Surgical Approach to Pediatric Mediastinal Masses Based on Imaging Characteristics

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Abstract

BACKGROUND: Pediatric mediastinal masses may be resected using an open or video-assisted thoracoscopic surgery (VATS) approach. We sought to define the preoperative imaging findings predicting amenability to VATS.

METHODS: This multicenter retrospective study of pediatric patients undergoing either VATS or open surgical mediastinal mass resection between 2008-2018 evaluated the preoperative imaging descriptors associated with VATS. Postoperative endpoints included length of stay (LOS), 30-day readmission, 90-day mortality and complication rates.

RESULTS: Mediastinal mass resection was performed in 33 patients. Median tumor size was 6 cm, and 51.5% had anterior mediastinal tumors. The 23 (69.7%) patients who underwent VATS were significantly older (144 months vs 32, *P*=0.01) and larger (33.6 kg vs 13.8 *P*=0.03). Preoperative imaging characteristics in VATS included “well circumscribed”, “smooth margins” and “cystic”, while the open surgery group were “heterogeneous” and “coarse calcification”. The open group had more germ cell tumors (60.0% vs 13.0%, *P*=0.16) but no difference in malignancy. VATS patients had shorter LOS (2 days vs 6.5, *P*=0.24). Readmission, complication and mortality rates were similar.

CONCLUSION: Pediatric patients with apparent malignancy frequently underwent open resection compared with the thoracoscopic group, although final malignant pathology was similar. Equivalent outcomes and shorter LOS should favor a minimally invasive approach.

LEVEL OF EVIDENCE: Level III

Highlights

- Risk stratification by image-defined risk factors (IDRF) is widely used in the preoperative assessment of pediatric neuroblastoma. No such imaging criteria exist to assist the preoperative planning of surgery for pediatric mediastinal masses.
- Using similar IDRF criteria to approach mediastinal masses in pediatric patients, thoracoscopic surgery, as opposed to open resection, can be performed safely with non-inferior postoperative outcomes.

Introduction

Mediastinal masses can develop in pediatric patients from local or transient cells during development or from metastatic malignant cells. Such masses are histopathologically and radiologically diverse, the most frequent being thymomas, neurogenic tumors, and benign cysts.

To assist in comprehensive treatment planning, preoperative imaging using computed tomography (CT) or magnetic resonance imaging (MRI) is often used to guide the surgical approach. For example, in

pediatric neuroblastoma, image-defined risk factors (IDRF) are features definable by objective and subjective imaging characteristics that are associated with a high risk of surgical complications[1]. The presence of IDRFs allows the surgeon to define high-risk factors, such as vascular encasement, airway compression, tumor infiltration and pedicle invasion, to guide operative approach. Similarly, in adult pancreatic cancer, specific imaging characteristics defining borderline resectable disease aid in the assessment of neoadjuvant treatment and need for vascular reconstruction[2]. These classification schemata for neuroblastoma and pancreatic adenocarcinoma not only contribute to disease staging but also assist in the preoperative surgical strategy[1, 3]. Unfortunately, no such categorizations currently exist in the realm of pediatric mediastinal masses to guide surgical approach.

Increasing utilization of thoracoscopy or video-assisted thoracoscopic surgery (VATS) for the resection of pediatric mediastinal masses has followed advances in surgical technique and surgeon expertise [4]. As with other minimally invasive surgical modalities, VATS is associated with improved surgical outcomes including shorter length of hospital stay, better cosmesis and improved patient satisfaction. However, preoperative planning for thoracoscopic resection of pediatric mediastinal masses has remained both a diagnostic and technical challenge due to the variability of patient age and size, presentation, as well as underlying tumor pathology[5–7].

We performed a retrospective analysis in pediatric patients with mediastinal masses to determine the role of VATS compared with open resection, using similar image-guided concepts derived by IDRF for treatment of neuroblastoma and resectability in pancreatic cancer. Furthermore, we sought evidence supporting the thoracoscopic approach to pediatric mediastinal masses.

