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ORIGINAL ARTICLE

Pediatric thymectomy: a study of national trends in demographics, short-term outcomes, and cost

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Abstract

Background Thymectomy in pediatric patients is an effective treatment for myasthenia gravis (MG), thymic neoplasms, and other rarer pathologies. It is an uncommon procedure in children and studies have focused on small, single-institution cohorts. We sought to better characterize its use by utilizing a national database.

Methods The Kids' Inpatient Database was used to identify hospital discharge records of patients ≤ 20 years old who underwent thymectomy. A retrospective cross-sectional analysis for 2003, 2006, 2009, and 2012 was performed. Trends in patient characteristics, diagnosis, surgical approach, and short-term outcomes were analyzed. Risk factors were identified using univariate and multivariate analyses.

Results There were 600 thymectomies identified. MG was the most common indication. Thoracoscopy is being used increasingly for all diagnoses except malignancy. The overall morbidity rate was 14.0%, with respiratory complications representing the largest group. No in-hospital deaths were identified. Private insurance was associated with shorter hospital stays and lower costs. Hispanic race was associated with more complications, longer stays, and higher costs. Thoracoscopic thymectomies had shorter stays than open procedures.

Conclusion Thymectomy in the pediatric population is being performed safely, with low morbidity and no identified mortalities. Thoracoscopy results in reduced length of stay and is being used increasingly. Of note, socioeconomic and racial factors impact outcomes.

Keywords Thymectomy · Myasthenia gravis · Thymoma · VATS · Thoracoscopy

Abbreviations

AHRQ	Agency for Healthcare Research and Quality
HCUP	Healthcare Cost and Utilization Project
ICD-9-CM	International Classification of Diseases, Ninth Edition, Clinical Modification
KID	Kids' Inpatient Database
MG	Myasthenia gravis
OR	Odds ratios
US	United States
USD	United States Dollars

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Introduction

Thymectomy is the standard treatment of thymoma and malignant neoplasms of the thymus [1–5], and it has been repeatedly demonstrated to be a safe and effective treatment for myasthenia gravis (MG) in both adult [1, 6–9] and pediatric patients [10–14]. Traditionally, thymectomies have been performed by either a median sternotomy or transcervical approach in both pediatric and adult patients. Transsternal thymectomy has been historically preferred, as it is thought to allow for a more complete resection of the diseased thymus [3, 6]. However, recent advances in technology and surgical technique have allowed surgeons to achieve similar resections and outcomes with minimally invasive approaches [7, 15]. Post-operative complications

and mortality rates are low in patients undergoing open thymectomy, and minimally invasive thoracoscopic techniques have further reduced complication rates and hospital stay lengths without negatively impacting outcomes in both pediatric and adult patients [1, 3, 4, 7, 10–12, 14]. The very low rate of pediatric thymectomy has made it difficult to study trends and analyze outcomes in large patient populations. The majority of past studies rely on small sample sizes from individual institutions.

The goal of this study was to leverage the national estimates provided by the Kids' Inpatient Database (KID) to characterize the use of pediatric thymectomy across the country, including indications, patient and hospital characteristics, and approaches. Furthermore, we aimed to evaluate predictors of short-term patient outcomes.

Methods

This study was deemed exempt from review by an Institutional Review Board because the Kids' Inpatient Database (KID) is a publicly available, de-identified database.

Database

A retrospective cross-sectional analysis of the KID was performed for the years 2003, 2006, 2009, and 2012. This database, collected and maintained by the Agency for Healthcare Research and Quality's (AHRQ) Healthcare Cost and Utilization Project (HCUP), contains data for approximately 80% of pediatric hospital discharge records of patients 20 years of age and younger in the United States. Discharge weights, provided by HCUP, were used for all analyses to produce nationally representative estimates of discharge records.

Discharge records obtained and reported contain patient-specific information including age at admission, gender, race, insurance status, comorbidities, diagnoses reported during the hospitalization, procedures performed during the hospitalization, length of stay, total reported charges, and mortality status. Diagnoses and procedures are reported using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) system. Hospital-specific information including region, size, and teaching-status are also included for each observation.

