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REVIEW / DERLEME

Videothoracoscopic surgery in children

Çocuklarda videotorakoskopik cerrahi

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ABSTRACT

Video-assisted thoracic surgery (VATS) is now being used with increasing frequency for a wide variety of indications in pediatric patients. Although there is no high level of evidence for the advantages of VATS in the pediatric patient group, the proven benefits of this method in the adult patient group have encouraged thoracic surgeons to perform VATS in this patient population. In this study, the procedures performed in pediatric patients under 18 years of age and their results were reviewed with the help of articles obtained as a result of searches using relevant keywords in the English literature (PubMed, Web of Science, EMBASE, and Cochrane). The frequency, indications, and results of the procedures performed differed according to age groups.

Keywords: Minimal invasive, pediatric surgery, video-assisted thoracic surgery.

ÖZ

Pediatrik hastalarda, video yardımlı torasik cerrahi (VATS), günümüzde çok farklı endikasyonlar ile artan sıklıkta kullanılmaktadır. Her ne kadar pediatrik hasta grubunda, VATS'nin avantajlarına ilişkin yüksek kanıt düzeyleri olmasa da, bu yöntemin erişkin hasta grubunda kanıtlanmış yararları, göğüs cerrahlarını bu hasta popülasyonunda da VATS yapma konusunda cesaretlendirmiştir. Bu çalışmada, İngilizce literatürde (PubMed, Web of Science, EMBASE ve Cochrane) ilgili anahtar kelimeler kullanılarak yapılan taramalar sonucu ulaşılan makaleler yardımıyla, 18 yaş altı pediatrik hasta grubunda uygulanan işlemler ve sonuçları derlendi. Yaş gruplarına göre yapılan işlemlerin sıklığı, endikasyonları ve sonuçları farklılık gösterdi.

Anahtar sözcükler: Minimal invaziv, pediatrik cerrahi, video yardımlı göğüs cerrahisi.

In the early 20th century, thoracoscopic interventions were first used in children in North America by Rodgers et al.[1] in 1979, and the first pediatric thoracoscopic lobectomy was reported by Rothenberg[2] in 2000. Indications for thoracoscopic interventions range from diagnostic biopsies to resections for malignancy and from treatment of empyema to treatment of hyperhidrosis. In the pediatric population, video-assisted thoracic surgery (VATS) is usually performed for benign pathologies. This is because malignant pathologies are generally more common in adults, and malignant pathologies in pediatric cases are at an advanced stage of diffuse disease that VATS cannot be performed at the time of diagnosis.[3] However, in recent years, as teams have gained experience and advanced imaging and prenatal diagnostic techniques have developed, there has been significant progress in oncologic surgery. The great advantages of thoracoscopy over thoracotomy have made its use increasingly widespread. Compared to thoracotomy, VATS has been associated with less postoperative pain, less blood loss, faster recovery time, less hospitalization, and better cosmetic and functional outcomes.[4-6] One of the most important advantages of VATS for the pediatric population is the prevention of musculoskeletal anomalies that may occur with thoracotomy.[7] Musculoskeletal anomalies have been reported in up to 62% of the children undergoing thoracotomy.[8] Despite these advantages, thoracoscopic surgery requires an experienced team to perform the procedure successfully, considering the surgical technique and anesthetic procedures. The use of either the VATS or thoracotomy approach should be carefully evaluated preoperatively, as it may be

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accompanied by congenital anomalies, such as costal fusions, vascular variations, and cardiac anomalies, which may be observed in pediatric patients.[9] Teams with experience in adult thoracoscopic surgery will be competent for these procedures after a certain learning curve. In their cumulative sum control chart (CUSUM) analysis, He et al.[10] revealed that surgeons should perform at least 57 procedures with different indications and difficulties to complete the learning curve and gain competence in pediatric thoracoscopic operations. Considering all these, VATS is a safe and effective treatment approach in the pediatric population when performed by an experienced surgical and anesthesia team.

