft Excel, Redmond, WA). The analysis included determination of ventilation parameters (respiratory rate [RR], tidal volume [Vt], peak inspiratory pressure [PIP] and positive end-expiratory pressure [PEEP]) and calculation of the mean intraoperative $SpO_2$ and mean end-tidal $CO_2$ ($ETCO_2$) values for each individual patient. The data used for analysis included all anesthetic events that occurred between the "procedure start" and "procedure finish" timestamps in each anesthetic record. Ventilation parameter ranges were determined using mean values plus or minus two standard deviations and then rounded to the nearest integer. Additionally, we collected $SpO_2$ data between the "initiation of single-lung ventilation" and "procedure start" time stamps. Statistical significance was determined by t-test and chi-square test for means and proportions, respectively. A p value less than 0.05 was considered statistically significant.

### 1.1. Patient population

All patients underwent prenatal imaging by ultrafast fetal magnetic resonance imaging and serial ultrasound at the Center for Fetal Diagnosis and Treatment at the Children's Hospital of Philadelphia. The patients included in this study were anticipated to be asymptomatic at birth based on imaging at 32 weeks gestation and were therefore delivered at their referring center, from where they were discharged home. Postnatally, all patients underwent a contrast-enhanced angio-computed tomography (angio-CT) scan using a reduced pediatric radiation dose protocol, at approximately 1 month of age. The prenatally diagnosed lung lesions were identified as persistent by CT-angiogram in all of the cases. All patients remained asymptomatic prior to the operation and were scheduled for elective surgery within a few weeks after the angio-CT was completed.

### 1.2. Thoracoscopic technique

All thoracoscopic lobectomies were performed using single lung ventilation and low-pressure (4 mmHg) carbon dioxide insufflation. Single-lung ventilation was established by advancement of the endotracheal tube under fluoroscopic guidance [4]. Patients were positioned in lateral decubitus with slightly prone angulation. The surgeon and the assistant stood facing the patient's anterior side. Although 4 ports were used in 20 of the first 33 patients, three ports proved sufficient thereafter. We use 20-cm-long 3-mm instruments for the operation, but prefer to use 5-mm ports (instead of 3-mm ports) in order to be able use the 5-mm sealing device through any of the ports, depending on the orientation of each individual vessel. We prefer not to use "trocar-less" incisions because they generate a constant $CO_2$ leak and provide minimal cosmetic benefit. The ports were placed to triangulate the major fissure in the 4th, 6th and 8th intercostal spaces with the telescope (4-mm 30°) in a "look down" orientation to the instruments. The pulmonary artery branches, depending on size, were either sealed with the Ligasure® device (Valleylab, Boulder, CO) alone, or ligated proximally with 2-O or 3-O Ethibond Excel® (Ethicon, Somerville, NJ) and sealed distally. The bronchi were ligated with a 2-O absorbable monofilament suture and clipped distal to the ligature. The pulmonary vein was ligated with 2-O Ethibond Excel® at the pericardium and clipped proximally to the tie. In the frequent circumstance of incomplete interlobar fissures, the lung parenchyma was divided with monopolar hook electrocautery and/or sealed with the Ligasure®. Specimens were removed through the caudal trocar site. In most cases a 12 Fr chest tube was left in place through the most inferior trocar site. Patients were extubated in the operating room and transported to the neonatal intensive care unit (NICU) for postoperative recovery.

## 2. Results

Between March 2005 and January 2014 we attempted 100 elective thoracoscopic lobectomies and performed 188 open lobectomies in infants who met our inclusion criteria. During the same period there were 10 thoracoscopic lobectomies performed on patients older than 4 months (19–32 weeks of age) that were all completed thoracoscopically. These were excluded from analysis to allow for comparison between the series. In the thoracoscopic group there were 54 males and 46 females, mean age at surgery was 7.3 (2–16) weeks and mean weight at surgery was 4.8 (2.1–7.7) kg. There were no significant differences in the demographics or in the anatomic distribution of affected lobes between the thoracoscopic and open groups (Table 1).

In the thoracoscopic group, a total of 104 lobes were resected in the 100 operations. Four patients had lesions involving two lobes and required a bilobectomy (one of them also underwent resection of an extralobar pulmonary sequestration). In the open group, a total of 192 lobes were resected in the 188 operations (4 bilobectomies).

The mean operative time of the thoracoscopic lobectomies was 185 (103–515) minutes, and the median operative time was 174 minutes (SD = 64 minutes). The mean operative time for the open lobectomies was 111 (56–272) minutes ($p < 0.001$) (Table 2).

Four patients in the thoracoscopic group received a transfusion, three intraoperatively (1 major hemorrhage, 1 minor hemorrhage, and one cumulative blood loss related to a long operation secondary to a fused fissure), and 1 postoperatively (bleeding at a trocar site). One patient required a transfusion (intraoperatively) in the open group ($p = 0.094$).

A 12 Fr chest tube was used in 90 of the thoracoscopic cases (90%), and remained in place for an average of 1.5 (1–11) days. Later in the series, if a fissure was complete and no parenchymal dissection was performed, no chest tube was placed. Chest tubes were initially placed on continuous suction and underwent a 4-hour water-seal trial the day after the operation prior to removal if there was no evidence of an air leak. A chest tube was used in all but one patient in the open group, and the mean time to chest tube removal was 1.5 (1–11) days ($p = 0.746$).

Five patients in the thoracoscopic group (5%) remained intubated after the procedure (none within the last 60 patients). Three patients had a slow recovery from anesthesia, one patient remained intubated owing to a long operation (515 minutes, the longest in the series), and one patient remained intubated owing to an intraoperative hemorrhage (converted to open). Four cases in the open group (2.1%)

**Table 1**
Demographic and anatomical characteristics of the thoracoscopic and open groups.

| | Thoracoscopic group | | | | | Open group | | | | | *p* value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of patients | 100 | | | | | 188 | | | | | - |
| Male/female | 54/46 | | | | | 91/97 | | | | | - |
| Mean age at surgery | 7.3 weeks (range: 2–16) | | | | | 7.9 weeks (range: 2–16) | | | | | 0.079 |
| Mean weight at surgery | 4.8 kg (range: 2.1–7.7) | | | | | 5 kg (range: 3.4–7.3) | | | | | 0.194 |
| Lobes affected | RU | RM | RL | LU | LL | RU | RM | RL | LU | LL | - |
| | 9 | 10 | 42 | 14 | 29 | 13 | 5 | 73 | 23 | 78 | |
| Bilobectomies | 4 cases | | | | | 4 cases | | | | | 0.583 |