SCIENTIFIC ARTICLE

Surgical outcome of pediatric thoracoscopic surgery: retrospective evaluation and literature review

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Abstract

Introduction

Minimally invasive thoracoscopic surgical techniques are increasingly being applied in paediatrics for a multiplicity of conditions. It has been shown to minimise thoracic musculoskeletal deformity and to improve pulmonary mechanics compared to open procedures.

Methods

All the children who underwent advanced thoracoscopic procedures from July 2020 up to December 2021 were retrospectively evaluated and reviewed with regard to outcome and complications. Techniques of thoracoscopic diaphragmatic hernia repair and decortication for empyema were standardized in our series.

Results

There were 26 children who underwent thoracoscopic procedures, out of which 14 were neonates having congenital diaphragmatic hernia and eventration. In addition, there were five children having infective pathologies, namely four empyemas and one lung abscess. All of them had successful thoracoscopic interventions. There were five children who had thoracic neoplastic lesions including three neurogenic tumours. Thoracoscopic diaphragmatic hernia repair was showing good post-operative outcome while the repair of congenital eventration was reported to have 75% recurrence following thoracoscopic repair.

Conclusions

Thoracoscopic techniques could be successfully utilized to treat a number of conditions in children. Case selection by predefined criteria and standardized technique in congenital diaphragmatic hernia repair have contributed for improved postoperative outcome. The technique of thoracoscopic repair of diaphragmatic eventration has to be revisited due to its higher recurrence rate in our setting probably due to technical difficulty. Thoracoscopic tumour resections have shown promising outcomes in our series.

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Introduction

Minimally invasive surgical(MIS) techniques are increasingly being applied in paediatrics for both diagnostic and therapeutic procedures. Minimally invasive thoracoscopic interventions were initially employed as a diagnostic modality but now have become the preferred therapeutic modality for many conditions such as congenital diaphragmatic hernia (CDH), parapneumonic empyema, and congenital pulmonary airway malformations etc. Compared to open surgical interventions, MIS has gained widespread acceptance due to less tissue trauma, less postoperative pain, reduced hospital stay and improved recovery, while thoracoscopy specifically has shown less risk of thoracic musculoskeletal deformities and improved pulmonary mechanics.

In one study, up to 35% of neonates developed significant musculoskeletal deformity after thoracotomy for oesophagal atresia and tracheo-oesophageal fistula repair [1], which could be minimised by thoracoscopic interventions. Precision in the dissection due to magnification and increasing use of a multiplicity of energy devices have improved outcomes after complex thoracoscopic interventions like pulmonary lobectomies. Several thoracoscopic interventions have become standardised and has led to improved postoperative outcomes such as CDH repair and pulmonary lobectomies. Our objective was to assess the outcome and complications of children who underwentadvanced thoracoscopic procedures over the last 2 years at Sirimavo Bandaranaike Specialised Children's Hospital (SBSCH), Peradeniya and Teaching Hospital Peradeniya, Sri Lanka.

Patients and methods

We performed a retrospective review of all children who underwent advanced thoracoscopic interventions from July 2019 up to December 2021 in SBSCH Peradeniya and Teaching hospital Peradeniya. The patient information and operative interventions had been collected on an Electronic Medical Record (EMR) database and were reviewed

retrospectively for the study. For the babies with CDH, selection for the thoracoscopic intervention was done according to the institutional criteria for the repair of congenital diaphragmatic hernia. For all other conditions, the selection was based on the technical feasibility to perform the thoracoscopic procedure.

All the neonatal patients were operated on under general anaesthesia with endotracheal intubation. Beyond the neonatal period, mainstem bronchial intubation was done selectively when the requirement and the technical feasibility were met. A standardized operative technique was developed and used in thoracoscopic diaphragmatic hernia repair and decortication of empyema.