SURGICAL TECHNIQUE

One-lung ventilation (OLV) is a problem that must be overcome during VATS in children. Airway size should be assessed according to the age and weight of the child, and the OLV method should be evaluated. As the age of children decreases, their oxygen requirements increase due to their lower functional residual capacity, and more ventilation-perfusion mismatches occur in the lateral decubitus position compared to adults.[11] Therefore, OLV tolerance decreases as the age of the case gets younger. It is very important to choose the appropriate size devices and place them correctly in the methods that will provide OLV in children, and success rates have significantly increased with the help of fiber optic bronchoscopy.[12] Double-lumen intubation is possible in children weighing 30-35 kg, which usually corresponds to children older than 12 years. Double-lumen intubation cannulas are also available for children over eight years of age.[13] In children in whom double-lumen intubation is not possible, selective main bronchial intubation can be performed with a cuffed or uncuffed single-lumen intubation tube; however, in such a case, lung collapse may not be achieved effectively due to air leakage. Another option is unilateral ventilation, which involves blocking the main bronchi with blockers after endotracheal intubation.[14] This blockade is usually achieved with blockers as small as 5 French. Studies have shown that the Fogarty catheter can be safely and effectively used as a bronchial blocker to achieve an OLV.[15] In cases where blockade cannot be achieved, the lung can collapse by carbon dioxide (CO_2) insufflation after single-lumen intubation. Usually, the lung collapses with 4-8 mmHg CO_2, and when the lung is completely deflated, the CO_2 is disconnected, and the blockade success is tested. Carbon dioxide insufflation may cause hemodynamic instability in young children.[16] However, this may be the only option for newborns. In this case, CO_2 insufflation at a pressure of 5 cmH_2O and a flow rate of 0.5-1 L/min is recommended.[13] Pediatric patients who underwent surgery without intubation using a face mask, laryngeal mask airway (LMA), or high-flow nasal cannula (HFNC) have also been reported in the literature.[17] In cases where CO_2 insufflation cannot be performed, it is also possible to perform the operation with intermittent apneic periods with low tidal ventilation if possible.

Depending on the clinical experience, uniportal, biportal, triportal, or subxiphoid VATS can be performed. An example of uniportal VATS is Halezaroglu et al.'s[18] extralobar sequestration excision in a 14-month-old child. Another example is Chou et al.,[19] who performed lung resections in seven congenital pulmonary airway malformation (CPAM) patients. However, the advantages of uniportal VATS over biportal and conventional three-port approaches are controversial since the small thoracic cavity makes instrument and camera management difficult and requires a larger (3-4 cm) incision. Lv et al.[20] successfully performed subxiphoid metastasectomy in a single session for lesions consisting of a total of five metastases in bilateral lower lobes at the age of eight years with Wilms' tumor, and no recurrence was observed at the four-month follow-up. The age of the child, anatomical location and histopathologic features of the lesion, comorbidities, anomalies, and imaging studies should be taken into consideration in deciding the surgical approach.

Usually, 3- to 5-mm trocars are used for ports. Visualization can be performed using 5-mm 30° or 0° optics. Telescopes of 3 mm, 5 mm, and 14 gauge are also available for use in neonates.[13] Instruments of 3-55 mm should be used for dissection. A utility incision is made as a 5-mm thoracic incision at the anterior axillary line fourth or fifth intercostal space junction, and exploration can be performed. The incision is then widened to 1.5-2 cm. The camera port is placed in the seventh to eighth intercostal space, and the camera is moved to this trocar. Vascular ligation can be performed using silk ligation, and the bronchus can be closed by suturing after division. Vascular structures can be ligated with hemoclips, and the distal part can be sealed with a LigaSure™ (LigaSure; Valleylab, Boulder, CO, USA). Sealing can be performed using a LigaSure alone for vessels <7 mm. The bronchus can be clipped with L hemoclips, and the distal part can be divided with tissue scissors. With the new 5-mm endostapler, it is also possible to provide a safe division using a similar method in adult patients.[21] A small-caliber chest tube or pigtail

catheter is inserted through the camera port. In the literature, there are cases in which surgeries were performed without drains in cases where the lung was not touched, as well as cases that were completed without drains, even after lung parenchyma resections that did not show air leakage in air leak control.[22]

Surgery is usually performed under general anesthesia in pediatric patients. Pain control using thoracic epidural analgesia is the gold standard. There are also studies showing that continuous or single-injection erector spinae plane block provides postoperative pain control for more than 48 h in pediatric patients.[23] Effective pain control in the postoperative period, particularly in cases followed by drains, is vital for effective ventilation and pulmonary rehabilitation.