To protect patient confidentiality, the data use agreement from the AHRQ and HCUP do not allow the reporting of information when the number of observations is less than or equal to 10. For that reason, all such samples will be reported in this analysis as ≤ 10, and any frequency will be adjusted accordingly. p values for these observations will be based on exact values.

Patient selection

Discharge records of all patients 20 years of age and younger who underwent thymectomy via an open approach (ICD-9-CM codes 07.80, 07.81, 07.82) or via a thoracoscopic approach (ICD-9-CM codes 07.83, 07.84) were selected. Over 3600 weighted cases were identified.

To exclude patients who underwent non-therapeutic thymectomies during unrelated thoracic procedures, only those patients with thymic pathology identified in the ICD9 diagnosis codes were selected. This includes myasthenia gravis (ICD-9-CM codes 358.0, 358.00, 358.01), thymic hyperplasia (ICD-9-CM code 254.0), malignant neoplasm of the thymus (ICD-9-CM codes 164.0, 235.8), benign neoplasm of the thymus (ICD-9-CM code 212.6), and other diseases of the thymus (ICD-9-CM codes 254.1, 254.8, 254.9). Additionally, if thymic pathology was identified but a significant concurrent thoracic procedure was performed, the patient was excluded. Any records with missing age, gender, discharge quarter, or primary diagnosis input data were excluded.

In-hospital outcome variables

The variables identified to evaluate in-hospital outcomes were complication rate, length of stay, and total hospital costs.

Complication rates were calculated as a percentage of patients that experienced at least one of a series of identified complications, including bleeding, dehiscence, surgical site infection, sepsis, transfusion reactions, ulcers, thromboembolic events, and cardiac, neurologic, pulmonary, and renal complications. Specific ICD-9-CM diagnoses codes for complications included are listed in Supplementary Table 1. A complication is defined as having one or more of these ICD-9-CM diagnoses.

Hospital charges, the amount billed, were converted into costs, the real cost of a hospitalization to the hospital [16], using HCUP-provided year- and hospital-specific cost–charge ratios. When hospital-specific information was unavailable, weighted local group averages were used. Costs were then converted into USD2012 using the Bureau of Labor Statistics Consumer Price Index (CPI) Inflation Calculator [17].

Statistical analysis

All statistical analyses were conducted using SPSS v.24 statistical software (IBM, Armonk, NY) [18]. A 95%

confidence interval ($p < 0.05$) was defined as statistical significance for all analyses.

Descriptive analysis was conducted for the selected therapeutic thymectomies in the sample to characterize the data over time and by procedure approach. Patient-specific variables included diagnosis (myasthenia gravis, thymus hyperplasia, benign neoplasm of thymus, malignant neoplasm of thymus, or other thymus disease), age, gender, race (white, black, Hispanic, other, and unknown), insurance status (private, Medicaid, self-pay, other), number of comorbidities, number of diagnoses, and number of procedures. Hospital-specific variables included region. Short-term outcomes variables included length of stay, total hospital costs (USD2012), and complication rate.

Trends in categorical variables were evaluated using Mantel–Haenszel linear-by-linear association Chi-squared test, and trends in continuous variables were evaluated using one-way ANOVA (for trend). The Pearson Chi-square test and one-way ANOVA were also used to evaluate differences in patient characteristics, hospital characteristics, and outcomes for each procedure type.

Univariate and multivariate regression analyses were performed to evaluate predictors of short-term outcome variables, including complication rates, length of stay, and total hospital costs. For categorical outcome variables, binary logistic regressions were conducted, and odds ratios (OR) and p values are reported. For continuous outcome variables, linear regressions were conducted, and coefficients and p values are reported. Variables identified as significant in univariate analysis ($p < 0.05$) were included in the multivariate model.