In all the thoracoscopic procedures, port placement was by the open Hassan technique. Port placement was done primarily to achieve triangulation, with the camera port changed to achieve optimum visibility during dissection. Intrathoracic insufflation was achieved at a pressure of 4-6mmgh to facilitate lung collapse. For diaphragmatic hernia repair, insufflation was only maintained until the contents were reduced to the peritoneal cavity. End-tidal C02 (EtC02) concentration was measured during all neonatal thoracoscopic interventions.

Results

In our series, 26 children underwent advanced thoracoscopic procedures. Out of these, 14 patients were neonates who underwent thoracoscopic repair of diaphragmatic hernia and congenital diaphragmatic eventration. The following table shows the spectrum of the thoracoscopic procedures during the study period.

Table 1. Spectrum of thoracoscopic procedures

Intervention	Number
Diaphragmatic hernia repair	10
Congenital eventration repair	04
Decortication for empyema	04
Resection of thoracic neuroblastoma	02
Resection of thoracic neurofibroma	01
Excision of mediastinal lymphangioma	01
Excision of thoracic wall Ewing's Sarcoma	01
Resection of pleuro pulmonary blastoma	01
Drainage of lung abscess	01
Lung lobectomy for congenital pulmonary airway malformation(CPAM)	01

Thoracoscopic diaphragmatic hernia and eventration repair

Thoracoscopic diaphragmatic hernia repair was undertaken in 10 neonates while repair of eventration was undertaken in 4 neonates within the study period. All the babies were selected for repair of hernia according to institutions criteria for selection[Table 2]. Out of these, thoracoscopic repair was undertaken in babies having an intra-abdominal stomach as determined by the chest and abdominal x-ray. All the babies with diaphragmatic eventration who were ventilated on admission due to respiratory distress were selected for repair.

Table 2. Preoperative criteria for surgical intervention in congenital diaphragmatic hernia

Institutional criteria for the repair of congenital diaphragmatic hernia
Preductal oxygen saturation more than 85% with FiO2 of 0.5%
Urine output of more than 1.5ml/kg/hour
Only one or no inotrope support
Normal mean arterial pressure for the gestational age

Preoperative findings

Out of all neonates, 9 (64.3%)were males and 5(35.7%) were females. Antenatal diagnosis of diaphragmatic hernia was possible in only 3(21.4%) patients. Ten babies were born at term while 4 babies were premature, with low birth weight noted in 6(42.9%) babies. Ten babies(71.4%) were having more than 93% preductal oxygen saturation and only one patient was on dobutamine support on admission to the surgical intensive care unit. Congenital cardiac anomalies were noted in 7 babies while pulmonary hypertension was noted to be severe in 5 patients. All the babies with diaphragmatic hernias had 48 hours of preoperative stabilisation to optimise the ventilation.

Table 3. Distribution of pulmonary hypertension in congenital diaphragmatic hernia and congenital eventration

Degree of pulmonary hypertension	Frequency	Percentage %
No	6	42
Mild	5	35.7
Moderate	1	7.1
Severe	2	14.3
Total	14	100

Table 4. Age at surgery in congenital diaphragmatic hernia and congenital eventration

Age in days	Frequency	Percentage %
2	1	7.1
3	5	35.7
4	4	28.6
5	1	7.1
6	2	14.3
7	1	7.1
Total	14	100

Intraoperative findings

Out of 10 babies with a diaphragmatic hernia, only one baby had primary repair while all others had patch repair with Prolene mesh. All the babies with eventration had a primary repair. The mean operative time for thoracoscopic repair was 132 minutes with a minimum of 85 and a maximum of 330 min. The first thoracoscopic repair had the longest operative time of 330 min in the series. End-tidal CO2(EtCO2) level was monitored every 15 minutes during the procedure to measure the impact of CO2 pneumothorax on the blood gas and acidosis. Mean EtCO2 was 34.6mmHG with a minimum of 26.8mmgh and a maximum of 38.14mmgh during the procedure. Only one baby was on Dobutamine support at the time of surgery which was tailed off post-operatively.

Postoperative findings

Intercostal drainage was done in all children, which was kept for a mean of 7.36 days. Inotropic support was given only for one patient which was tailed off post-operatively. Five babies were complicated with neonatal sepsis following the procedure, who were managed with broad-spectrum antibiotics, and recovered. One baby following CDH repair died on day 10 due to sepsis and related complications.

