Paediatric thoracoscopy: State of the art

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Summary

Brad Rogers reported the first significant use of thoracoscopy in children in the late 1970s. Over the past two decades there has been an exponential growth and expansion of this technique. Many advanced procedures, including lobectomy, repair of tracheo-oesophageal fistula, excision of mediastinal tumours and diaphragmatic hernia repairs, are being done routinely in paediatric surgery centres around the world. This article reviews the state of the art of thoracoscopic surgery in children. The author selected five procedures which in his opinion are most relevant for this discussion. The thoracoscopic technique seems to offer a favourable alternative to open surgery, but more clinical research is necessary to confirm the benefits of minimal access surgery.

Thoracoscopy is a technique that has been used since the turn of the 20th century. It has grown exponentially since then and has now become a part of the armamentarium of many paediatric surgeons.

The first experience with thoracoscopy was reported by Jacobeus in 1910.[1] He used a rigid cystoscope through a port to lyse adhesions in the pleural space as part of treatment for tuberculosis. In the late 1970s the first significant paediatric diagnostic and therapeutic experience was reported by Rogers and Moazam.[2] They modified equipment to evaluate intra-thoracic lesions and performed lung biopsies and limited pleural debridement for empyema.

Since the early 1990s there has been a dramatic evolution in paediatric thoracoscopic surgery. This was brought about by the development of high-resolution cameras, special equipment, including smaller scopes, and new energy sources that could seal blood vessels and lung tissue as well as the endoscopic linear stapler. All these advances decreased the technical difficulties of thoracoscopic procedures. The experience gained and the skills developed in minimal invasive surgery, as well as modern techniques for single-lung anaesthesia, furthered the advancement of thoracoscopic surgery.

Many thoracoscopic procedures are being done routinely today, and the numbers continue to increase. Thoracoscopy is now used extensively for biopsies of the lung and many mediastinal lesions, as well as for debridement and decortication for empyema. Today many advanced procedures, including lobectomies, repair of tracheo-oesophageal fistulas, excision of mediastinal tumours and diaphragmatic hernia repairs, are done by paediatric surgery centres around the world.[3] More than 20 types of assisted thoracoscopic procedures have been described for infants and children over the past two decades.[4]

Thoracoscopic procedures are fraught with difficulties, which include a small working space, difficulty in controlling vascular structures, two-dimensional vision and limited tactile feedback, all of which result in a steep learning curve. Hence the question can be asked as to whether thoracoscopic surgery is worth while.

Several advantages provide sufficient reason to try. Thoracoscopy eliminates long and painful thoracotomy wounds, and also the long-term muscular skeletal morbidity associated with a thoracotomy.[5] This includes shoulder muscle girdle weakness, chest deformities, and spine and breast deformities. Jaureguizar *et al.* reported 35% significant musculo-skeletal deformities postoperatively in 35% of a series of 89 patients who underwent a thoracotomy for tracheo-oesophageal fistula (TOF).[6] Because of magnification the surgeon has superior visibility of the important nerves and vascular structures in the chest, which helps to avoid injuries to them. Another advantage is a shorter hospital stay and recovery following minimal access surgery. Patients who undergo lung biopsies and biopsies of other structures can be discharged on the same day. The repair of an open ductus arteriosus can now be performed safely with hospitalisation of less than 24 hours.[7]

Selected thoracoscopic procedures

Tracheo-oesophageal fistula repair

Thoracoscopic repair of oesophageal atresia is considered a technical milestone for minimal access surgery.[8] This operation was first performed during the International Paediatric Endosurgery Group meeting in Berlin in 1999, with surgeons watching the procedure on video.

There are a few contraindications to thoracoscopic repair, including severe haemodynamic instability, body weight of less than 2 000 g, and inability to tolerate periods of single-lung ventilation.[5]

The procedure is done with the baby placed in the prone position, with the right side slightly elevated. A low-flow pneumothorax is used, which makes main stem intubation or the use of bronchial blockers unnecessary. It is not necessary to divide the azygos vein, but when indicated, it can be done using only diathermy. Ligation of the fistula with a titanium clip may be inadequate in the long term, and a suture ligation is preferable to clipping.[5,8,9]

