Turkish Journal of Thoracic and Cardiovascular Surgery 2024;32(4):412-418

ORIGINAL ARTICLE / ÖZGÜN MAKALE

Thoracic surgery in children and adolescents: Experience from the thoracic surgery unit of a single referral center

Çocuklarda ve ergenlerde göğüs cerrahisi: Bir sevk merkezinin göğüs cerrahisi biriminden deneyimler

Hanan Hemead, Nora Mamdouh, Akram Allam, Ahmed Abdelaziz

Department of Cardiothoracic Surgery, Faculty of Medicine, Alexandria University, Alexandria, Egypt

ABSTRACT

Background: The study aimed to highlight and evaluate thoracic surgical procedures performed in children and adolescents and demonstrate the extent to which thoracic surgeons can benefit this population.

Methods: This retrospective study included 200 pediatric patients (100 males, 100 females; mean age: 14.7±6.7 years; range, 1 month to 21 years) who underwent thoracic surgery between January 2018 and January 2023. Patients' indications for surgery, surgical approach, complications, length of hospital stay, need for intensive care admission, and mortality were evaluated.

Results: The most commonly performed surgery was sympathectomy (30.5%), followed by decortication (16%) and traumatic exploration (14%). Approximately 50% of surgeries were minimally invasive. The average length of hospital stay was 2.8 days, and the rate of intensive care admission was 20%. The intraoperative and postoperative complication rate was 10%.

Conclusion: The concept of treating pediatric patients as small-size adults is irrational. Pediatric patients need special care and tailored guidelines due to their peculiar physical, psychological, and anatomical characteristics. We believe that having a dedicated team of thoracic surgeons trained and subspecialized for pediatric thoracic pathologies will improve outcomes. Furthermore, more research must be directed to this age group to establish evidence-based consensus and guidelines.

Keywords: Adolescent, child, pediatric, thoracic surgery.

ÖZ

Amaç: Çalışmada, çocuk ve ergenlerde uygulanan göğüs cerrahisi prosedürleri vurgulandı ve değerlendirildi ve göğüs cerrahlarının bu popülasyona ne ölçüde fayda sağlayabileceği gösterildi.

Çalışma planı: Bu retrospektif çalışmaya Ocak 2018 - Ocak 2023 tarihleri arasında göğüs cerrahisi uygulanan 200 çocuk hasta (100 erkek, 100 kadın; ort. yaş: 14.7±6.7 yıl; dağılım, 1 ay-21 yıl) dahil edildi. Hastaların ameliyat endikasyonları, kullanılan cerrahi yaklaşım, komplikasyonlar, hastanede kalış süresi, yoğun bakıma yatış gereksinimi ve mortalite değerlendirildi.

Bulgular: En sık yapılan ameliyat sempatektomi (%30.5) idi ve bunu dekortikasyon (%16) ve travmatik eksplorasyon (%14) izledi. Ameliyatların yaklaşık %50'si minimal invaziv idi. Ortalama hastanede kalış süresi 2.8 gündü ve yoğun bakıma yatış oranı %20 idi. Ameliyat sırası ve ameliyat sonrası komplikasyon oranı %10 idi.

Sonuç: Çocuk hastalara küçük boyutlu bir yetişkin gibi davranma kavramı akılcı değildir. Çocuk hastalar, kendilerine özgü fiziksel, psikolojik ve anatomik özellikleri nedeniyle özel bakıma ve özelleştirilmiş kılavuzlara ihtiyaç duymaktadır. Pediatrik torasik patolojiler üzerine eğitim almış ve uzmanlaşmış göğüs cerrahlarından oluşan bir ekibin sonuçları iyileştireceğini düşünüyoruz. Ek olarak, kanıta dayalı bir fikir birliği ve kılavuzlar oluşturmak adına bu yaş grubuna yönelik daha fazla araştırma yapılmalıdır.

Anahtar sözcükler: Ergen, çocuk, pediatrik, torasik cerrahi.

Pediatric thoracic surgery, both in children and adolescents, is challenging due to the unique physiological and anatomical characteristics of this cohort of patients. Furthermore, they require specialized anesthetic, perioperative, and operative management compared to adults. The paucity of thoracic pathologies in this age group has led to decreased interest in research and guidelines for these patients.