Surgical techniques for unique operations are mentioned in each chapter. The VATS experience of our clinic in the pediatric population is summarized in Table 1 and Table 2.

CONGENITAL LUNG MALFORMATIONS

Congenital lung malformations (CLMs) are a broad spectrum of malformations, including anatomical anomalies of the airway and lung, such as congenital airway malformations, pulmonary sequestrations, and congenital lobar emphysema.

The most common subtype of CLM is congenital airway malformation. Congenital airway malformation is also the most common indication for VATS pulmonary resection in the pediatric population, accounting for 5-18% of all congenital anomalies.[24] Early diagnosis of these anomalies is possible with fetal imaging tests, such as prenatal ultrasonography.

Nasr and Bass[25] found no significant difference in complications and operative time between thoracoscopic procedures and thoracotomy in their meta-analysis for congenital airway malformation. Hung et al.,[17] in their 14-year series of 100 cases, compared thoracotomy and thoracoscopy, and no difference was found in terms of operation time and the need for postoperative intubation in children older than six months. In addition, they showed that the thoracoscopic approach was more advantageous, with less intensive care unit stay, less intubation, and fewer complications, which is consistent with the literature. In children younger than six months, these results were more favorable in favor of thoracotomy. In a meta-analysis of 40 case series by Xie et al.[26] comparing VATS with thoracotomy for patients with CLM, VATS was associated with fewer complications, less use of epidural anesthesia, less hospitalization, and tube monitoring time, but required a longer operative time. However, the duration of surgery varies greatly according to the experience of the surgical clinic.[26]

One of the indicators of clinical experience is the rate of conversion from VATS to thoracotomy. As the rate of conversion to thoracotomy is higher in symptomatic patients in the literature, it is a safer and more effective approach to select primarily asymptomatic patients for thoracoscopic operations in less experienced clinics. Children with chronic pneumonia may not be managed with unilateral ventilation, and this is an independent risk factor for conversion to thoracotomy.[27] Clark et al.[28] reported a 21.7% conversion rate from thoracoscopy to thoracotomy in their 10-year single-center study. They explained that unilateral ventilation is not tolerated, and management of strong adhesions is

Table 1. Numerical data of patients who underwent VATS in our clinic

	n	%	Mean±SD	Median	Min-Max
Age (year)			14.0±3.7	15	1-17
Sex					
Male	45	72.6			
Female	17	27.4			
Length of hospitalization (day)				5	
Chest-tube duration (day)				5	
Operative time (min)			118.15±42.01	120	60-240
Intubation					
Double-lumen	50	80.6			
Single-lumen	11	17.7			
Tracheotomy	1	1.6			

VATS: Video-assisted thoracic surgery; SD: Standard deviation.

more difficult with thoracoscopy. However, it should be noted that the conversion rate dropped from 66.7% in 2010 to 0% in 2020. This shows that as the experience of the center increases, the conversion rates decrease significantly. In a multicenter European study published in 2021, there were no patients who converted to thoracotomy, and the median operation time was reported as 92.2 min.[29]

Pulmonary sequestration is nonfunctional lung tissue without bronchial connections. It is supplied by an anomalous systemic artery that usually originates from the descending aorta and accounts for 1% of all CLM.[30] Treatment is surgical due to recurrent infections, malignant transformation, and hemoptysis originating from systemic arteries. In recent years, owing to advances in radiologic evaluations, sublobar

