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Costs of Treating Children with Complicated Pneumonia: A Comparison of Primary Video-Assisted Thoracoscopic Surgery and Chest Tube Placement

Samir S. Shah, MD, MSCE[1,2,3,5], **Thomas R. Ten Have, PhD**[2,5], and **Joshua P. Metlay, MD, PhD**[2,4,5,6]

[1] Divisions of Infectious Diseases and General Pediatrics, The Children's Hospital of Philadelphia, Philadelphia, PA

[2] Department of Biostatistics and Epidemiology, University of Pennsylvania School of Medicine, Philadelphia, PA

[3] Department of Pediatrics, University of Pennsylvania School of Medicine, Philadelphia, PA

[4] Department of Medicine, University of Pennsylvania School of Medicine, Philadelphia, PA

[5] Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, PA

[6] Veterans Affairs Medical Center, Philadelphia, PA

Abstract

Objectives—To describe charges associated with primary video-assisted thoracoscopic surgery and primary chest tube placement in a multicenter cohort of children with empyema and to determine whether pleural fluid drainage by primary video-assisted thoracoscopic surgery was associated with cost-savings compared with primary chest tube placement.

Study Design—Retrospective cohort study

Setting and Participants—Administrative database containing inpatient resource utilization data from 27 tertiary care children's hospitals. Patients between 12 months and 18 years of age diagnosed with complicated pneumonia were eligible if they were discharged between 2001 and 2005 and underwent early (within two days of index hospitalization) pleural fluid drainage.

Main Exposure—Method of pleural fluid drainage, categorized as video-assisted thoracoscopic surgery or chest tube placement.

Address for correspondence (no reprints): Dr. Samir S. Shah, Room 1526 (North Campus), Division of Infectious Diseases, The Children's Hospital of Philadelphia, 34th Street and Civic Center Boulevard, Philadelphia, PA 19104. Telephone: (215) 590-4378; Fax: (215) 590-0426; shahs@email.chop.edu.

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Acquisition of data: Shah
Analysis and interpretation of data, including statistical expertise: All authors Drafting of the manuscript: Shah
Critical revision of the manuscript for important intellectual content: All authors
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Study supervision: Shah, Metlay

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Results—Pleural drainage in the 764 patients was performed by video-assisted thoracoscopic surgery (n=50) or chest tube placement (n=714). There were 521 (54%) males. Median hospital charges were $36,320 [interquartile range (IQR), $24,814–$62,269]. The median pharmacy and radiologic imaging charges were $5,884 (IQR, $3,142–$11,357) and $2,875 (IQR, $1,703–$4,950), respectively. Adjusting for propensity score matching, patients undergoing primary video-assisted thoracoscopic surgery did not have higher charges than patients undergoing primary chest tube placement.

Conclusions—In this multicenter study, we found that the charges incurred in caring for children with empyema were substantial. However, primary VATS was not associated with higher total or pharmacy charges than primary chest tube placement, suggesting that the additional costs of performing video-assisted thoracoscopic surgery are offset by reductions in length of stay and requirement for additional procedures.

Keywords

pleural effusion; empyema; thoracoscopy; resource utilization

Introduction

Empyema complicates the course of up to one-third of children hospitalized with community-acquired pneumonia.[1, 2] Treatment of children with empyema is associated with significant utilization of healthcare resources. Most children with empyema require prolonged hospitalization[3–5], undergo multiple invasive procedures[6–9], require multiple radiologic studies[2, 8,10], and receive prolonged courses of antimicrobial, analgesic, and sedative medications.[11]

Our previous multicenter study found that children with empyema undergoing primary video-assisted thoracoscopic surgery (VATS) had a 24% shorter length of stay and an 84% reduction in the requirement for repeat pleural drainage procedures.[12] A review of observational studies by Avansino et al.[5] and a small randomized trial by Kurt et al.[13] also suggested that primary drainage by VATS was associated with a shorter length of hospital stay and fewer repeat pleural fluid drainage procedures than drainage by chest tube placement. Studies addressing the costs and savings associated with different management strategies have yielded conflicting results.[11, 13–16] Although VATS is more expensive than primary chest tube placement in terms of physician and procedural costs, it is not clear whether these additional costs are offset by associated reductions in length of stay and repeat procedures. A decision analysis by Cohen et al. concluded that chest tube with fibrinolysis was the preferred strategy unless the length of stay associated with primary chest tube placement routinely exceeded 10 days.[17]