Results

Demographics, diagnoses, and post-operative outcomes

Patient and hospital characteristics, approach, and in-hospital outcomes of pediatric thymectomy patients in the United States are detailed in Table 1. Of the 600 thymectomies identified through 2003, 2006, 2009, and 2012, 392 (65.4%) were performed on females and 208 (34.6%) were performed on males. The median age of patients was 15 years (IQR 11–18). The median age declined from 16 (IQR 12–18) in 2003 to 13 (IQR 9–17) in 2012 ($p = 0.001$). White patients represented the greatest proportion of procedure utilization (41.9%), followed by black patients (18.0%) and Hispanic patients (15.4%). 15.9% of hospitalizations did not have race recorded. Medicaid-insured patients undergoing therapeutic thymectomy increased from 17.0% in 2003 to 38.8% in 2012 ($p = 0.001$). A plurality of procedures was performed in hospitals in the Southern region of the United States (48.8%).

The total number of thymectomies performed did not change significantly over time nor did the indications for thymectomy (Fig. 1). The most common diagnosis for which therapeutic thymectomy was performed was myasthenia gravis (69.4%). Of note, there were 1734 hospitalizations with myasthenia gravis as the primary diagnosis over the years studied; of those, 24.0% underwent thymectomy during the hospitalization. Other diagnoses included hyperplasia of the thymus (15.3%), benign neoplasm of the thymus (13.8%), and malignant neoplasm of the thymus (2.7%). Of note, of the 92 patients identified with a diagnosis of thymic hyperplasia, 43.5% also had a diagnosis of MG or thymic neoplasm. Those that did not have a concurrent diagnosis most likely had myasthenia gravis but were coded as thymic hyperplasia based on histological examination.

The median length of stay over the years studied was 3 days (IQR 2–5), and the median cost was $11,726 (IQR $8426–$18,888). Length of stay ($p = 0.758$) and cost ($p = 0.092$) did not change over time. Approximately, 14.0% of patients had at least one complication diagnosis, of which pulmonary complications, including pneumothorax, acute respiratory failure, and pulmonary insufficiency, were the most common (Table 2). There were no cases of in-hospital mortality identified in our sample.

Surgical approach

The code for thoracoscopic thymectomy was introduced in 2009, at which point 27.1% of procedures were performed by this approach. In 2012, this increased to 44.4% ($p = 0.002$). Table 3 compares the patient and hospital characteristics and in-hospital outcomes of open versus thoracoscopic thymectomy for the 279 procedures performed in 2009 and 2012. Thoracoscopy was used more frequently in 2012 than 2009 for all diagnoses except malignancy. The most common indication for thoracoscopy was MG (78.8%). Southern hospitals performed the greatest number of thymectomies during 2009 and 2012, but they represented a significantly greater proportion of open procedures than thoracoscopic procedures (55.9% vs. 36.7%, $p = 0.002$). On the other hand, Midwestern hospitals performed relatively more thoracoscopic procedures than open procedures (25.5% vs. 12.8%, $p = 0.007$).

Patient age, gender, and race are not associated with any significant difference in surgical approach. While not statistically significant in this cohort, thoracoscopic patients trended towards private insurance (66.7% vs. 54.4%, $p = 0.053$), while open patients trended towards Medicaid insurance (37.2% vs. 26.3%, $p = 0.063$).

Thoracoscopic approach was associated with shorter hospital stays with a median length of stay of 2 days (IQR 1–3), compared to open approach with a median length of stay of 4 days (IQR 3–6); $p = 0.006$. There was no significant

Table 1 Patient and hospital characteristics, surgical approach, and in-hospital outcomes in the United States (2003, 2006, 2009, 2012)