Corresponding author: Nora Mamdouh.

E-mail: nora95youssef@gmail.com

Doi: 10.5606/tgkdc.dergisi.2024.26639

Received: August 05, 2024
Accepted: September 17, 2024
Published online: October 30, 2024

Cite this article as: Hemead H, Mamdouh N, Allam A, Abdelaziz A. Thoracic surgery in children and adolescents: Experience from the thoracic surgery unit of a single referral center. Turk Gogus Kalp Dama 2024;32(4):412-418. doi: 10.5606/tgkdc.dergisi.2024.26639.

The pathological spectrum in this age group is also different from their adult counterpart. For instance, primary small cell and non-small cell lung cancers are exceedingly rare in the pediatric population. On the other hand, other predominate neoplasms, such as pulmonary pleuroblastomas, infantile fibrosarcoma, and inflammatory myofibroblastic tumors, can be challenging to diagnose due to overlapping radiological findings or can be misdiagnosed as an infection due to the high incidence of infections in this population.[1] In addition, inhaled foreign bodies threatening airway patency are commonly encountered in the pediatric population, which requires an emergency intervention to avoid devastating outcomes. Nowadays, congenital malformations are becoming increasingly easier to detect, either with fetal imaging or in the neonatal period, and severe forms often require timely intervention at an early stage.

An immature immune system, difficult airway management, and different cardiopulmonary regulatory responses are other factors to consider when dealing with this category of patients. Surgical approaches are modified to correlate with this distinctive anatomical setup in pediatrics. For instance, surgeons prefer performing anterolateral thoracotomies and muscle-sparing incisions to spare chest wall muscles, which are important for the functionality and chest wall integrity of the growing child.[1,2]

The concept of treating children as small-sized versions of adults has proved to be irrational due to the peculiar physiological, psychological, and anatomical characteristics of this group of patients, which makes the evolution of pediatric thoracic surgery as a subspeciality inevitable. In many countries, pediatric thoracic surgery is carried out by pediatric surgeons, whereas in other centers, including our center, most of these patients are managed by general thoracic surgeons, except for neonatal thoracic surgeries, which are still managed under the service of pediatric surgery. This study aimed to present our experience in the last five years in pediatric thoracic surgery on children and adolescents.

PATIENTS AND METHODS

In this retrospective study, 200 patients (100 males, 100 females; mean age: 14.7±6.7 years; range, 1 month to 21 years) who underwent thoracic surgery at the Faculty of Medicine, Alexandria University between January 2018 and January 2023 were included. Patients aged 21 years and younger were included in the study in adherence to the definition of pediatric thoracic surgery by the USA Food and Drug Administration and the American Academy of Pediatrics.[3-5] The study protocol was approved by the Faculty of Medicine, Alexandria University Ethics Committee (date: 17.11.2022, no: 0305853). The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the participants and/or parents of the participants.

Patients' indications for surgery, surgical approach, complications, length of hospital stay, need for intensive care admission, and mortality were evaluated. Cases were classified into seven main categories: primary hyperhidrosis, infections and inflammatory diseases, trauma, neoplastic, autoimmune disorders, congenital malformations, and spontaneous pneumothorax (Figures 1, 2). Distribution of different categories according to each age group is shown in Table 1.

Detailed history taking and physical examination followed by chest X-ray were performed in all patients. Further imaging with chest ultrasonography, computed tomography, and magnetic resonance imaging were performed when required according to the pathology.

RESULTS

The most encountered indications for surgery were primary hyperhidrosis and empyema, followed by myasthenia gravis and trauma (hemothorax and hemopericardium). There was also a considerable proportion of patients who presented with metastatic pulmonary lesions and mediastinal masses. Lung cysts and foreign body aspiration, requiring surgery, were the least encountered pathologies (Figures 3, 4). Despite having a rare incidence in the pediatric population, juvenile myasthenia gravis was the third most common indication for surgery (6.5%), following primary hyperhidrosis and empyema.

The most commonly performed surgeries were sympathectomies (30.5%) and lung decortication (16%). The least performed procedure was pneumonectomy (0.5%; Table 2). About half (49.5%) of the surgeries were performed thoracoscopically (Table 3).