Table 2. Characteristics of patients who underwent VATS in our clinic

Indication	Operation type	Histopathology	n	%
Pneumothorax	Wedge	Bullous lung	11	17.7
Hydatid cyst	Wedge	Hydatid cyst	1	1.6
Pleura			3	4.8
	Decortication	Foreign body-type giant cell reaction	1	1.6
	Biopsy	Fibrinous pleuritis	2	3.2
Bronchiectasis	Lobectomy	Bronchiectasis	1	1.6
Mediastinum	Mass biopsy		4	6.4
		Lymphoma	3	4.8
		Fibrolipomatous tissue	1	1.6
	Lymph node biopsy		2	3.2
		Reactive lymph node	1	1.6
		Necrotizing granulomatous lymphadenitis	1	1.6
	Mass excision		3	4.8
		Thymic carcinoma	1	1.6
		Ganglioneuroma	1	1.6
		Neuroblastoma	1	1.6
	Cyst excision		4	6.4
		Thymic cyst	2	3.2
		Gastroenteric cyst	1	1.6
		Hemangioma	1	1.6
Metastasectomy	Wedge		2	3.2
		Osteosarcoma	1	1.6
		Rhabdomyosarcoma	1	1.6
	Lobectomy	Rhabdomyosarcoma	1	1.6
Parenchymal lesions	Wedge		4	6.4
		Langerhans cell histiocytosis	1	1.6
		Lymphangiomatosis	1	1.6
		Lymph node	1	1.6
		Organized pneumonia	1	1.6
Chest wall deformity	Nuss procedure	Pectus excavatum	14	22.5
Sequestration	Segmentectomy	Sequestration	1	1.6
Hyperhidrosis	Sympathectomy		10	16.1
Trauma	Exploration	Hemothorax	1	1.6
Total			62	

VATS: Video-assisted thoracic surgery.

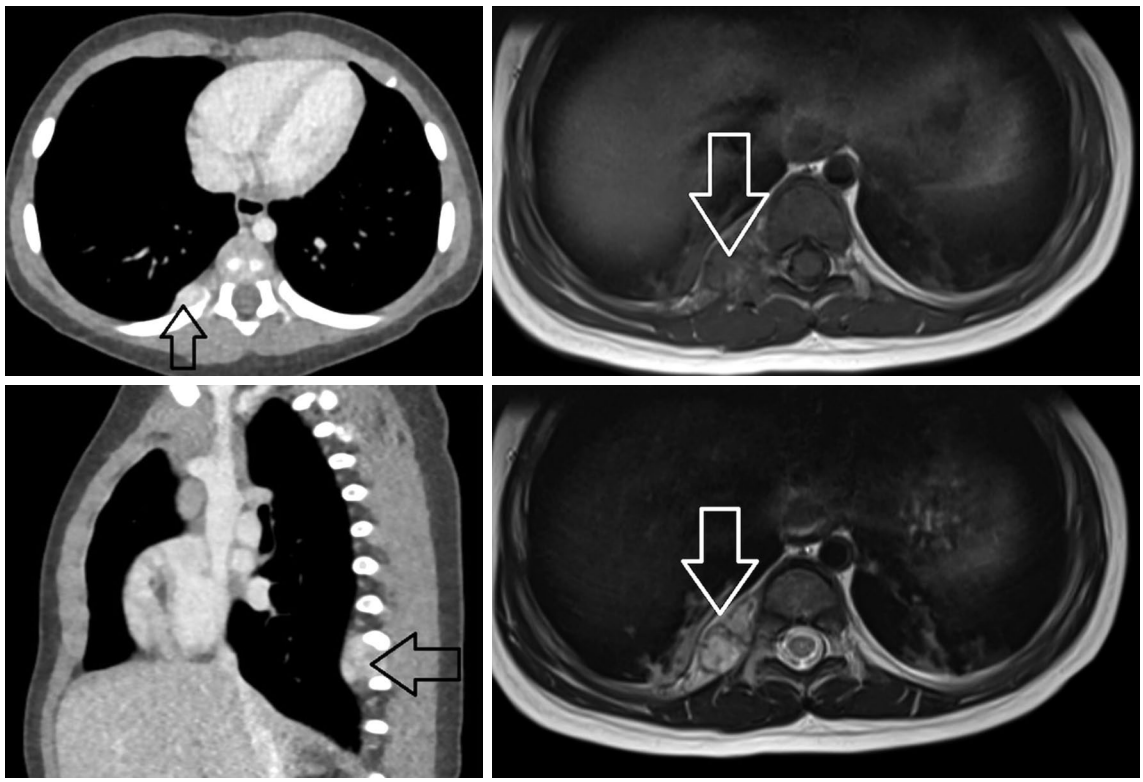

Figure 1. Preoperative computed tomography and magnetic resonance imaging of a one-year-old patient with a mediastinal mass.

resections, such as segmentectomy or wedge resection, have also been performed in cases where lobectomy is classically performed. In cases where the lesion is large and tight adhesions are observed, hybrid operations utilizing the magnifying effect of the thoracoscope through a mini-thoracotomy incision have also been reported in the literature.[30] Kestenholtz et al.[31] successfully treated 14 pediatric cases of pulmonary sequestration with VATS.