Variable	Total	2003	2006	2009	2012	*p* value
Total (%)	600	153 (25.5)	168 (28.0)	144 (24.0)	135 (22.5)	
Procedure type	279	–	–	144 (51.6)	135 (48.4)	
Open	64.5%	–	–	72.9%	55.6%	0.002
Thoracoscopic	35.5%	–	–	27.1%	44.4%	0.002
Diagnosis						
Myasthenia gravis	69.4%	66.0%	69.5%	71.3%	71.1%	0.311
Hyperplasia	15.3%	22.7%	10.7%	14.7%	13.3%	0.068
Benign Neo.	13.8%	15.7%	12.5%	13.2%	14.1%	0.738
Malignant Neo.	2.7%	< 6.5%	< 6.0%	< 6.9%	< 7.4%	0.244
Other disease	11.5%	11.7%	15.0%	11.1%	7.4%	0.166
Age	15 (11–18)	16 (12–18)	15 (12–18)	16 (11–18)	13 (9–17)	0.001
Female	65.4%	63.7%	63.7%	60.8%	70.4%	0.764
Race						
White	41.9%	45.0%	39.5%	43.8%	40.0%	0.610
Black	18.0%	16.0%	18.0%	16.0%	22.2%	0.097
Hispanic	15.4%	16.8%	13.2%	17.4%	14.8%	0.644
Other race	8.1%	< 6.5%	< 6.0%	8.3%	17.0%	< 0.001
Unknown race	15.9%	13.7%	26.9%	14.6%	< 7.4%	0.010
Insurance status						
Medicaid	29.5%	17.0%	34.5%	28.5%	38.8%	0.001
Self-pay	2.8%	< 6.5%	< 6.0%	< 6.9%	< 7.4%	0.762
Private	60.3%	69.9% %	54.2%	65.3%	51.5%	0.019
Other	7.3%	9.8%	8.3%	< 6.9%	< 7.4%	0.512
Hospital region						
Northeast	15.0%	20.1%	10.1%	14.0%	16.3%	0.559
Midwest	19.0%	19.5%	20.8%	18.9%	16.3%	0.416
South	48.8%	44.2%	52.4%	49.0%	49.6%	0.512
West	17.2%	16.2%	16.7%	18.2%	17.8%	0.655
Length of stay	3 (2–5)	3 (2–5)	3 (2–6)	2 (3–5)	2 (3–5)	0.758
Total costs	11,726 (8426–18,888)	10,648 (7232–15,480)	12,429 (8362–20,109)	12,078 (9237–22,355)	11,728 (9068–19,465)	0.092
Comp. rate	14.0%	12.4%	10.8%	18.8%	14.8%	0.223

Mantel–Haenszel linear-by-linear Chi-square test was used for evaluation of binary variables; one-way ANOVA was used for evaluation of continuous variables. Median and interquartile range (Q1–Q3) given for continuous factors

A p value of <0.05 was used to denote significance. Analysis of procedure type only includes hospitalizations in 2009 and 2012

difference in complication rate or total hospital costs between the two surgical approaches.

Determinants of length of stay, complications, and costs

Univariate predictors of complications, length of stay, and total hospital costs for pediatric thymectomy patients are presented in Table 4. Complication rates were increased in patients with malignant neoplasm of the thymus (OR = 2.98, $p = 0.040$), compared to patients with MG. Age and gender were not associated with any significant difference in complication rate. Black (OR = 2.14, $p = 0.025$) and Hispanic race (OR = 2.14, $p = 0.025$) were identified as predictors of complications. Hispanic patients had longer hospital stays ($p < 0.001$) and higher total costs ($p = 0.002$) than white patients. Privately insured individuals had shorter hospital stays ($p < 0.001$) and lower total costs ($p < 0.001$) than Medicaid patients. Patients in hospitals in the Midwest ($p = 0.015$) and South regions ($p = 0.003$) of the US incurred significantly lower costs than patients in the Northeast. Patients with two or more comorbidities identified in KID had higher complication rates (OR = 2.06, $p = 0.041$), longer hospital stays ($p < 0.001$), and higher costs ($p < 0.001$) than patients without any comorbidities. Thoracoscopic approach was associated with significantly shorter hospital