Two babies developed acute renal impairment including the one who died following diaphragmatic hernia repair. Intercostal tube drainage was done for all the neonates and was removed at a mean of 7.36 days following the procedure. Out of the 4 babies following eventration repair, 3 babies represented recurrence and were subjected to redo operation. There were no recurrences following CDH repair. Nearly 43% of babies were extubated 4-5 days after the procedure.

Decortication for empyema and drainage of pulmonary abscess

Thoracoscopic decortication was performed in 4 patients for complicated empyema[Table 5]. In 3 children the empyema was in the fibrinopurulent stage. In two children, preoperative fibrinolytic therapy with Tissue Plasminogen Activator(tPA) was continued for 7 days but there was no demonstrable improvement and both of them were on a ventilator due to trapped lungs. Both of them were having high fever spikes with elevated inflammatory markers. Due to poor response to fibrinolytic treatment and the complicated nature of empyema, thoracoscopic decortication was done.

Table 5. Details of children who underwent thoracoscopic decortication for empyema

Patient No	Age (years)	Sex	Stage of Empyema	Pre Op tPA therapy	Post Op tPA therapy
1	3	Female	Fibrinopurulent	Given	Given
2	2	Female	Fibrinopurulent	Given	Given
3	3 8/12	Female	Fibrinopurulent	Not given	Given
4	1	Male	Early organising	Not given	Not given

In all patients, a three-port approach was done and the decortication was completed within 90 minutes. The procedure was done under tracheal intubation and two intercostal drainage tubes were inserted for optimum drainage of purulent fluid. Postoperatively three of them were given intrapleural tPA(Tissue Plasminogen Activator) therapy after 48 hours to improve pleural drainage from intercostal tubes. All of them improved dramatically after the decortication with good pulmonary function.

The fourth patient had a complicated parapneumonic effusion secondary to infection of congenital pulmonary airway malformation. He did not require ventilator support and underwent early primary thoracoscopic decortication.

The child with lung abscess presented with high fever, cough and respiratory distress but didn't require ventilation. She was initially treated with broad-spectrum antibiotics for nearly 10 days but did not show evidence of improvement. The abscess was located in the right middle lobe in the subpleural location. During thoracoscopy, the abscess was found to be extending through the visceral pleura and walled off by the parietal pleura without developing into an empyema. The abscess was completely drained and revealed to be a fungal abscess which needed prolonged antifungal treatment.

Table 6. Details of intra thoracic neoplastic lesions

Tumour	Type	Age	Size of tumour	Location of tumour	Type of intubation	Duration of surgery
Neuroblastoma 1	Malignant	8M	3.0X3.0cm	Right apical C2-C3	Left main stem	180 min
Neuroblastoma 2	Malignant	1Y6M	3.0X2.5cm	Right C4-C5	Tracheal (left main stem failed)	90 min
Neurofibroma	Benign	7Y	8.0X6.0cm	Left cervico thoracic	Tracheal	240 min
Ewing's tumour	Malignant	2Y	5.0X4.0cm	Right 8-10 ribs	Tracheal	260 min
Lymphangioma	Benign	2Y7M	7.0X5.0cm	Right paracardiac	Tracheal	320 min
Pleuro Pulmonary Blastoma	Malignant	2Y9M	8.0X7.0cm	Right lung middle lobe	Tracheal	190 min

Resection of intrathoracic tumours

Thoracoscopic interventions were done on six children with intrathoracic neoplastic lesions. Out of these, except for pleuropulmonary blastoma, all others had extrapulmonary lesions. Both children with neuroblastoma attempted to have left main stem bronchial intubation but only one succeeded [table 6]. All the children had lateral positioning with the table tilt to achieve a near prone position depending on the need. The intrathoracic insufflation of gas was limited up to 4-8mmgh pressure during the procedure. Neo-adjuvant chemotherapy was given for the first child with neuroblastoma, and the one with Ewing's sarcoma. Both of them had a remarkable response and the tumours were adequately downstaged.