PLEURAL EMPYEMA

Pleural empyema is defined as accumulation of pus in the pleural cavity. The incidence of empyema has been shown to be 0.6%, with mortality rates as high as 8%.[32] The primary treatment approach is drainage and intravenous antibiotics (3-4 weeks). However, these infections are often complicated. Optimal treatment in cases of multiloculation, late organization, and poor response to conservative treatment remains controversial.[33] In the latest published British Thoracic Society pleural effusion guideline, streptokinase use is not recommended, and tissue plasminogen activator and deoxyribonuclease have been shown to shorten the duration of hospitalization and decrease the likelihood of persistent fever but increase the risk of posttreatment complications compared to placebo.[34] Since the standards of intrapleural therapy for children, particularly neonates, are not well established in the

Figure 2. Skin closure after minimally invasive surgery in a one-year-old patient.

literature, early VATS appears to be a useful and safe treatment option. The aim of VATS is to achieve lung expansion and remove the infected material from the pleural cavity. Historically, this operation could be performed by thoracotomy; however, in the minimally invasive era, these operations are now performed by VATS. Goldschlager et al.[35] demonstrated that decortication and drainage by thoracoscopy is an effective treatment option for thoracotomy in the pediatric population. Kalfa et al.[36] showed that early thoracoscopy (<4 days) shortened disease progression (6.2-8.2 days) and provided significant benefit. Recent publications have demonstrated that early thoracoscopic decortication shortens hospital stay and accelerates disease resolution.[37] In Leung and Chang's[33] study, 43-day-old-baby was complicated after four days of drainage and antibiotherapy and was operated by VATS. A 3-mm miniscope was used, and ventilation was provided with intermittent apneic periods of low tidal volume. The patient was discharged after complete clinical and radiological resolution during the postoperative period. The youngest case in the literature is the VATS empyema pouch consolidation and decortication operation performed by Sanghvi et al.[38] for methicillin-resistant *Staphylococcus aureus* empyema in a 20-day-old male infant. There were no perioperative complications, and the patient was discharged after 14 days of intravenous antibiotic treatment. The chest radiograph one month later was completely normal. Huang et al.[39] successfully performed uniportal debridement and decortication of empyema in a series of 21 patients. No perioperative complications, conversion to thoracotomy, or recurrence was observed. In conclusion, in the pediatric population, VATS debridement and decortication can be safely and effectively performed in the second and third stages of empyema, with less antibiotic treatment, early recovery, and less hospital stay.

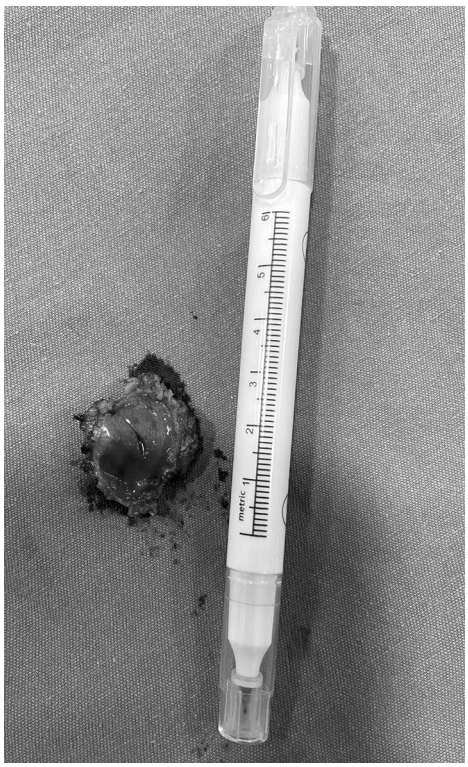

Figure 3. Excised mediastinal lesion in a one-year-old patient.