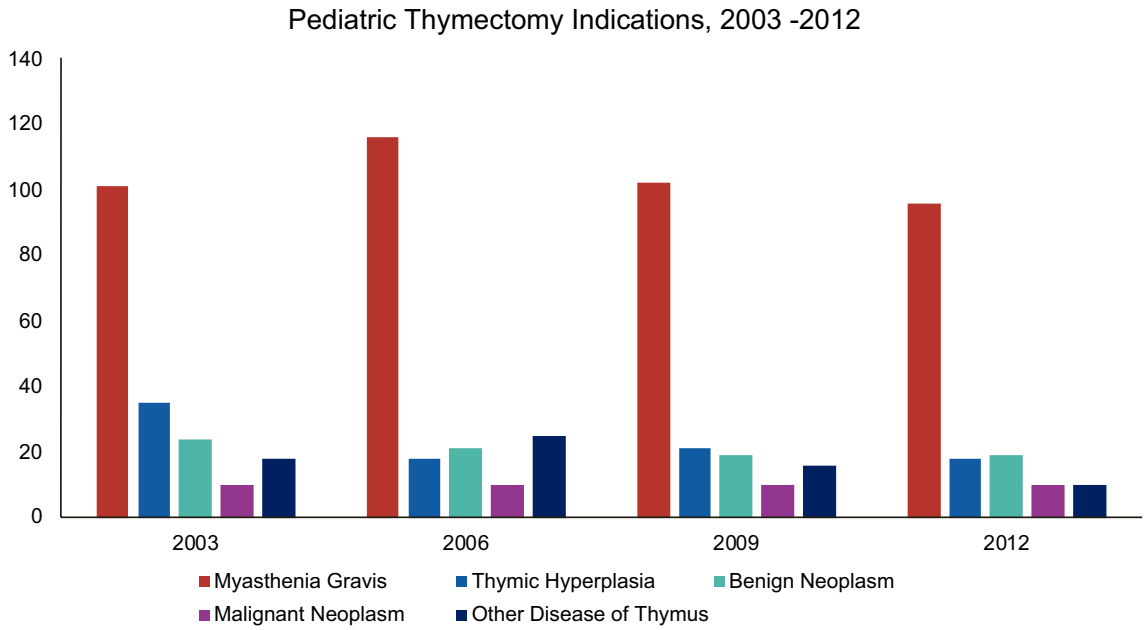

Fig. 1 Indications for pediatric thymectomy

Table 2 Most common thymectomy patient complications

Complication	Count	Percent (%)
Pulmonary complications	71	11.9
Cardiac complications	< 10	< 1.9
Minor hemorrhagic complications	< 10	< 1.9
Renal complications	< 10	< 1.9
Major hemorrhagic complications	0	0
Mortality	0	0
Total complications	84	14.0

stays ($p = 0.006$) than open thymectomies in the years 2009 and 2012, but approach had no significant impact on complication rates (OR = 0.905, $p = 0.764$) or hospital costs (coefficient = −3101, $p = 0.237$).

In multivariate analysis (Table 5), patient diagnosis was the greatest predictor of complication rate, with patients with malignant neoplasm of the thymus exhibiting significantly higher likelihood of experiencing a complication than MG patients (OR = 5.87, $p = 0.019$). Patients with MG were not significantly more likely to experience respiratory complications than patients without MG ($p = 0.104$). Surgical approach and diagnosis remained predictors of hospital length of stay, with thoracoscopic approach ($p = 0.029$) and a diagnosis of only hyperplasia of the thymus ($p = 0.035$) associated with shorter stays. Similar to the findings of univariate analysis, privately insured patients were more likely to incur lower costs than Medicaid patients ($p = 0.028$). Midwest and Southern hospitals experienced better overall outcomes than Northeast hospitals, with comparable LOS and complication rate but significantly lower costs. Increasing comorbidities were associated with poorer outcomes. While univariate analysis showed race to be a predictor of short-term outcomes, multivariate analysis revealed no significant association.

Discussion

Thymectomy remains a rare procedure among pediatric patients, and existing data regarding trends, procedure indications, surgical approach, socioeconomic factors, and patient outcomes are limited and rely on retrospective single-institution studies. A systematic review conducted by Madenci et al. in 2017 analyzed 488 pediatric patients from multiple studies over a 16-year period who underwent thymectomy for MG to better understand patient outcomes and improvements in disease severity. While the authors concluded that thymectomy is a safe intervention for MG patients with relatively few complications, the study also highlights the fact that the quality of existing data is poor [13]. The use and outcomes of thymectomy in pediatric patients with other conditions have been less extensively studied. Though thymectomy is the preferred treatment for thymoma and thymic malignancy, the low prevalence of these conditions has been limited to analyses of institutional outcomes [5].