Pneumonectomy was performed in a single patient, a six-year-old girl who presented with traumatic avulsion of the left main bronchus following blunt chest trauma. Cytoreductive surgery was performed as a redo-surgery for an eight-year-old girl who presented with regrowth of a previously resected pleuropulmonary blastoma, which was resistant to chemotherapy. Staged thoracotomy was performed

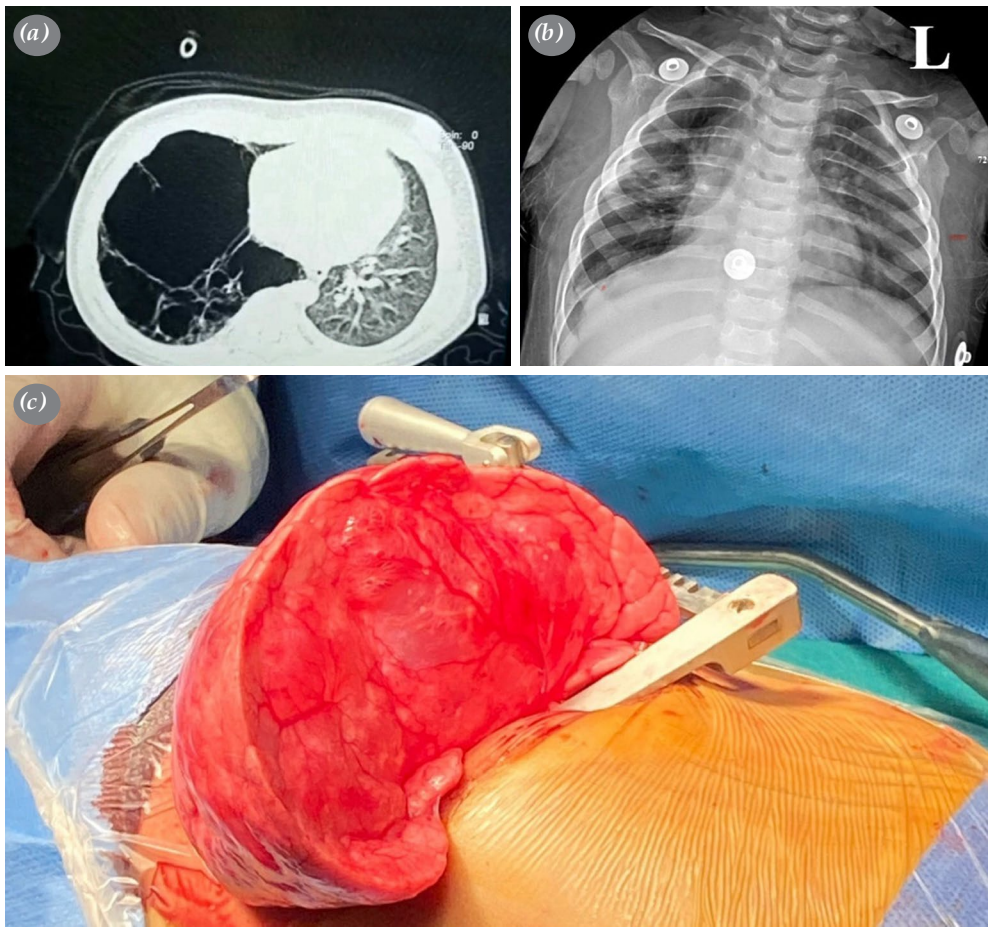

Figure 1. Right lower lobe congenital lung malformation in a six-month-old child. **(a)** Preoperative computed tomography. **(b)** Postoperative radiograph. **(c)** Intraoperative view.

in three cases. Two of them had bilateral pulmonary metastasis and underwent bilateral staged pulmonary metastasectomy. The third child had bilateral hydatid cysts and underwent cystectomy and capitonnage, starting with the complicated side.

The intraoperative and postoperative complication rate was 10%. The recorded complications were intraoperative bleeding necessitating blood transfusion, prolonged air leak, wound infection, atelectasis, and postsympathectomy pneumothorax requiring chest drain insertion.