Methods

Study Cohort

A retrospective review was performed on all pediatric patients with mediastinal masses who underwent resection primarily by four pediatric surgeons within the Kaiser Permanente Southern California Healthcare System from May 2008 to September 2018. Approval was obtained from the Institutional Review Board of Kaiser Permanente Southern California (#2211). A computed tomography (CT) or magnetic resonance imaging (MRI) of the chest was performed in all patients with a mediastinal mass to evaluate the imaging characteristics and tumor size. Patient medical records were reviewed for demographic information including sex, age and weight at the time of surgery, preoperative diagnosis, mediastinal location, operative technique, and length of hospital stay (LOS). Postoperative complications, readmission rates, final surgical pathology and length of follow-up were assessed through subsequent hospital and clinic encounters.

Surgical Technique

Preoperative imaging was used to assess feasibility of thoracoscopic approach. The surgical approach was primarily at the surgeon’s discretion. Factors influencing a VATS approach included adequate patient

age/weight, size of tumor and mediastinum relative to patient size, encasement of vessels, relative location of important vascular structures such as the aortic arch or innominate vein, and malignant-appearing tumor characteristics. If patients lacked any preoperative risk factors precluding them from attempting a thoracoscopic approach, then VATS was attempted. The open conversion rate was 0%.

Statistical Analyses

Patient demographics, tumor characteristics, and perioperative outcomes were reported as medians with ranges for continuous variables, and frequencies and percentages for categorical variables. Comparative analyses between cohorts were conducted using χ^2 or Fisher's exact tests for categorical variables and Student's *t*-test for continuous variables. *P*-values less than 0.05 were considered statistically significant. All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC).

Results

During the study period, a total of 33 pediatric patients underwent resection for mediastinal masses. There were 23 patients (69.7%) who had VATS and 10 patients (30.3%) who had open resection (Table 1). Male patients comprised 42.4% of the study cohort, not significantly different between the VATS and open groups. Median age at the time of operation was 84.2 months. Patients who underwent thoracoscopic resection were significantly older (144 months vs 31.6, $P = 0.0098$) and heavier (33.6 kg vs 13.8, respectively, $P = 0.033$) than patients who had open surgery.

Table 1
Patient demographics, tumor characteristics, and perioperative outcomes after thoracoscopic or open surgery

	Total (N = 33)	Thoracoscopic (N = 23)	Open (N = 10)	P-Value
Demographics				
Age, months (median, IQR)	84.2 (29–157)	144 (37–168)	31.6 (7–45)	0.0098
Male, N (%)	14 (42.4%)	9 (39.1%)	5 (50.0%)	0.56
Weight, kg (median, IQR)	29.2 (12–45)	33.6 (16–69)	13.8 (8–27)	0.033
Tumor characteristics				
Tumor size, cm (median, IQR)	6 (4.1-7)	5 (3-7.4)	6 (6–7)	0.28
Tumor/weight, cm/kg (median, IQR)	0.2 (0.1–0.5)	0.2 (0.1–0.4)	0.6 (0.2-1)	0.15
Location				0.50
Anterior	17 (51.5%)	11 (47.8%)	6 (60.0%)	
Posterior	12 (36.4%)	8 (34.8%)	4 (40.0%)	
Middle	4 (12.1%)	4 (17.4%)	0 (0%)	
Pathology group				0.16
Germ cell	9 (27.3%)	3 (13.0%)	6 (60.0%)	
Neurogenic	9 (27.3%)	6 (26.1%)	3 (30.0%)	
Sarcoma	4 (12.1%)	3 (13.0%)	1 (10.0%)	
Bronchogenic cyst	3 (9.1%)	3 (13.0%)	0 (0%)	
Lymphatic	3 (9.1%)	3 (13.0%)	0 (0%)	
Thymic	3 (9.1%)	3 (13.0%)	0 (0%)	
Other	2 (6.1%)	2 (8.7%)	0 (0%)	
Malignant	9 (27.3%)	5 (21.7%)	4 (40.0%)	0.40
Patient outcomes				
LOS (days) (median, IQR)	3 (2–7)	2 (1–3)	6.5 (4–14)	0.24
Readmission at 30 Days, N (%)	2 (6.1%)	1 (4.4%)	1 (10.0%)	0.52
Mortality at 90 Days, N (%)	1 (3.0%)	0 (0%)	1 (10.0%)	0.30