ESOPHAGEAL DUPLICATION CYST

Esophageal duplication cysts are rare congenital anomalies that are seen predominantly in boys. In recent years, the feasibility of reliable thoracoscopic surgery for foregut duplication cysts in pediatric patients has been described in the literature.[40] The largest study in the literature is a series of 27 cases by Bratu et al.[41] In this series, they obtained a shorter hospital stay and follow-up with drainage, in favor of thoracoscopy. The incidence of intraoperative complications is much lower with the thoracoscopic approach. Da Col et al.[40] successfully excised an esophageal duplication cyst in an 18-month-old boy by VATS using a 5-mm stapler device. The child was transferred to the intensive care unit without a drain, and no pneumothorax was observed on the postoperative film. The patient was discharged on the fourth postoperative day without complications. As prenatal imaging becomes more common, thoracoscopic interventions are being performed in younger patients. Cuch et al.[42] successfully thoracoscopically excised esophageal duplication cysts in a 15-day-old neonate.

CONGENITAL DIAPHRAGMATIC HERNIA

Congenital diaphragmatic hernia is caused by dysplasia or developmental disorders of the diaphragm. It is more common on the left side at a ratio of six-to-one, and 2% of cases are bilateral.[43] It can cause pulmonary dysplasia and pulmonary hypertension due to herniation of abdominal organs into the thoracic cavity. Traditional therapeutic approaches involve transthoracic or transabdominal diaphragmatic repair. Studies comparing minimally invasive approaches, including laparoscopy and thoracoscopy, with the open approach have shown that the endoscopic approach has better results in terms of operative time, hospitalization, postoperative mechanical ventilation time, and postoperative analgesic requirement.[44,45] However, patients are at risk of developing hypercarbia and hypoxia during surgery. Studies have shown that

recurrence rates are also higher in VATS.[46,47] The reason for the higher recurrence rate is thought to be that suture spacing and knot tightness cannot be evaluated and applied well with VATS compared to open surgery.[48]

HYDATID CYST

Hydatid cyst is a disease caused by *Echinococcus granulosus* and *Echinococcus multilocularis*, endemic in Türkiye with a rate of 2-12/100,000. The first thoracoscopic intervention for hydatid cysts was performed in 1993.[49] Today, parenchyma-sparing minimally invasive approaches to hydatid cysts are applied in experienced clinics. In a series of 72 cases of hydatid cysts, Ma et al.[50] compared VATS with thoracotomy and found that VATS was associated with a shorter hospital stay, less intraoperative bleeding, less chest tube follow-up, lower postoperative pain scores, and lower treatment costs.

One of the most important factors to be considered in hydatid cyst surgery is the prevention of contamination. In addition to standard VATS preparations, two different aspiration systems are set up for the cyst contents and surrounding tissue. After exploration, gauze impregnated with 10% hypertonic saline or povidone iodine is placed around the lesion containing hydatid cyst. After the cyst content is drained with a needle, the germinative membrane is removed with ring forceps, paying attention to contamination. It is then checked for an open bronchial orifice, which is sutured if present, and the pericyst tissue is cleaned with hypertonic saline or povidone iodine for 5 min and then capitonnage is performed. Anatomic resection, such as wedge resection, segmentectomy, or lobectomy, may be required depending on the cyst localization.

A systematic review revealed that uniportal VATS is an effective and safe method for cysts <15 cm. In another study, cysts >10 cm, hilar cysts, multiple cysts in one lung, and children younger than 10 years were contraindicated for VATS.[51] In their subsequent study, they abandoned this contraindication by stating that any cyst could be removed after its size had been reduced by aspiration.[52] Several studies have shown that multiple cysts can be removed, despite some surgical difficulties.[53,54] Cysts <2 cm can be removed with good radiological planning due to the difficulty of palpation.[55]