A single mortality was encountered in a 21-year-old male who presented with a large mediastinal mass causing cardiac tamponade. An emergency

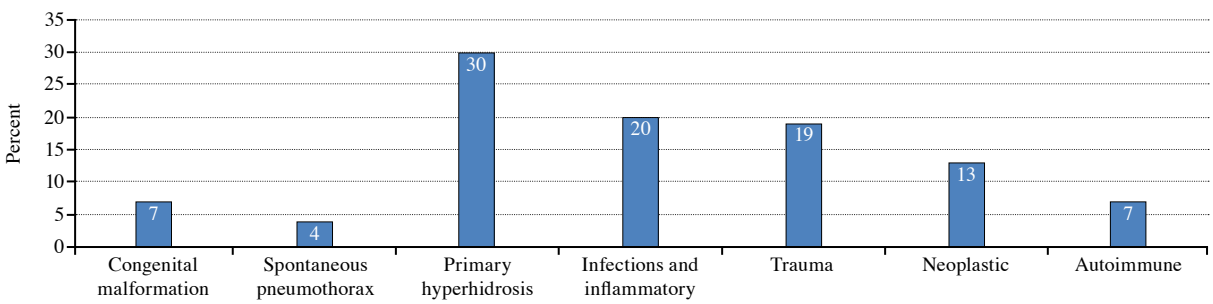

Figure 2. A bar chart showing different categories of diseases and their distribution in our study.

Table 1. Distribution of categories according to each age group

Category	Age range				
			Adolescence		
	Infancy 0 to <2 years	Childhood 2 to <11 years	Early 11 to 14 years	Middle 15 to 17 years	Late 18 to 21 years
Primary hyperhidrosis	-	9	8	16	28
Infections & inflammatory diseases	3	2	6	2	9
Trauma	-	5	1	9	23
Neoplastic	1	10	1	1	13
Autoimmune disorders	-	1	-	1	13
Congenital malformations	4	2	1	2	4
Spontaneous pneumothorax	-	-	-	-	7

thoracotomy was performed, and a large mass invading the pericardium was resected with R1 margins. Histopathological examination revealed synovial sarcoma. The patient died on the 33rd day after the operation due to respiratory failure and rapid tumor regrowth.

The mean length of hospital stay was 2.8±3.9 days, and the rate of intensive care admission was around 20% (n=40). Admissions to the intensive care unit were preoperatively decided for high-risk patients, mainly infants, patients presenting with myasthenia gravis, airway injuries, large mediastinal masses, and patients who had emergency exploration or pneumonectomy. Unplanned intensive care admission was not encountered. A prolonged hospital stay was more common in patients with pleural decortication, as they had a higher incidence of prolonged air leak, atelectasis, and prolonged antimicrobial treatment.

Figure 3. Biportal video-assisted thoracoscopic sympathicolysis in a 16-year-old child.

DISCUSSION

Our center is a tertiary care university hospital serving four heavily populated governorates with an estimated 14 million inhabitants. Pediatric thoracic surgery has been conducted by our cardiothoracic surgery department since its establishment. Pediatric cases are performed by dedicated general thoracic surgery consultants and managed by anesthetists with special interest in pediatric thoracic surgery to ensure high-quality care.

The most common pathologies encountered in our practice are primary hyperhidrosis and empyema. Primary hyperhidrosis is a condition of excessive bilateral symmetrical sweating, mainly in palms, with no underlying medical condition. Excessive palmar sweating can cause a severe psychological and social impact on the individual. Surgery offers an immediate sustained response with high satisfaction rate. Alternative nonsurgical treatments, such as topical therapy and botulinum injections, are expensive and not definitive. Thoracoscopic sympathicolysis is being performed in our center as a day case surgery with high success rate.[6] According to our experience, we prefer performing bilateral sympathicolysis with the patient positioned in the semi-Fowler position.