The costs and potential savings associated with various drainage strategies are important considerations in the treatment of children with empyema. Physicians must balance the costs against clinical outcomes and if future longitudinal studies demonstrate relative equivalence of VATS and chest tube placement in long-term clinical outcomes, then cost may become a determining factor in treatment preferences. Therefore, the objectives of this study were to describe the charges associated with primary VATS and primary chest tube placement in a multicenter cohort of children with empyema and to determine whether pleural fluid drainage by primary VATS was associated with cost-savings compared with primary chest tube placement.

Patients and Methods

Data Source

Data for this retrospective cohort study were obtained from the Pediatric Health Information System (PHIS), an administrative database that during the study period contained inpatient resource utilization data from 27 not-for-profit pediatric hospitals in the United States.[18] Participating hospitals account for 20% of all tertiary care general (rather than subspecialty) children's hospitals, which are located in 17 U.S. states and the District of Columbia; no more than 1 hospital is present in a specific region. These hospitals are affiliated with the Child Health Corporation of America (Shawnee Mission, KS), a business alliance of children's hospitals.

Data quality and reliability are assured through a joint effort between the Child Health Corporation of America and participating hospitals. Systematic monitoring occurs on an ongoing basis to ensure data quality. Specific processes include bimonthly coding consensus meetings, coding consistency reviews, and quarterly data quality reports. For the purposes of external benchmarking, participating hospitals provide discharge data including patient demographics, diagnoses, and procedures. Total hospital charges in the PHIS database are adjusted for hospital location using the Centers for Medicare and Medicaid price/wage index. Data are de-identified prior to inclusion in the PHIS database but a unique identifier permits tracking of individual patients across multiple admissions to the same hospital. The protocol for the conduct of this study was reviewed and approved by The Children's Hospital of Philadelphia Committees for the Protection of Human Subjects.

Patients

Patients between 12 months and 18 years of age diagnosed with complicated pneumonia were eligible for this study if they were discharged from any of the 27 participating hospitals between January 1, 2001 and December 31, 2005 and underwent pleural fluid drainage within two days of hospitalization. Patients undergoing thoracotomy were excluded since VATS is the preferred approach to pleural fluid drainage when operative therapy is deemed necessary.[19] Patients younger than 12 months of age were excluded because VATS is technically more difficult and, therefore, less likely to be performed in this younger age group. Patients with conditions known to increase the risk of severe infection were excluded using previously validated International Classification of Diseases, 9th Revision (ICD-9) discharge diagnosis codes that indicate chronic diseases or immunosuppressive conditions, including malignancy, neuromuscular disease, complex congenital heart disease, and human immunodeficiency virus infection.[20] If a child was hospitalized more than once during the study period, only the first hospitalization was included in the analysis.

Study Definitions

Study patients were identified in the PHIS database using ICD-9 discharge diagnosis codes indicating a pleural effusion (defined by an ICD-9 code of either 510.0, 510.9, 511.1, or 513.0) as the primary diagnosis and at least one additional discharge diagnosis code for pneumonia (ICD-9 codes 480–486). The ICD-9 discharge diagnostic codes for pneumonia show >85% concordance with the diagnosis of pneumonia as determined by medical record review[21] and have been used in other administrative database studies that helped define key processes of care for community-acquired pneumonia in adults.[22–24] Pleural drainage procedures were identified using procedure codes for video-assisted thoracoscopic surgery (VATS) (34.21) and thoracostomy tube (chest tube) (34.04).

Outcomes

The primary dependent variable was the price/wage index adjusted total hospital charges (which includes room charges and charges for all clinical services and procedures as well as pharmacy and radiologic imaging charges) during the index hospitalization. Additional dependent variables were pharmacy charges and radiologic imaging charges during the index hospitalization.