Other procedures

Thoracoscopy for cystic lung disease

Cystic lung disease was intervened thoracoscopically in a 14 years old girl having congenital pulmonary airway malformation (CPAM) of the right lower lobe. She presented initially with a lower respiratory tract infection and was found to have a right lower lobe CPAM. The resection was accomplished thoracoscopically. Lung collapse was achieved with intrathoracic insufflation up to 8mmgh. There were no untoward effects of thoracic insufflation on the ventilation during the procedure. The major fissure was found to be complete and pulmonary arterial branches were divided before the division of the pulmonary venous branches. Vascular branches were taken up by ultrasonic dissector and endoscopic clips. Bronchial branches were taken up by endoscopic clips and vascular staplers. She had an uneventful recovery postoperatively.

Discussion

Since the first diagnostic thoracoscopy was performed in 1971 by Klimkovitch and coworkers,[2], there had been numerous diagnostic and therapeutic thoracoscopic procedures developed for children. Many advanced thoracoscopic procedures in children were successively introduced after thoracoscopic lobectomy was performed by Rothenberg and oesophagal atresia repair was done in Berlin.[3] Currently, many thoracoscopic procedures are being standardised in children and evidence is emerging on its applicability and improved outcomes compared to open procedures.

The advantages of minimally invasive thoracoscopic surgery compared to open surgery are well substantiated with special emphasis on minimising long-term thoracic deformity associated with open thoracotomy.[1] However, surgeons' learning curve and feasibility of performing advanced thoracoscopic surgery in children have long lagged due to a lack of training opportunities and unfamiliarity with thoracic and pulmonary anatomy and anatomical variations.[4] In our setup, as an initial step of starting thoracoscopic interventions, empyemas were treated with thoracoscopic decortication successfully. With increasing experience in anaesthesia for thoracoscopy, neonatal thoracoscopic interventions for diaphragmatic hernia were performed with excellent postoperative outcomes. For neonatal procedures, thoracic insufflation was done up to 4mmhg and up to 8-10 mmHg for older children. Tracheal intubation along with insufflation has shown to achieve a similar outcome compared to single lung ventilation in thoracoscopy.[5] In our series, only one procedure was done with selective bronchial intubation and single lung ventilation.

Thoracoscopic congenital diaphragmatic hernia repair

Since the introduction of thoracoscopic CDH repair by Van De Zee.[6] the outcome has been assessed by numerous studies. Even though the technology and experience have improved over the last 2 decades, surgical complications are still not comparable with open surgery. In our series, the selection of neonates for thoracoscopic CDH repair was done with the use of a predefined criterion. Intraoperative hypercapnia and acidosis are well-documented complications of thoracoscopic CDH repair.[7] In our series, intraoperative end-tidal CO2 concentration was assessed as an indirect measurement of acidosis. Mean EtCO2 was 34.6mmgh which was acceptable for neonates undergoing thoracoscopic CDH repair.[7] Significant Intraoperative acidosis has been demonstrated in up to 40%of babies during thoracoscopic surgery in neonates.[8]

Institutional preoperative criteria for the surgical intervention have been consistently used to identify the candidates for surgical intervention, and the thoracoscopic intervention was not offered for the babies with CDH having stomach or liver up in the thorax. The presence of the spleen was not a contraindication for thoracoscopic intervention. Recurrence following thoracoscopic CDH repair has been documented to be up to 24% in one review, with a higher recurrence rate noted following primary repair.[9] In our series, up to now, no recurrence has been noted following CDH repair but a 75% recurrence rate has been observed following thoracoscopic eventration repair. Patch repair has been adopted in 95% of patients in our series which has possibly contributed to less recurrence following thoracoscopic diaphragmatic hernia repair. In one series, 33% recurrence has been noted following direct repair and 12% recurrence following patch repair.[10] In our series, patch repair was adopted with a low threshold which resulted in the reconstruction of the dome and minimal tension repair.