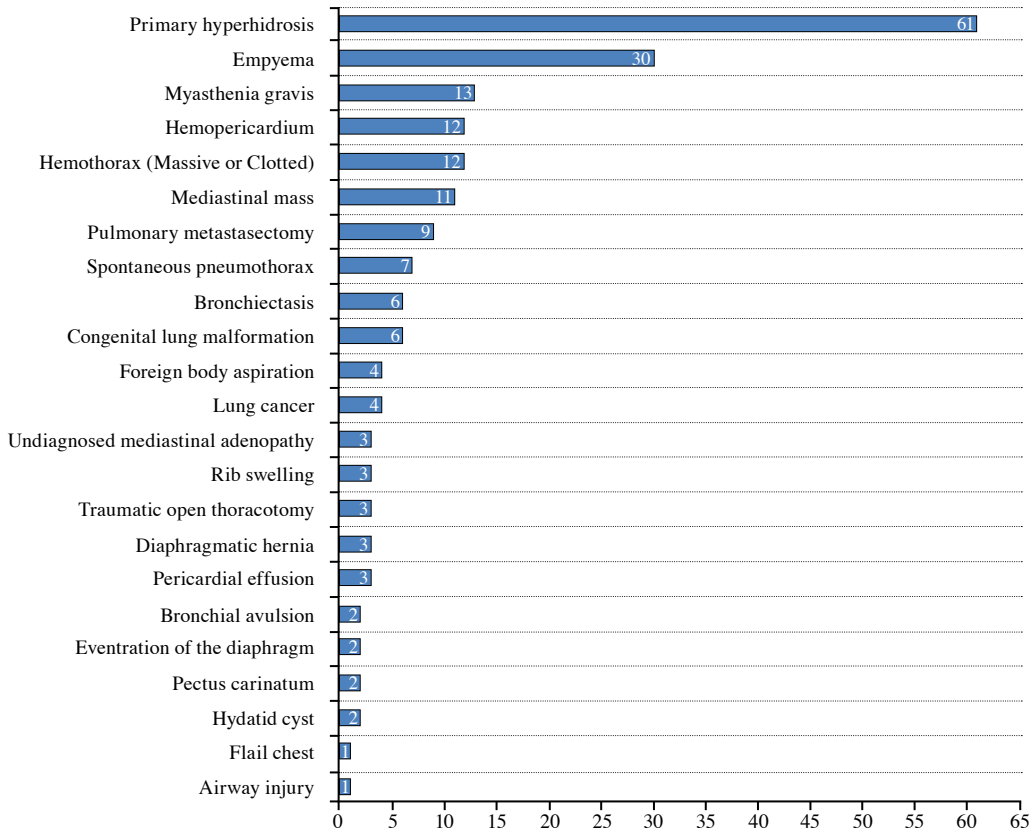

Figure 4. A chart showing different indications for surgery with the number and percentage of cases for each indication.

Table 2. Distribution of procedures

Procedure	n	%
Sympathectomy	61	30.5
Lung decortication	32	16
Traumatic exploration	27	13.5
Lobectomy	18	9
Thymectomy	16	8
Sub-lobar pulmonary resection	8	4
Mediastinal mass excision or biopsy	8	4
Bullectomy and pleurectomy	7	3.5
Diaphragmatic repair or plication	5	2.5
Chest wall or rib resection	3	1.5
Bronchotomy	3	1.5
Pericardial window	3	1.5
Mediastinal lymph node biopsy	3	1.5
Modified Ravitch procedure	2	1
Tumor debulking	2	1
Cystectomy and capitonnage	1	0.5
Pneumonectomy	1	0.5
Total	200	100

Table 3. Different surgical approaches

Approach	n	%
Video-assisted thoracoscopic surgery	95	47.5
Thoracotomy	88	44
Sternotomy	6	3
Staged thoracotomy	3	1.5
Hybrid video-assisted thoracoscopic surgery	2	1
Bilateral submammary incision	2	1
Subxiphoid incision	1	0.5
Mediastinotomy	1	0.5
Cervical mediastinoscopy	1	0.5
Redo-thoracotomy	1	0.5
Total	200	100

We believe that this position, compared with the lateral decubitus position, allows downward displacement of the lung by gravity, better exposure of the operative area, performing the procedure on both sides in the same setting without the need for repositioning, and more efficient deairing at the end of the procedure. In addition, the use of low-pressure carbon dioxide

insufflation avoids complications of high-pressure carbon dioxide in this age group.

In this study, most cases of empyema were due to a complication of untreated or suboptimally treated pneumonia. Our catchment area includes underserved areas with poor access to medical services. Many children with chest infections in these areas are initially overlooked and inadequately treated with traditional practices and herbal medicinal products. This has led to high incidence of complicated parapneumonic effusion and high referral rate of pediatric patients with Stage 3 empyema requiring pleural decortication. Thoracoscopic surgery is attempted when feasible. However, in cases with dense adhesions and trapped lung, we convert to either mini-thoracotomy or conventional thoracotomy if necessary.