Covariates

The primary exposure was the receipt of primary VATS versus primary chest tube placement. Model covariates included age, sex, race, asthma as a comorbid diagnosis, season, and empiric antibiotic regimen.

Statistical Analysis

Categorical variables are presented as frequencies and percents. Continuous variables are presented as median and inter-quartile range (IQR) values for non-parametric data. For univariate analysis, the Wilcoxon Rank Sum test was used to compare differences in charges and length of stay between children undergoing primary VATS and primary chest tube placement.

Patients undergoing primary VATS and primary chest tube placement were matched on propensity score. The propensity score is a patient-specific estimated probability of receiving a specific treatment (in this case, pleural fluid drainage by VATS or chest tube) in observational studies based on a patient's observed covariates.[25] Matching patients receiving different treatments on propensity scores reduces bias when comparing non-randomized treatment groups.[25–27] The probability (i.e., the propensity score) that a patient would receive VATS was estimated using a multivariable logistic regression model incorporating the following covariates related to receiving VATS: age, sex, race, asthma as a comorbid diagnosis, season, and empiric antibiotic regimen. The model's calculated c-statistic (area under the curve), which represents the predictive capacity of the model, was 0.683. This c-statistic indicates that the model provides a better estimate than expected by chance alone (i.e., if the c-statistic were equal to 0.5), and also that there is little evidence of non-overlapping propensity score distributions between the different treatment groups. Hence, matching treatment and control patients for the propensity score was effective in controlling for baseline imbalances between treatment groups.[28] Specifically, we matched each patient undergoing primary VATS with up to 7 patients undergoing primary chest tube placement with similar propensity scores using nearest neighbor matching[29] with a caliper set at one quarter of the standard deviation of the logit of the propensity scores.[30]

An analysis based on a fixed effects linear regression model was performed to account for the matching of patients undergoing primary VATS with patients undergoing primary chest tube placement on propensity score. The fixed effects linear regression model included dummy variables for matched groups to control for any confounding not accounted for by the matched factors; this approach also adjusted the variances of VATS effect estimates on outcome for such matching. The model was used to determine the association of initial pleural fluid drainage procedure type and the outcomes (total, pharmacy, and radiologic imaging charges). Because the charge outcome data had a skewed distribution, our analyses were performed using logarithmically transformed charge values as the dependent variable. Two-tailed *P*-values <0.05 were considered statistically significant. Data were analyzed using STATA, version 9.2 (Stata Corporation, College Station, TX).

Results

During the study period, 961 patients with empyema underwent early pleural fluid drainage. Patients undergoing thoracotomy (n=197) were excluded. In the remaining 764 patients, pleural drainage was performed by VATS (n=50) or chest tube placement (n=714). There were 521 (54%) males. The racial distribution included patients classified as White (67%), Black (17%), or other race (11%); the race was unknown for 5% of patients. Characteristics of patients stratified by primary procedure type are shown in Table 1.

Median hospital charges were $36,320 (IQR, $24,814–$62,269). The total hospital charges exceeded $200,000 for 5% of patients overall, including 1 (2.0%) patient undergoing VATS and 40 (5.6%) patients undergoing primary chest tube placement. The median pharmacy and radiologic imaging charges were $5,884 (IQR, $3,142–$11,357) and $2,875 (IQR, $1,703–$4,950), respectively. In an unadjusted comparison that included all patients, total, pharmacy, and radiologic imaging charges were all higher for patients undergoing primary chest tube placement, though this difference was only significant for radiologic imaging charges (Table 2). Among the subset of patients 1 to 5 years of age, all three charge categories were significantly lower for subjects undergoing primary VATS compared to subjects undergoing primary chest tube placement. There were no significant differences between older children undergoing primary VATS or primary chest tube placement in any charge category (Table 2). A pneumonia-related readmission with 14 days of discharge from the index hospitalization occurred in 10 (1.4%) of 714 children undergoing primary chest tube placement and in none of the 50 children undergoing primary VATS (chi-square, P=0.40).