Abbreviations: IQR (interquartile range), LOS (length of stay)

	Total (N = 33)	Thoracoscopic (N = 23)	Open (N = 10)	P-Value
Complication, N (%)	5 (15.2%)	2 (8.7%)	3 (30.0%)	0.15
Median Follow-Up Months (IQR)	62.1 (32–97)	66.9 (32–102)	53.2 (24–86)	0.43
Abbreviations: IQR (interquartile range), LOS (length of stay)				

The median tumor size was 6.0 cm (VATS 5.0 cm vs open 6.0 cm, $P = 0.28$). The most common tumor location was in the anterior mediastinum (51.5%) followed by the posterior mediastinum (36.4%) for the total cohort. More patients in the open resection group had anterior mediastinal masses than in the VATS group (60.0% vs 47.8%, $P = 0.50$). Preoperative imaging characteristics prominent in VATS included “well-circumscribed,” “smooth margins,” and “cystic mass,” while terminology in the open group included “heterogeneous” and “multiple coarse calcifications.” Fig. 1 shows preoperative CT or MRI examples of four pediatric patients with mediastinal masses.

Within the open group, four patients (40%) had a thoracotomy and four patients (40%) had a median sternotomy. The remaining two patients had a clamshell and thoracoabdominal incision (data not shown).

The open group had more germ cell tumors than the thoracoscopic group (60.0% vs 13.0%, $P = 0.16$); however, the latter had more even distribution of sarcoma, bronchogenic cyst, lymphatic, and thymic pathologies (Table 1). There was no difference in malignancy between the two surgery groups with an overall rate of 27.3% malignant masses in the total cohort.

VATS patients had shorter LOS compared with open patients (2 days vs 6.5, $P = 0.24$). Readmission, complication and mortality rates were similar between the groups (Table 1). Three patients had pneumothorax or hydrothorax complications requiring postoperative chest tube placement. One patient died within 90 days postoperatively due to complications from her rare genetic syndrome [ROHHAD (rapid onset obesity with hypothalamic dysregulation, hypoventilation, and autonomic dysregulation)], where she suffered from anoxic brain injury and was terminally extubated. Median follow-up time was 62.1 months for the entire cohort.

Discussion

Preoperative evaluation of a patient with a mediastinal mass can be wide-ranging and vary depending on the source of the recommendations and tumor anatomy[8]. Our study shows that pediatric patients with mediastinal masses that had malignant-appearing characteristics on preoperative imaging frequently underwent open resection compared with the thoracoscopic group, even though rate of final malignant pathology was similar. Moreover, postoperative outcomes were not significantly different between the two surgical groups.

IDRF-negative tumors are typically associated with a minimally invasive approach, although these low-risk tumors have not been shown necessarily to have improved oncologic outcomes such as rate of complete resection, recurrence, and overall survival[9]. In our study, given equivalent postoperative outcomes on readmission, complication, and survival rates between the VATS and open surgery groups, coupled with shorter LOS in the VATS group, preoperative consideration should be weighted towards a minimally invasive approach under amenable patient conditions. Thoracoscopy has long been shown to be a safe and effective method to resect lesions in the mediastinum, has gained popularity in increasingly complex thoracoscopic procedures, and is associated with improved surgical outcomes and lowered morbidity[4, 8]. We recommend that the thoracoscopic approach should always be attempted in the absence of anatomic restrictions.