Thymectomy is part of the multimodal management of juvenile myasthenia gravis.[7] After medical optimization of their myasthenic symptoms, our patients underwent thymectomy, with smooth postoperative recovery. Derderian et al.[8] concluded that video-assisted thoracoscopic thymectomy is safe and effective in children, with less operative blood loss, postoperative pain, and better cosmetic results compared to the open approach. All our patients were operated by video-assisted thoracoscopic surgery. Patients were positioned in semi-supine position for easier conversion to sternotomy whenever needed.[9] However, none of the studied cases were converted to open surgery. A right-sided approach was used in all cases as we believe that it provides a better working space and allows visualization of both phrenic nerves.

Pediatric lung cancer, either primary or metastatic, differs from adult lung cancer. Primary lung cancer in pediatrics is rare, with an estimated incidence of 0.2% of all childhood malignancies. Shao et al.[10] reported the two most common primary lung cancers in their study were carcinoid tumors and pleuropulmonary blastoma. This was also found in our study, as well as the distribution in different age groups, regardless of the difference in the sample size in both studies. Pleuropulmonary blastoma is more common in childhood, while carcinoid tumors are more common in adolescents.[11] Metastatic lung cancer is more common than primary lung cancer.[12] Pulmonary sublobar resection is usually performed for lung secondaries.[13] According to Döngel et al.[13] most of the lung secondaries were osteosarcoma and Ewing's sarcoma. In our study, osteosarcoma and Wilms tumor were among the most common pathologies. The surgical approach in both studies was similar, with thoracotomies being performed more than video-assisted thoracoscopic surgery. According to our experience, thoracotomies in pulmonary metastatectomy allow better localization of pulmonary nodules and palpation of the whole lung, allowing the detection of any nodule not observed in the preoperative radiology. This is of paramount importance in surgical removal of lung secondaries performed for therapeutic resection of all lesions. On the other hand, diagnostic procedures for solitary pulmonary nodules can be done by video-assisted thoracoscopic surgery, particularly in peripherally located lesions.

For undiagnosed mediastinal lymphadenopathy, we operated on three cases, two of which were operated on by video-assisted thoracoscopic surgery and one by mediastinoscopy. We preferred video-assisted thoracoscopic surgery as it allows for adressing any associated pleural or lung pathology and provides a wider working space for dealing with the bulky calcified lymph nodes we encountered, which were found to be due to sarcoidosis and tuberculosis by histopathology.

When inherited or acquired predisposing factors are present, children and adolescents have a higher likelihood of developing primary spontaneous pneumothorax than adults, and early surgical treatment is proposed to be better, particularly the uniport or biport thoracoscopic approach.[14] Bullectomy and pleurodesis were performed by video-assisted thoracoscopic surgery, either uniportal or multiportal, in most of our cases. Minimally invasive surgery causes less pain, provides better cosmetic results, and allows for more efficient postoperative chest physiotherapy, leading to shorter hospital stays and chest tube duration. Only two cases were operated on by thoracotomy, due to the shortage in articulating thoracoscopic stapler reloads at the time of their surgery.

Kanngiesser et al.[2] reported that the most common indication of surgery in children in their study was oncological, with 20.5%, while infections were less common, with 8.5%. All their cases were operated on by open thoracotomy. Our data differed from their study, with primary hyperhidrosis representing 30.5%, followed by infections and inflammatory indications (20%) and oncologic patients (13%).

Pediatric thoracic surgery is considered a challenging entity due to the peculiar physiological, psychological, and anatomical characteristics and

immature immune and cardiopulmonary responses in this age group. The pathologies encountered in this group of patients are different from those commonly observed in adults, which means the need for different management approaches. Furthermore, physiological response and cardiovascular reserve to surgical stress and perioperative complications are immature in the pediatric age group, differing from the adult population.

In some centers, pediatric thoracic procedures are performed by pediatric surgeons. In other institutions, thoracic surgery in children is an integral part of cardiothoracic surgical training. We believe that pediatric thoracic surgeries are optimally managed by dedicated thoracic surgeons and anesthetists in high-volume centers. We believe that cardiothoracic training programs should integrate exposure and training in pediatric thoracic surgery to ensure a generation of thoracic surgeons who are well-experienced in managing this cohort of patients.