To adjust for the above relationships between covariates and VATS treatment with propensity score matching, all patients undergoing primary VATS were matched by propensity score with patients undergoing primary chest tube placement. Of the 50 patients undergoing primary VATS, 48 patients were each matched with 7 patients undergoing chest tube drainage, one patient was matched with 5 patients undergoing chest tube drainage, and one patient was matched with 4 patients undergoing chest tube drainage. The characteristics of matched patients undergoing primary VATS and primary chest tube placement were not significantly different (Table 1).

Adjusting for the propensity score matching, patients undergoing primary VATS did not have higher total or pharmacy charges than patients undergoing primary chest tube placement, regardless of age (Table 3). However, patients undergoing primary VATS had significantly lower radiologic imaging charges than patients undergoing primary chest tube placement (Table 3). The r-square values for total, pharmacy, and radiologic imaging charges were each <0.01, substantiating that the variation in charges was not explained by procedure type. In stratified analysis, differences in total hospital charges between patients undergoing primary VATS or primary chest tube placement were not significant within any of the age groups.

Discussion

In this multicenter study, we found that the charges incurred in caring for children with empyema were substantial. However, primary VATS was not associated with higher total or pharmacy charges than primary chest tube placement. Children 1 to 5 years of age undergoing primary VATS incurred lower radiologic imaging charges than children undergoing primary chest tube placement. However, there was no difference in radiologic charges between the two groups for children older than 5 years of age. The results of this study suggest that the additional costs of performing VATS are offset by reductions in length of stay (LOS) and requirement for additional procedures.

Current studies have reported conflicting results on the potential cost savings of primary VATS compared with primary chest tube placement. These studies have used different methodologic approaches and, with one exception,[15] were limited to single centers. Li et al.,[15] using administrative data from the Kids' Inpatient Database, found significantly lower total hospital charges for children undergoing primary operative therapy (defined as decortication performed within two days of hospitalization) than children undergoing primary non-operative therapy. An important limitation of the study by Li et al.[15] is that the 953 patients classified as receiving non-operative therapy were heterogeneous with respect to predicted outcomes because the non-operative group included those undergoing no drainage, thoracentesis, early or late chest tube placement, and late VATS. This limitation likely biased the study in favor of primary operative therapy. The 4 patients undergoing primary VATS in the observational study by Meier et al.[11] had greater procedural charges but modest decreases in total charges compared with the 27 patients undergoing primary chest tube placement; however, the small sample size precluded multivariable analysis.

Three small randomized clinical trials have also been performed.[13, 14, 16] Costs for primary chest tube placement were 20% lower than costs for VATS in a single-center randomized trial of 60 patients conducted in the United Kingdom.[14] In the U.S., St. Peter et al.[16] found that mean total hospital charges were approximately 35% lower for patients undergoing primary chest tube placement (n=18) compared with patients undergoing primary VATS (n=18). In contrast, Kurt et al.[13] found no significant difference in total hospital charges between patients at one hospital in the U.S. undergoing primary VATS (n=10) and patients undergoing primary chest tube placement (n=8) despite the fact that children undergoing VATS had a significantly shorter length of hospital stay than children undergoing chest tube placement. There are several possible reasons for such discrepancies among the three studies. In the studies by Sonnappa et al.[14] and St. Peter et al.,[16] while primary VATS was the more costly strategy, there was no difference in hospital length of stay between children undergoing primary VATS versus primary chest tube placement. Furthermore, children undergoing primary chest tube placement were not more likely to require repeat pleural drainage than children undergoing primary VATS. The lack of differences in outcomes stands in stark contrast to studies conducted in the U.S., where primary VATS has consistently been associated with shorter hospitalizations and fewer repeat pleural drainage procedures than primary chest tube placement.[12, 13, 15] Differences in causative organisms, timing of presentation for pleural drainage, frequency of chemical fibrinolysis, operative technique, and systems of care could potentially account for such differences in outcomes of children undergoing VATS in one center compared with another.