This thoracoscopic procedure has several advantages, one of the most important of which is excellent visibility, especially for identification of the fistula and the vagus nerve.[5,8] Magnification also allows precise dissection of the upper pouch of the oesophagus. Another advantage is that it reduces retraction trauma. The lung is collapsed by the insufflation pressure,

eliminating the use of retractors. Thirdly, the small incisions made in the thoracoscopic method reduce pain and result in better cosmesis. An anastomotic stricture is a frequent complication (30 - 40%).[8-10] Factors that could play a role are too small an opening in the upper pouch, too many stitches and excessive handling of tissue. Leaking of the anastomosis occurs in 12 - 22% of patients, but most of these can be treated conservatively.[9,10] Another concern is that the transpleural approach might lead to a higher risk of mediastinitis and empyema. There is, however, no evidence that this is so.[5,10] A retropleural dissection and repair of a TOF is possible and was first done by Lee in 2002 (cited by Albanese[8]).

In a multi-institutional analysis by Holcomb *et al.* in 2005,[5] a retrospective review was done of the thoracoscopic repair of 104 tracheo-oesophageal atresias at six institutions. The results for these patients were comparable to those achieved through thoracotomy.

Thoracoscopic lung biopsies

Lung biopsy was one of the first procedures to be performed thoracoscopically, and is one of the most common thoracic procedures performed in children today. With the thoracoscopic approach the entire surface of the lung and pleura can be evaluated and multiple biopsies can be obtained.

Lung biopsies are frequently needed in cases of interstitial lung disease and isolated lesions associated with malignancy. In lesions associated with tumours, biopsies are done for staging and for evaluation of residual masses after chemotherapy.[11,12] The ability to obtain specimens thoracoscopically greatly decreases the morbidity associated with an open lung biopsy. The pre-operative work-up of most lung biopsies requires routine chest radiographs as well as computed tomography (CT) or magnetic resonance imaging (MRI) scans.

Small lung nodules not located on the lung surface pose difficulties during bronchoscopic biopsies, mainly because of lack of tactile sensation. Recently techniques have been developed to guide the surgeon to the lesion. These include microcoil labelling, leaving a small needle in the lesion, and intra-operative ultrasound. The most common technique is CT-guided needle localisation using methylene blue or a blood patch to mark the area overlying the lesion.[13] Localisation is preferably done just before the biopsy. A frozen section should be done in theatre to confirm the presence of the lesion before removal of the ports.[14]

Most biopsies are done with the patient in the lateral decubitus position. Port placement is modified depending on the location of the lung lesion. In older children an endostapler can be used to perform the biopsies. In infants endoloops can be used to seal the lung at the base of the specimen. In cases of small lesions, the specimen can be exteriorised through the port. For larger lesions the specimen must be removed in an endoscopic bag.

Lobectomy

Thoracoscopic lobectomy is one of the most technically demanding minimal access procedures. Because of the complex nature of lung pathology, the risk of bleeding and the unique anaesthetic considerations, this procedure was initially not readily accepted.[15,16]

Indications for lobectomy include both congenital and acquired disease. These lesions include intra- and extra-lobar sequestration, congenital cystic adenomatoid malformations, lobar emphysema and, on rare occasions, malignancy.[16]

To perform this surgery safely, the surgeon must have extensive experience as well as a clear understanding of lung anatomy. Initially a hybrid technique with a combination of a mini-thoracotomy and a 2- to 3-port thoracoscopy was used. As experience was gained, and with improved technology, the mini-thoracotomy part was eliminated.[15]

For most patients single-lung ventilation is necessary to create adequate space for visibility and dissection. Even patients with extensive parenchymal disease can tolerate this for an extended period of time. In patients with lesions that occupy a large space, it is sometimes beneficial to decompress these cysts to create adequate space.[17] Previously a major concern was adequate control of blood vessels. With development of the endoscopic stapler and sealing devices (e.g. the LigaSure vessel sealing system (Covidien, Mansfield, MA, USA), which can seal up to 7 mm blood vessels), this can now be done safely and adequately. In older patients satisfactory closure of the bronchus can be achieved with an endoscopic stapler. In younger patients direct suture closure or clipping of the bronchus can be done.

