Primary Early Thoracoscopy and Reduction in Length of Hospital Stay and Additional Procedures Among Children With Complicated Pneumonia

Results of a Multicenter Retrospective Cohort Study

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Objective: To determine the effect of initial procedure type on the length of hospital stay (LOS) and on the requirement for additional pleural fluid drainage procedures in a large multicenter cohort of children with pneumonia complicated by pleural effusion.

Design: Retrospective cohort study.

Setting: Administrative database containing inpatient resource use data from 27 tertiary care children's hospitals.

Participants: Patients between 12 months and 18 years of age diagnosed as having complicated pneumonia were eligible for the study if they were discharged from the hospital between January 1, 2001, and December 31, 2005, and underwent early (within 2 days of the index hospitalization) pleural fluid drainage.

Intervention: Pleural fluid drainage, categorized as chest tube placement, video-assisted thoracoscopic surgery (VATS), or thoracotomy.

Main Outcome Measures: The LOS and the requirement for additional pleural fluid drainage.

Results: Nine hundred sixty-one of 2862 patients (33.6%) with complicated pneumonia underwent early pleural fluid drainage. Initial procedures included chest tube placement (n=714), VATS (n=50), and thoracotomy (n=197). The median patient age was 4.0 years (interquartile range, 2.0-8.0 years). The median LOS was 10 days (interquartile range, 7-14 days). Two hundred ninety-eight patients (31.0%) required at least 1 additional pleural fluid drainage procedure, and 44 patients (4.6%) required more than 2 pleural fluid drainage procedures. In linear regression analysis, children undergoing primary VATS had a 24% (adjusted β coefficient, –0.24; 95% confidence interval, –0.41 to –0.07) shorter LOS than patients undergoing primary chest tube placement; this translated into a 2.8-day reduction in the LOS for those undergoing early primary VATS. In logistic regression analysis, patients undergoing primary VATS had an 84% (adjusted odds ratio, 0.16; 95% confidence interval, 0.06-0.42) reduction in the requirement for additional pleural fluid drainage procedures compared with patients undergoing primary chest tube placement.

Conclusion: Our large retrospective multicenter study demonstrates that, compared with primary chest tube placement, primary VATS is associated with shorter LOS and fewer additional procedural interventions.

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COMMUNITY-ACQUIRED pneumonia is the most common serious bacterial infection occurring in children. In the United States, more than 600 000 children require hospitalization for pneumonia each year[1,2]; up to one-third of these children develop pneumonia-related pleural effusion,[3,4] a process often referred to as "complicated pneumonia." Most children with complicated pneumonia are hospitalized for more than 2 weeks,[5-7] undergo multiple invasive procedures,[8-11] require several radiologic studies,[4,10,12] and receive prolonged courses of antibiotics and analgesic and sedative medications.[13]

Early pleural fluid drainage is thought to improve the outcome of children with complicated pneumonia.[14-18] Drainage strategies include chest tube placement, video-assisted thoracoscopic surgery (VATS), and thoracotomy. VATS allows for pleural debridement, which is not possible by chest tube placement. Furthermore, VATS is less invasive than thoracotomy. However, studies to date have not provided sufficient information on the relative efficacy of these interventions; therefore, there is substantial practice variation. Current studies[5,8-13,16,19-23] have been limited by small sample size, selection bias, and failure to adjust for confounding variables. In a meta-analysis of these studies,

Avansino et al[7] found that primary operative therapy reduced the median length of hospital stay (LOS) by 45% and the frequency of additional procedures by 90%. However, interpretation of the meta-analysis results is hampered because only observational studies with heterogeneous study designs were available for inclusion and because analytic measures to exclude the possibility of confounding could not be performed. These limitations make it difficult to determine the optimal types of therapeutic interventions that will lead to the best possible outcome for children with complicated pneumonia.

The present study comprises a large multicenter cohort of children with complicated pneumonia undergoing early pleural fluid drainage. We sought to determine the effect of initial procedure type on the LOS and on the requirement for additional pleural fluid drainage procedures.

METHODS

DATA SOURCE

Data for this study were obtained from the Pediatric Health Information System (PHIS), an administrative database that during the study period contained inpatient data from 42 not-for-profit freestanding pediatric hospitals in the United States.[24] These hospitals are affiliated with a business alliance of children's hospitals (Child Health Corporation of America, Shawnee Mission, Kansas). Data quality and reliability are assured through a joint effort between the Child Health Corporation of America and participating hospitals. The data warehouse function for the PHIS database is privately managed (Solucient LLC, Evanston, Illinois). For 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 and wage index. Patients are deidentified before inclusion in the PHIS database, but a unique identifier permits tracking of individual patients across multiple admissions to the same hospital. Twenty-seven participating hospitals also submit resource use data for each hospital discharge (eg, pharmaceutical dispensings and imaging and laboratory studies); patients from these 27 hospitals were eligible for inclusion in this study. The protocol for the conduct of this study was reviewed and approved by The Childrens Hospital of Philadelphia committees for the protection of human subjects.