The role of preoperative imaging is decisive in diagnosis, staging and treatment planning, delineating IDRF and resectable cancers as well as guiding surgical approach. On preoperative imaging, lesions concerning for malignancy include heterogeneity with indistinct margins, calcifications, areas of necrosis, hemorrhage and contrast enhancement, as well as involving other anatomic compartments, crossing midline, or encasing and displacing important structures[10]. Our approach to the preoperative planning of mediastinal mass resection evaluates the size of the tumor and mediastinum relative to the size of the patient and supports VATS in spite of malignant-appearing disease. Unless patient risk factors and vessel encasement do not physically allow for a thoracoscopic approach, VATS is normally the attempted modality in all cases. Our study shows that the postoperative outcomes are not significantly different between the thoracoscopic and open surgery groups, with slight improvement in the duration of hospital stay in the minimally invasive group. Therefore, thoracoscopic resection may harbor overall benefit over open resection and should be attempted whenever possible.

Limitations to this study include a small sample size and inherent retrospective nature. While we have demonstrated a variety of pediatric patients in our multicenter study with mediastinal masses and various histopathology, our review is likely under-powered to detect a significant difference in outcomes and can only show non-inferiority of the thoracoscopic approach compared with open resection. We suspect that with a larger sample size, the length of stay difference between the VATS and open surgical group would achieve statistical significance, with a significantly lower LOS days in the minimally invasive group.

Conclusions

We have demonstrated that resection of mediastinal masses in pediatric patients can be safely performed using a thoracoscopic surgical approach. VATS is successful even in cases where preoperative imaging characteristics appear malignant or have other image-defined risk factors. A wider study incorporating more patients is required to confirm our findings. However, our analysis thus far does show that VATS is not inferior to open resection and, given the safety and possible benefits, should be considered for all suitable patients.

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Figures

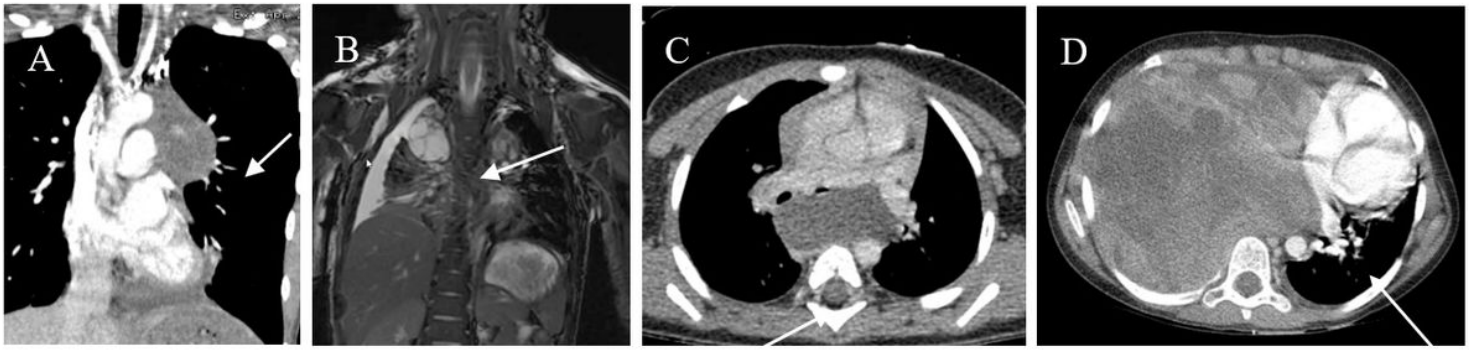

Figure 1

Preoperative CT and MRI examples with arrows localizing the mediastinal masses

A) 13 year-old female with a large 14 cm anterior mediastinal mass of heterogeneous density, mostly cystic in nature. Approach: thoracoscopic. Final pathology: benign cystic teratoma.

B) 3 year-old female with 6 cm anterior mediastinal mass extending from the right neck to right chest, multiloculated cystic in appearance. Approach: thoracoscopic. Final pathology: lymphovascular malformation.

C) 14 month-old female with 5 cm middle mediastinal cyst posterior to trachea and carina, well-circumscribed and likely represents a duplication cyst. Approach: thoracoscopic. Final pathology: bronchogenic cyst.

D) 7 year-old female with large posterior mediastinal mass 14 x 12 x 17 cm extending across midline and compressing the left atrium, very heterogenous in nature. Status post neoadjuvant therapy prior to surgical resection. Approach: open. Final pathology: Ewing’s sarcoma.