The bulk of recent pediatric studies of thymectomy has focused on the efficacy and outcomes of the procedure in

Table 3 Patient and hospital characteristics by surgical approach

Variable	Open	Thoracoscopic	*p* value
Total (%)	180 (64.5%)	99 (35.5%)	
Diagnosis			
Myasthenia gravis	67.2%	78.8%	0.041
Hyperplasia	14.5%	13.1%	0.749
Benign Neo.	15.0%	11.1%	0.365
Malignant Neo.	<5.6%	0.0%	0.033
Other disease	10.6%	7.1%	0.338
Age	15 (11–18)	14 (9–17)	0.095
Female	63.3%	69.7%	0.284
Race			
White	42.5%	40.8%	0.820
Black	18.4%	19.4%	0.846
Hispanic	15.1%	17.3%	0.622
Other race	12.3%	13.3%	0.826
Unknown race	11.7%	9.2%	0.506
Insurance status			
Medicaid	37.2%	26.3%	0.063
Self-pay	2.8%	3.0%	0.904
Private	54.4%	66.7%	0.053
Other	5.6%	4.0%	0.585
Hospital region			
Northeast	14.5%	17.3%	0.546
Midwest	12.8%	25.5%	0.007
South	55.9%	36.7%	0.002
West	16.8%	20.4%	0.461

Pearson Chi-square test was used for evaluation of binary variables; one-way ANOVA was used for evaluation of continuous variables. Median and interquartile range (Q1–Q3) given for continuous factors

A p value of <0.05 was used to denote significance. Analysis only includes hospitalizations in 2009 and 2012

MG [10–14], which we identified as the most common indication in the dataset, representing 71.1% of all thymectomies performed in 2012. Madenci et al. identified only three post-operative deaths, none of which occurred during the patient's hospitalization or were associated with the procedure. They identified complication rates ranging from 0 to 30%, with respiratory complications, infection, and need for repeat thymectomy being the most common [13]. Infection was not common in our sample. However, our finding of 0% in-hospital mortality and a 14.0% complication rate across all diagnoses, driven by the rate of respiratory complications, is consistent with these findings. Of note, due to the possibility of a minor post-operative pneumothorax (likely being picked up by a coder) following a thoracoscopic procedure, the true complication rate may be lower.

Several studies also highlight the improved outcomes of thoracoscopic approach compared to open approach for MG patients [10–12, 14]. In a retrospective review by Goldstein et al. of 28 pediatric myasthenia patients who underwent thymectomy between 1990 and 2013, 16 received median sternotomy and 12 underwent a thoracoscopic thymectomy. Both groups experienced a similar reduction in disease severity over long-term follow-up, but patients who underwent thoracoscopy experienced a significantly shorter initial length of stay and a lower complication rate [12]. A similar reduction in hospital stay length was found with thoracoscopy in a separate retrospective analysis of 14 patients [14]. While we found no significant difference in complication rate or costs between the two approaches, thoracoscopy was associated with a shorter LOS.

Improved in-hospital outcomes of patients undergoing a minimally invasive approach support the increasing national prevalence of thoracoscopic thymectomies between 2009 and 2012, from 27.1 to 44.4%. Retrospective single-institution studies comparing the surgical approaches also highlight a recent shift towards predominantly minimally invasive approaches, with the majority of open thymectomies studied occurring prior to 2006 [11, 12, 14]. This difference in surgical approach was not seen for diagnoses of thymoma or malignant neoplasm of the thymus, highlighting the presumed importance of complete resection in management of these conditions [3].

Due to a lack of large, multi-center studies of pediatric thymectomy, data regarding patient demographics and their association with surgical outcomes are scarce and difficult to interpret. Single-institution studies have examined thymectomy in MG as young as 1–2 years old, but the majority is performed in patients over the age of 10 [10, 12, 14]. Thymectomy for management of thymoma tends to be for younger patients, with over half in one study under the age of 10 [5]. Our results reveal an average patient age of 13.8. As in other studies, [12–14], the majority of procedures in our analysis was performed on female patients (64.6%), which is likely due to the greater prevalence of juvenile myasthenia gravis in females [19].