In a cost-effective analysis, Cohen et al.[17] concluded that chest tube placement with instillation of fibrinolytic agents was the dominant strategy when the LOS associated with chest tube placement was 10 days or less. In contrast, our study, which compared children undergoing early pleural fluid drainage by either VATS or chest tube placement, found that primary VATS was not more costly than primary chest tube placement. The median LOS for patients undergoing primary chest tube placement in our study was 9 days; a value below the threshold found by Cohen et al.[17] to be cost-effective for chest tube placement with fibrinolysis. The difference can in part be accounted for by the assumptions made by Cohen et al.[17] The estimated failure rate of chest tube with fibrinolysis was 9% (range, 0%–17%) while the estimated failure rate of VATS was 10% (range, 0%–20%). In our study, the failure rate was substantially lower for VATS and higher for primary chest tube placement. While it is also possible that chest tube placement with fibrinolysis is associated with better outcomes than chest tube placement alone, a large multicenter randomized trial did not find any benefit of fibrinolysis in adults with complicated pneumonia.[31]

After adjustment for potential confounders, our study found no significant reduction in pharmacy charges in children undergoing primary VATS compared with primary chest tube placement. The absence of a reduction in pharmacy charges was somewhat surprising since medication use, particularly intravenous narcotic and antibiotic use, correlates with length of hospitalization, which was shorter for children undergoing VATS in this study. The absence of such differences may relate to several factors. It is possible that children are receiving continuous rather than intermittent narcotic infusions. Such pain control strategies have been shown to result in better pain control, less narcotic medication use, and earlier transition to oral analgesics. In an observational study of 31 patients, Meier et al.[11] found more modest unadjusted reductions of approximately 25% in pharmacy charges and 30% in radiologic imaging charges for the 4 patients undergoing primary VATS compared with patients undergoing chest tube drainage.

This study has several limitations. As with any study using administrative data, discharge diagnosis coding may be inaccurate. We attempted to minimize the impact of such miscoding by limiting the study population to patients with a primary discharge diagnosis of pleural effusion and an additional diagnosis code for pneumonia. It is possible that patients with metastatic dissemination of infection (e.g., endocarditis) had these infections rather than pleural effusion listed as the primary diagnosis, potentially leading to disproportionate exclusion of the most severely ill patients. However, the impact of such exclusions is probably minimal since the metastatic infection rather than the initial procedure is likely to be the primary determinant of hospital charges in such cases.

While the propensity score accounted for the measured factors related to VATS, factors that could not be measured, such as duration of symptoms, prior antibiotic therapy, and effusion size and character that may influence the decision to perform this procedure, were not adjusted for using the propensity score approach. It is likely that patients with protracted symptoms and more severe disease would be most likely to undergo primary VATS. These unmeasured differences in baseline disease characteristics would likely lead to an underestimation of the benefit of primary VATS compared with primary chest tube placement, thus biasing our findings toward the null hypothesis when primary VATS actually leads to cost saving. Additionally, the PHIS database provides billed charge data rather than cost data, which may overestimate the economic impact of performing either procedure since payers frequently reimburse at rates less than full charges. Charge data can also vary by geographic region. We adjusted charges for hospital location using the Centers for Medicare and Medicaid price/wage index to account for this latter possibility.

Finally, since this study was limited to free-standing children's hospitals, it is unlikely that this data is generalizable to community settings. Since VATS requires specialized surgical training, most community hospitals do not have surgeons with the technical training and expertise to perform this procedure. However, this study is generalizable to tertiary care children's hospitals that are not included in the PHIS database. The strength of this multi-center study lies in the inclusion of an ethnically and geographically heterogeneous population.

Conclusions

The results of this study suggest that the additional costs of performing VATS are offset by reductions in length of stay and requirement for additional procedures.

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Abbreviations in the manuscript

ICD-9	International Classification of Diseases, 9th Revision
LOS	Length of stay
PHIS	Pediatric Health Information System
VATS	Video-assisted thoracoscopic surgery

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Table 1

Characteristics of patients undergoing primary video-assisted thoracoscopic surgery compared with all patients undergoing primary chest tube placement and with the subset of patients matched by propensity score.