PRIMARY SPONTANEOUS PNEUMOTHORAX

The peak incidence of primary spontaneous pneumothorax is observed in the late adolescence period, with male predominance, but it is rare in children. The incidence of primary spontaneous pneumothorax in children is 0.1%.[56] Since there is no guideline for pneumothorax in the pediatric population, guidelines for adults are generally used. Conservative treatment and needle aspiration, which may be the first-line treatment in adults, are not supported by pediatric surgeons. The recurrence rate with these treatments is up to 50%.[57] The consensus for the treatment of prolonged air leak in pediatric cases is stapler blebectomy and mechanical pleurodesis with a minimally invasive approach.[58] In their study, Leys et al.[59] performed surgery directly after risk assessment with thoracentesis. The recurrence rates were 15% and 60% in the VATS and conservative groups, respectively. A study with 1,040 patients conducted in 2018 showed that when early VATS and chest tube groups were compared, the VATS group had a reduced length of hospital stay, hospital costs, and readmissions.[60] There is insufficient evidence to establish guidelines for the pediatric population; however, a level 3 meta-analysis conducted in 2020 suggested that early surgical intervention is superior to conservative management in pediatric patients.[61] In a study by Bjutterworth et al.,[62] it was shown that children with air leakage for more than three days were unlikely to recover spontaneously. There is no consensus on surgical technique. When total and partial pleurectomy are compared, studies have shown that complication rates may increase with total pleurectomy, whereas recurrence rates increase with partial pleurectomy.[63,64] In the study by Sahin et al.,[56] 31 VATS procedures were performed, and no recurrence was observed in patients who underwent total pleurectomy, while recurrence occurred in only one of 18 patients who underwent partial pleurectomy, and there was no difference in terms of complications. Partial pleurectomy with VATS and stapler blebectomy is a safe and successful treatment method in pediatric patients with prolonged air leakage.

MEDIASTINAL TUMORS

Minimally invasive surgery (MIS) has been successfully used for diagnostic and curative purposes for mediastinal masses, and VATS is most commonly used for diagnostic purposes in patients with mediastinal tumors (Figure 1). Video-assisted thoracic surgery allows the entire pleural and lung surfaces to be explored, and multiple biopsies should be performed in cases requiring multiple biopsies, such as germinal tumors. It is also possible to perform diagnostic procedures using a single trocar in patients with low bleeding risk.[65] Thoracotomy and VATS are the standard surgical approaches

for curative mediastinal tumor operations. With thoracotomy, tumor exploration can be achieved and adhesions can be managed more easily. However, open surgery causes more bleeding, resulting in longer operation and recovery times. Video-assisted thoracic surgery for mediastinal tumors uses the visual superiority of thoracoscopy, which allows for clearer visualization of anatomical structures. This results in less bleeding, smaller incisions, faster recovery time, and fewer postoperative complications (Figure 2).[66] The disadvantage is that it is difficult to perform an operation in a smaller operating field in accordance with oncologic principles. This requires experienced anesthesia and surgical teams. There are doubts regarding whether complete resection can be achieved using VATS. In a thymectomy series performed in children with myasthenia gravis, successful results similar to those of an adult series were obtained.[67] DeCou et al.[68] achieved good early survival with complete resection in five children with neuroblastoma, but tumor transplantation occurred in a few children. Da et al.[66] studied 137 pediatric mediastinal tumor patients and showed that the VATS group had better results in terms of operation time, blood transfusion requirement, and postoperative hospital stay. There are studies in the literature showing the need for thoracotomy for tumors larger than 6-8 cm for adults.[69,70] Although there is no established size limit in pediatric cases, there are opinions that the important thing is the ratio of the ipsilateral thoracic cavity and tumor size.[9] Da et al.[66] found that the median tumor diameter for pediatric patients was 7.6±3.8 cm in the thoracotomy group and 4.4±1.7 cm in the VATS group.

The rate of conversion to thoracotomy for mediastinal malignancies is up to 15%. In experienced centers, this rate can be reduced to zero.[65] In recent studies, successful results have been obtained with operations performed without a chest tube, without harming patient safety and increasing the complication rate, and it was observed that postoperative pain and hospitalization time were shortened.[71] There are no guidelines for minimally invasive oncological surgery for the pediatric population based on standardized and randomized trials.[72] Therefore, except for large and experienced centers, there are not many centers that perform oncologic surgery with minimally invasive methods.