Consistent with national pediatric data highlighting an upward trend in public insurance coverage over the past two decades [20], we found that the percentage of Medicaid-insured patients undergoing thymectomy increased between 2003 and 2012. This finding is common across analyses of other procedures using the KID [21]. Despite this increase, Medicaid-insured patients made up a larger percentage of open thymectomies than thoracoscopic thymectomies, and most thoracoscopic thymectomies were performed on privately insured patients. This may suggest that insurance status is a proxy for access to care, with privately insured patients having greater access to newly developed therapeutic techniques.

Goldstein et al., in their comparison of open and thoracoscopic approaches to thymectomy for pediatric MG patients, found no significant difference in approach based on race [12]. Similarly, we found race to not be associated

Table 4 Univariate Predictors of complications, length of stay, and total hospital costs for pediatric thymectomy patients (2003, 2006, 2009, 2012)

Predictor	Complication rate		Length of stay		Total hospital cost	
	OR	*p* value	Coeff.	*p* value	Coeff.	*p* value
Procedure type						
Open	Reference		Reference		Reference	
Thoracoscopic	0.905	0.764	−2.056	0.006	−3010	0.237
Diagnosis						
Myasthenia gravis	Reference		Reference		Reference	
Hyperplasia	0.498	0.079	−2.201	<0.001	−7762	0.001
Benign Neo.	0.505	0.099	−0.966	0.158	−417	0.856
Malignant Neo.	2.976	0.040	0.751	0.594	3700	0.436
Other disease	0.558	0.174	−2.226	0.003	−4538	0.070
Race						
White	Reference		Reference		Reference	
Black	1.731	0.105	0.656	0.316	3270	0.137
Hispanic	2.143	0.025	2.427	<0.001	7130	0.002
Other race	2.498	0.025	1.007	0.260	8515	0.005
Unknown race	1.103	0.800	1.114	0.098	790	0.726
Insurance status						
Medicaid	Reference		Reference		Reference	
Self-pay	1.544	0.479	1.296	0.357	6674	0.158
Private	0.666	0.128	−1.882	<0.001	−6570	<0.001
Other	2.640	0.013	0.083	0.933	322	0.923
Hospital region						
Northeast	Reference		Reference		Reference	
Midwest	0.448	0.056	−0.715	0.371	−6542	0.015
South	0.656	0.188	−0.635	0.351	−6728	0.003
West	0.927	0.838	1.124	0.169	−558	0.838
# Comorbidities						
0	Reference		Reference		Reference	
1	1.636	0.069	0.878	0.110	3324	0.076
2+	1.864	0.072	3.877	<0.001	8.768	0.001

Binary logistic regression was used for evaluation complication rate, and linear regression was used for evaluation of length of stay and total costs

A p value of <0.05 was used to denote significance. Analysis of procedure type only includes hospitalizations in 2009 and 2012

with choice of approach; however, univariate analysis revealed differences in patient outcomes based on race. Black and Hispanic patients were each approximately two times more likely to experience a complication than white patients. Hispanic race was also associated with longer hospital stays and increased hospital costs. Our results revealed similar disparities in patient outcome by insurance status, with privately insured patients experiencing shorter hospital stays and reduced hospital costs. As mentioned previously, analyses of the association between patient demographics and surgical outcomes are very limited in pediatric thymectomies. However, national analyses of other major pediatric surgical procedures reveal similar associations between socioeconomic status and outcome [21].

The hospital-level characteristics provided by the KID also revealed regional differences between approach selection and outcomes. Hospitals in the Southern US perform the most thymectomies. Thymectomies performed in the South and the Midwest are also associated with lower hospital costs than those performed in the Northeast.