The outcome of neonatal thoracoscopic eventration repair has been studied minimally. Even though the initial outcome was satisfactory in our series, late-onset recurrence (after 3 months) was common following eventration repair. The aetiology of recurrence was unclear in our series but was thought to be due to technical difficulty in the repair and non-excision of the thinned dome of the diaphragm during the repair. However, in a recent study, excision of the sac was not practised during the repair but plication only, which has resulted in a 93% success rate.[11]

Thoracoscopy for infective pathology of pleura and lung

Empyema and lung abscess are common infectious pathologies which need surgical intervention when medical management fails. Parapneumonic effusion leading to established empyema needs aggressive treatment to prevent progression to the organising stage of empyema which could cause trapped lung.[12] Primary fibrinolytic treatment versus primary VATS and decortication is still a subject of controversy in view of the outcome. In a meta-analysis comparing primary operative therapy with non-operative therapy for paediatric empyema, a significantly reduced risk of failure has been demonstrated in the operative arm compared to non-operative management.[13] Thoracoscopic decortication as salvage therapy after failure of fibrinolytic treatment was done in two of our patients. In many series, it has been demonstrated that surgical intervention has improved the outcome of children who had a failure of initial medical management.[13] Early decortication after the failure of fibrinolytic treatment could prevent morbidity of thoracoscopic decortication when performed at a later stage of organising empyema. However, the risk of bleeding is higher when VATS was performed after fibrinolytic treatment.[13] There were no hemorrhagic or septic complications following the procedure in all four of our patients. In empyema, decortication is recommended to be completed within 90 min to prevent hypoxemia and septic complications.

Lung abscess is primarily treated with intravenous antibiotics but surgical intervention becomes necessary when there's a poor response to antibiotics.[14] The conventional surgical intervention for failed medical treatment of lung abscess is open pneumonectomy or formal lobectomy.[15, 14] Lung abscesses could occur due to aerobic or anaerobic organisms, while Staphylococcus aureus is a common organism. In our patient, purulent fluid yielded fungal organisms hence protracted treatment with antifungals was given.

Thoracoscopic pulmonary lobectomy

Pulmonary lobectomies on children are done for a variety of conditions such as congenital pulmonary airway malformations, pulmonary sequestrations, bronchogenic cysts, pleuropulmonary blastoma and congenital emphysema.[16] Thoracoscopic lobectomy is one of the most demanding operations due to the complexity of vascular and bronchial anatomy in the lung. Identifying the vascular and bronchial structures with certainty and controlling them with appropriate energy devices and staples are crucial for a successful lobectomy.

Despite the advantages of thoracoscopic procedures, there's a relative lag in the adoption of these procedures due to the complexity of the anatomy of the lung and the inadequate training opportunities on thoracoscopic procedures. However thoracoscopic lobectomy has become a well-accepted procedure, backed by many studies in the literature.[17]

Resection of intrathoracic tumours

In children 60% of the neurogenic tumours of the thorax are malignant, hence thoracoscopic interventions are feared with the risk of recurrence due to inadequate resection and port site seeding. Thoracoscopy is being increasingly applied in the resection of these tumours and the overall outcome has been satisfactory with similar results demonstrated compared to open thoracotomy. But despite the benefits of thoracoscopy, resection of neurogenic tumours is still a subject of controversy.

In a multi-institutional retrospective case analysis, thoracoscopic tumour resection has shown good outcomes without any evidence of port site recurrence.[18] but recurrence at the thoracostomy site has been demonstrated in a few studies.[19] Overall the literature indicates that thoracoscopic interventions are effective for the treatment of thoracic neurogenic tumours in children.[19]

For benign neoplastic conditions like mediastinal lymphangioma, thoracoscopic excision has been accomplished.[20] The risk of recurrence will be high in these lesions if it is closely related to pericardium or great vessels.[20]

All authors disclose no conflict of interest. The study was conducted in accordance with the ethical standards of the relevant institutional or national ethics committee and the Helsinki Declaration of 1975, as revised in 2000.

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