Thoracoscopic surgery follows the same principles as open surgery, namely completion of the fissure, control of blood vessels and division of the bronchus. For lower lobectomies the first step is mobilisation and division of the inferior pulmonary ligament. The pulmonary artery is then isolated, sealed and divided with the LigaSure system. Ligation of the vein before the artery can lead to congestion of the lobe. The inferior pulmonary vein is then divided, followed by the bronchus. Upper lobectomies are technically more difficult procedures, with a higher conversion rate.[18] Dissection of the upper lobe starts with sealing and dividing the superior pulmonary vein. The upper lobe is then stripped from the main pulmonary artery while dividing segmental vessels. For removal of middle lobes, the major and minor fissures are completed and vascular structures are then divided, followed by the bronchus.[15,16]

Albanese and Rothenberg[19] published their experience with 144 consecutive lobectomies in 2007. Of these 144 patients, 141 procedures were done thoracoscopically. Only one intra-operative complication occurred. Average operation time was longer than for conventional open surgery, but hospital stay was shorter (2 - 8 days). They showed that a thoracoscopic lobectomy is feasible, safe and effective.

Bochdalek hernia

Minimally invasive surgery is ideally suited for the treatment of all forms of diaphragmatic hernias, including Bochdalek hernias. Early experience was first reported in infants with delayed presentation. Subsequently neonatal thoracoscopic repairs have been successful using primary repairs as well as patch repairs,[20] with the use of synthetic or biosynthetic mesh. The thoracoscopic approach appears to be more successful in the less severely affected neonate, including a favourable lung-head

ratio, neither liver nor gastric herniation, minimal ventilator settings, and absence of significant pulmonary hypertension.[21] Herniation of the stomach into the chest is associated with a high rate of conversion to open surgery. Pre-operative need for extracorporeal membrane oxygenation (ECMO) is not a contraindication.[20]

The pulmonary hypoplasia provides adequate working space. Single-lung ventilation is not required and low-pressure, low-flow CO_2 insufflation is used to keep the hypoplastic lung compressed. Reduction of the hernia content is usually easily achieved, and is aided by CO_2 insufflation. The sac, which is often not removed, can also be helpful in this reduction. In most cases the defect can be closed with interrupted, non-absorbable sutures. If there is no lateral diaphragm present, the defect can be closed using pericostal sutures.[22] If the closure is under tension or not possible, prosthetic mesh can be used.

Some of the benefits of the thoracoscopic approach are improved visualisation, earlier institution of enteral feeds and fewer abdominal adhesions. A disadvantage is that malrotation or other intra-abdominal pathology may be missed.

Some paediatric surgeons advocate the laparoscopic approach because of better manoeuvrability of instruments, but visibility is obscured once the bowel is reduced into the abdomen. The laparoscopic approach is a good option for late-presenting Bochdalek hernias, since more working space is then available.[23]

Recent studies report conversion rates from 3% to 14%.[21,24] In most series operation time is longer than that for the open procedure.[21] Recurrence rates from 14% to 21% have been reported, but this may be an underestimate since follow-up is often short term.[21,25]

Mediastinal tumours and cysts

Sternotomy or thoracotomy has traditionally been used to evaluate and treat mediastinal masses. Today thoracoscopy is increasingly used to perform these procedures. The advantages over a standard thoracotomy in terms of morbidity and recovery have been well documented.

Positioning is of the utmost importance: the patient should be positioned in such a way that gravity will cause the lung to fall away and facilitate exposure.[26]

The posterior mediastinum is the site of a heterogeneous group of foregut cysts, inflammatory processes and neurogenic tumours of the sympathetic nervous system. These lesions are relatively easy to excise, but meticulous haemostasis is important. Teratomas and lymphomas are the most common tumours of the anterior mediastinum, and are easily approached and dissected from surrounding structures. Pre-operative imaging is important to identify the relationship to important vascular structures. Intra-operative sonography may also help.

Patrick and Rothenberg[26] operated on 39 patients with mediastinal tumours. Thirty-eight of the 39 procedures were successfully completed thoracoscopically. Recently Valla *et al.*[27] reported on their experience with the thoracoscopic removal of 9 mediastinal neurogenic tumours. Tumour resection was macroscopically completed in all cases. None of the patients needed conversion. Because of low morbidity and quick recovery, thoracoscopic resection is an effective way to biopsy and resect most benign mediastinal lesions in children. More experience and longer follow-up are needed before we can promote this approach for malignant tumours.

Conclusion

Recent advances in minimal access surgery have dramatically altered our approach to intra-thoracic lesions. Many advantages have been reported, but prospective controlled studies comparing open and minimal access procedures to confirm the benefits of minimal access surgery are still lacking.

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