There are certain limitations of the database that must be acknowledged. First, as an administrative database, data selection and analysis are reliant on ICD-9-CM diagnosis and procedure codes extracted from discharge records. There are nuances in specific diagnoses and procedure approaches that cannot be distinguished using these codes. For instance, our distinction of "open" thymectomy includes patients undergoing both transsternal and transcervical approaches, which may introduce heterogeneity.

Table 5 Multivariate predictors of complications, length of stay, and total hospital costs for pediatric thymectomy patients (2009, 2012)

Predictor	Complication rate		Length of stay		Total hospital cost	
	OR	*p* value	Coeff.	*p* value	Coeff.	*p* value
Procedure type						
Open	–		Reference		–	
Thoracoscopic	–	–	−1.660	0.029	–	–
Diagnosis						
Myasthenia gravis	Reference		Reference		Reference	
Hyperplasia	0.557	0.300	−2.205	0.035	−4852	0.169
Benign Neo.	0.756	0.586	−0.852	0.422	−1243	0.735
Malignant Neo.	5.869	0.019	0.299	0.889	7694	0.284
Other disease	0.371	0.281	−1.779	0.171	−2312	0.602
Race						
White	Reference		Reference		Reference	
Black	2.140	0.109	−0.083	0.935	3834	0.265
Hispanic	1.147	0.805	0.748	0.487	134	0.972
Other race	2.425	0.088	0.459	0.694	6289	0.116
Unknown race	3.097	0.034	0.814	0.506	2458	0.559
Insurance status						
Medicaid	–		Reference		Reference	
Self-pay	–	–	−0.089	0.540	−2882	0.708
Private	–	–	−1.396	0.079	−5878	0.028
Other	–	–	−0.838	0.618	−4544	0.422
Hospital region						
Northeast	–		–		Reference	
Midwest	–	–	–	–	−12,419	0.006
South	–	–	–	–	−12,943	<0.001
West	–	–	–	–	−6781	0.115
# Comorbidities						
0	Reference		Reference		Reference	
1	1.145	0.735	0.780	0.341	3108	0.258
2+	2.521	0.065	4.514	<0.001	12,785	0.002

Binary logistic regression was used for evaluation complication rate, and linear regression was used for evaluation of length of stay and total costs. Any variables found to be insignificant in univariate analysis were excluded in multivariate analysis

A p value of <0.05 was used to denote significance. Analysis only includes hospitalizations in 2009 and 2012

However, from review of relevant literature, the transcervical approach is rarely reported as compared to transsternal. Additionally, the diagnosis codes for thymic neoplasm limit the analysis to a binary comparison of benign vs. malignant, without the ability to compare histopathological subtypes. Different hospital systems can also have varied methods of reporting, and data entry errors are possible. Furthermore, the procedure codes specific to the thoracoscopic thymectomies were introduced in the year 2007; so all analysis comparing the approaches are restricted to data points in 2009 and 2012. Additionally, the KID reports independent hospitalizations rather than patients. Therefore, complications and outcomes can only be tracked over the course of a single hospitalization, and complications that arise after discharge are not captured. Finally, while we find that minimally invasive techniques are associated with reduced length of stay, we also recognize that this likely is biased toward particular institutions with expertise in these techniques, which the KID is not able to identify due to its sampling method. With such rare disease processes, there is also a lack of consensus on the medical management of these patients. It may be that the severity of a patient's illness, whether their oncologic status or the severity of their auto-immune process, is a driver of surgical outcome rather than the approach itself. This analysis is not possible using these data but certainly warrants further exploration.

Conclusion

Thymectomy in the pediatric population is being accomplished with low rates of morbidity and zero mortality. The thoracoscopic approach is increasing in frequency and resulting in reduced length of stay compared to an open approach. Of note, socioeconomic and racial factors play a role in both surgical approach taken and short-term post-surgical outcomes.

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Compliance with ethical standards

Conflict of interest Michael A. Catalano, BS declares that he has no conflict of interest. Clancy W. Mullan, MD declares that he has no conflict of interest. Barrie S. Rich, MD declares that she has no conflict of interest. Richard D. Glick, MD declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. Patient data was obtained from a publicly available database.

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