	Patients with video-assisted thoracoscopic surgery (N=50)*	All patients with chest tube (N=714)	*P*-value**	Patients with chest tube matched by propensity score (N=345)	*P*-value**
Age Category					
1 to 5 years	15 (30.0)	230 (32.2)	0.701	89 (25.8)	0.820
>5 to 13 years	13 (26.0)	212 (29.7)		95 (27.5)	
>13 to 18 years	22 (44.0)	272 (38.1)		161 (46.7)	
Season					
Winter	21 (42.0)	269 (37.7)	0.021	152 (44.1)	0.991
Spring	18 (36.0)	159 (22.3)		119 (34.5)	
Summer	1 (2.0)	99 (13.9)		8 (2.3)	
Fall	10 (20.0)	187 (26.2)		66 (19.1)	
Race* **					
Black	4 (8.2)	127 (18.9)	0.082	27 (7.8)	0.322
White	36 (73.5)	470 (69.9)		280 (81.2)	
Other	9 (18.4)	75 (11.2)		38 (11.0)	
Male sex	25 (50.0)	329 (46.0)	0.591	172 (49.9)	0.985
Asthma	4 (8.0)	50 (7.0)	0.790	21 (6.1)	0.604
Empiric vancomycin	16 (32.0)	296 (41.5)	0.188	99 (28.7)	0.631
Median length of stay (days)	7 (6–11)	10 (7–14)	0.004	9 (6–14)	0.018

*Values listed as number (percent) except for length of stay which is listed as median (interquartile range)

**P-value reflects comparison with patients undergoing primary video-assisted thoracoscopic surgery

***Race missing for 1 patient undergoing video-assisted thorascopic surgery and 42 patients undergoing chest tube placement.

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Table 2

Unadjusted comparison of total, pharmacy and radiologic imaging charges between patients undergoing primary video-assisted thoracoscopic surgery and primary chest tube placement.*

	Video-assisted thoracoscopic surgery (N=50)	Chest tube (N=714)	*P*-value**
Total hospital charges ($)			
All ages combined	32,136 (24,002–51,260)	36,618 (24,921–62,576)	0.401
Age 1 to 5 years	29,450 (22,076–34,457)	40,564 (25,952–77,214)	0.047
Age >5 to 13 years	48,473 (27,986–106,907)	35,610 (23,575–60,231)	0.105
Age >13 to 18 years	32,276 (24,002–47,450)	34,666 (25,108–58,568)	0.523
Pharmacy charges ($)			
All ages combined	4,385 (2,940–9,084)	5,978 (3,184–11,636)	0.123
Age 1 to 5 years	3,180 (2,305–5,332)	6,050 (2,854–12,220)	0.021
Age >5 to 13 years	5,577(3,747–16,088)	5,442 (3,070–9,524)	0.380
Age >13 to 18 years	5,859 (2,965–9,084)	6,220 (3,873–12,008)	0.306
Radiologic imaging charges ($)			
All ages combined	1,779 (1,036–3,478)	2,939 (1,781–4,981)	<0.001
Age 1 to 5 years	1,391 (909–2,362)	3,082 (1,988–5,427)	<0.001
Age >5 to 13 years	4,587 (701–5,798)	2,804 (1,661–4,863)	0.843
Age >13 to 18 years	2,066 (1,193–2,642)	2,906 (1,709–4,745)	0.014

* Values listed as median (interquartile range)

** Comparisons using the Wilcoxon Rank Sum test

Table 3

Propensity-matched analysis comparing total, pharmacy, and hospital charges in patients undergoing primary video-assisted thoracoscopic surgery with patients undergoing primary chest tube placement.*

Charge Category	Difference in Charges	Coefficient	95% Confidence Interval	*P*-value
Total Charges	$8,114	0.004	−0.229 to 0.227	0.972
Pharmacy Charges	$2,357	−0.137	−0.430 to 0.155	0.356
Radiologic Imaging Charges	−$800	−0.426	−0.673 to −0.179	0.001

*This model used log-transformed charge data. The following variables were included in the propensity score: age, sex, race, asthma as a comorbid diagnosis, season, and empiric antibiotic regimen.