In pediatric mediastinal tumor cases, VATS in accordance with oncologic principles is thought to contribute to survival due to advantages such as easy postoperative pain control, early recovery time, and early postoperative adjuvant therapy (Figure 3).[9]

PRIMARY PALMAR HYPERHIDROSIS

Primary hyperhidrosis is a somatic disorder characterized by excessive sweating, usually affecting the hands, axillae, and feet without any underlying disease. It affects approximately 1% of the population. It usually starts in adolescence but rarely develops in childhood.[73] Foul-smelling sweating can affect the child's social relationships and school success, which can cause major problems in the child's psychosocial development. Systemic treatments, such as ammonium chloride-based antiperspirants, iontophoresis, botulinum toxin A injection, anticholinergic agents, glycopyrrolate, and methantheline bromide, are among the first-line treatment options. However, treatment success is not at the desired level.[74] Therefore, surgery is an effective treatment option since curative results can be achieved. Surgery usually involves destruction of the sympathetic chain by transection, resection, ablation, and clipping of the T3-T4 ganglia and thereby reducing the sympathetic response. Although the procedure can be performed with single or multiple ports, no difference has been reported in terms of postoperative pain. The operation can be curative but may be followed by compensatory sweating of the back, legs, groin, and abdomen. Compared to simultaneous bilateral sympathectomy, compensatory sweating with sequential sympathectomy is rare.[73] Hyperhidrosis surgery can be performed without drains, resulting in a good cosmetic result and less hospitalization time.

PULMONARY PARENCHYMAL BIOPSIES AND PULMONARY METASTASECTOMY

Thoracoscopic biopsies for diffuse or local involvement of the lungs are also performed in pediatric patients. Chest radiography may be required for the preoperative evaluation of diffuse involvement, and CT evaluation may be required for planning localized patients. If there is no special condition, it is technically easier to perform a biopsy from the right side for diffuse pathologies. Severe air leaks can be observed in cases repaired with a LigaSure and simple suturing. Although 5-mm endostaplers are available on the market, larger standard staplers are very difficult to manipulate in the pediatric thoracic cavity when access is not possible.[13] Localization of the lesion in VATS can be challenging, particularly for lesions deeper than 1 cm. High diagnostic accuracy can be achieved with intraoperative ultrasonography,

microcoils, and methylene blue marking.[75] High diagnostic accuracy can be achieved with VATS in selected cases with good preoperative evaluation.

Except for a small case series, there are no studies with large data on pulmonary malignancies in the pediatric population.[65] Video-assisted thoracic surgery has a major disadvantage when the complete resection of pulmonary metastases is crucial. Intraoperatively detected nodules that cannot be detected by imaging methods are very likely to be undetectable by VATS because manual palpation cannot be performed. In 202 patients with a limited number of metastases, recurrence, and mortality rates were similar between thoracotomy and VATS.[76] Port-site metastases have also been reported in the literature.[77] Successful results can be obtained with VATS in select cases with peripherally located metastases.

THORACIC TRAUMA

Laparoscopic and thoracoscopic interventions for diagnostic and therapeutic purposes are becoming increasingly common in pediatric trauma patients. With minimally invasive surgery, the sequelae formation observed in open procedures is prevented. In studies reported in the literature, MIS resulted in less postoperative pain, shorter hospital stay, better recovery time, and lower cost than open surgery. In a 20-year single-center experience by Stringel et al.,[78] the mean hospital stay of patients in the MIS and open surgery groups was 7±1.9 and 15±15.1, respectively. Alemayehu et al.[79] successfully operated with thoracoscopy in 13 of 200 patients with MIS and had a median hospital stay of 6.3±6.5 days. Of the 200 cases, 65% were completed minimally invasively, and the majority of cases that were converted to open surgery were due to bowel perforation. Parelkar et al.[80] successfully operated two cases of traumatic diaphragmatic hernia at the age of 1.5 and 12 years with VATS and no recurrence occurred in a three-year follow-up. The use of VATS for diagnostic and therapeutic purposes in stable pediatric trauma patients is a safe and effective method.

In conclusion, minimally invasive surgery is increasingly becoming the gold standard treatment in all fields owing to its advantages for patients. In experienced centers, safer and more successful results can be achieved with VATS than with other treatment approaches.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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