The limitations of our study included the retrospective, single-center design. Additionally, the distribution of pathologies depended on our map of diseases, institutional facilities, and surgical expertise.

In conclusion, pediatric thoracic surgery is a challenging subspecialty that requires cumulative experience and dedicated training to provide high-quality care. The lack of established guidelines for the pediatric population and the variety of pathologies, which are not commonly observed in the adult population, make direct application of some standard thoracic practices routinely performed in adult thoracic surgery unfeasible. In addition, enhanced recovery after thoracic surgery, robotic-assisted thoracic surgery, and other novel evolving technologies are exclusively studied in the adult population. Therefore, there is a rising need to adjust and extensively assess them before being applied safely in the pediatric population. This study highlighted our experience regarding rare pediatric diseases, such as hyperhidrosis, primary spontaneous pneumothorax, juvenile myasthenia gravis, pediatric trauma, and infections.

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

Author Contributions: Idea/concept, literature review: A.A.; Design, critical review: H.H.; Control/supervision, materials: A.A.; Data collection and/or processing, analysis and/or interpretation, writing the article, references and fundings: N.M.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Lichtenberger JP 3rd, Biko DM, Carter BW, Pavio MA, Huppmann AR, Chung EM. Primary lung tumors in children: Radiologic-pathologic correlation from the radiologic pathology archives. Radiographics 2018;38:2151-72. doi: 10.1148/rg.2018180192.
2. Kanngiesser P, Liewald F, Halter G, Sunder-Plassmann L. Thoracic surgery in children. Eur J Cardiothorac Surg 2005;28:50-5. doi: 10.1016/j.ejcts.2005.03.010.
3. Center for Devices and Radiological Health. Pediatric medical devices treat or diagnose diseases and conditions. New Hampshire: Food and Drug Administration; 2019.
4. Center for Devices and Radiological Health. Pediatric Expertise for Advisory Panels - Guidance for Industry and FDA Staff. 2024. Available at: https://www.fda.gov.
5. Hardin AP, Hackell JM; Committee on Practice and Ambulatory Medicine. Age limit of pediatrics. Pediatrics 2017;140:e20172151. doi: 10.1542/peds.2017-2151.
6. Hemead HM, Etman W, Hemead S, Elrewany E, Abdelaziz A. Patients' satisfaction after bilateral thoracoscopic sympathicolysis. J Minim Access Surg 2023;19:478-81. doi: 10.4103/jmas.jmas_179_22.
7. O'Connell K, Ramdas S, Palace J. Management of juvenile myasthenia gravis. Front Neurol 2020;11:743. doi: 10.3389/fneur.2020.00743.
8. Derderian SC, Potter DD, Bansal S, Rowse PG, Partrick DA. Open versus thoracoscopic thymectomy for juvenile myasthenia gravis. J Pediatr Surg 2020;55:1850-3. doi: 10.1016/j.jpedsurg.2019.11.013.
9. Kaba E, Cosgun T, Ayalp K, Alomari MR, Toker A. Right sided VATS thymectomy: "current standards of extended thymectomy for myasthenia gravis". Video-assist Thorac Surg 2017;2:30.
10. Shao W, Liu J, Li B, Guo X, Sun J, Li H, et al. Primary lung cancer in children and adolescents: Analysis of a surveillance, epidemiology, and end results database. Front Oncol 2023;13:1053248. doi: 10.3389/fonc.2023.1053248.
11. Yadav MK, Singhal M, Bhatia A, Kapoor R, Gupta N, Khandelwal N. Pleuropulmonary blastoma in adolescence: A rare tumor beyond first decade of life. Lung India 2015;32:281-4.
12. Özkan M. Pulmonary tumors in childhood. Turk Gogus Kalp Dama 2024;32(Suppl1):S73-S7.
13. Döngel İ, Özkan B, Tanju S, Toker A. Pulmonary sublobar resections in pediatric patients. Turk Gogus Kalp Dama 2014;22:99-103. doi: 10.5606/tgkdc.dergisi.2014.8470.
14. Furia S, Breda C. Primary spontaneous pneumothorax in children and adolescents: A systematic review. Pediatr Med 2019;2:12.