PATIENTS

Patients between 12 months and 18 years of age diagnosed as having complicated pneumonia were eligible for this study if they were discharged from any of the 27 hospitals participating in the PHIS between January 1, 2001, and December 31, 2005, and underwent pleural fluid drainage within 2 days of the index hospitalization. Patients younger than 12 months were excluded because bronchiolitis is most prevalent in this age group and because it may be difficult to distinguish viral bronchiolitis from community-acquired pneumonia. Patients with conditions known to increase the risk of severe infection were excluded using previously validated *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes that indicate chronic diseases or immunosuppressive conditions, including malignant neoplasm, neuromuscular disease, complex congenital heart disease, and human immunodeficiency virus in-

fection.[25] If a child was hospitalized for complicated pneumonia more than once during the study period, only the first hospitalization was included in the analysis; subsequent readmissions were considered treatment failures if they occurred within 14 days of the index discharge.

STUDY DEFINITIONS

Study patients were identified in the PHIS database using the *ICD-9* codes indicating pleural effusion (code 510.0 [empyema with fistula], 510.9 [empyema without fistula], 511.1 [pleurisy with effusion], or 513.0 [abscess of lung, including necrotic pneumonia]) as the primary diagnosis and at least 1 additional code for pneumonia (codes 480-486). The *ICD-9* codes for pneumonia show greater than 85% concordance with the diagnosis of pneumonia as determined by medical record review[26] and have been used in other administrative database studies[27-29] that helped define key processes of care for community-acquired pneumonia in adults. Pleural drainage procedures were identified by the following *ICD-9* codes: code 34.04 (thoracostomy tube [chest tube]), 34.21 (video-assisted thoracoscopic surgery [VATS]), or 34.02 or 34.09 (thoracotomy). Readmission related to treatment failure was defined as hospitalization with a primary discharge diagnosis of pneumonia within 14 days of the discharge date from the index hospitalization.

DEPENDENT VARIABLES

The LOS comprised the first dependent variable. The second dependent variable was the requirement for an additional pleural fluid drainage procedure during the index hospitalization.

INDEPENDENT VARIABLES

The primary independent variable, initial pleural fluid drainage procedure, was classified into the mutually exclusive categories of chest tube placement, VATS, or thoracotomy. Other covariates considered for inclusion in the models as potential confounders were age, sex, race/ethnicity, season, empirical antimicrobial therapy, receipt of corticosteroid therapy or chemical fibrinolysis (ie, intrapleural streptokinase or urokinase), and the presence of asthma as a comorbid condition. Race/ethnicity was included in the final models because there seems to be variation among different racial/ethnic groups with respect to outcomes for children hospitalized with pneumonia.[30]

STATISTICAL ANALYSIS

Continuous variables were described using mean, median, range, and interquartile range (IQR) values, while categorical variables were described using frequencies and percentages. We also conducted regression analyses to examine the independent effect of drainage procedures on primary and secondary outcomes. Linear regression analysis was used to examine the LOS and the hospital charges, and logistic regression analysis was used to examine the requirement for additional pleural fluid drainage procedures. Building of the multivariate models began with the inclusion of procedure type, our primary exposure of interest. The diagnosis of asthma was included in all models because of data suggesting an effect of this variable on clinical outcomes.[31,32] Other variables were considered for inclusion in the multivariate model if $P < .20$ in bivariate analysis[33]; these variables remained in the final multivariate model if they were statistically significant or if their inclusion confounded the association between procedure type and out-

Table 1. Demographic Characteristics of Children With Complicated Pneumonia Stratified by Early Primary Pleural Fluid Drainage Procedure

Variable	No. (%)			
	Chest Tube Placement (n = 714)	VATS (n = 50)	Thoracotomy (n = 197)	Total (N = 961)
Male sex	385 (53.9)	25 (50.0)	111 (56.5)	**521** (54.2)
Age category, y				
1-5	230 (32.2)	15 (30.0)	60 (30.5)	**305** (31.7)
>6-13	212 (29.7)	13 (26.0)	68 (34.5)	**293** (30.5)
>14-18	272 (38.1)	22 (44.0)	69 (35.0)	**363** (37.8)
Race/ethnicity[a]				
Black	127 (18.9)	4 (8.2)	33 (17.5)	164 (18.0)
White	470 (69.9)	36 (73.5)	132 (83.0)	**638** (66.4)
Other	75 (11.2)	9 (18.3)	24 (12.7)	108 (11.9)
Government insurance	240 (33.6)	10 (20.0)	73 (37.1)	**323** (33.6)
Asthma	50 (7.0)	4 (8.0)	15 (7.6)	**69** (7.2)
Chemical fibrinolysis	6 (0.8)	0	1 (0.5)	**7** (0.7)
Systemic corticosteroids	34 (4.8)	1 (2.0)	11 (5.6)	**46** (4.8)
Empirical vancomycin therapy	296 (41.5)	16 (32.0)	80 (40.6)	**392** (40.8)

Abbreviation: VATS, video-assisted thoracoscopic surgery.
[a] Do not sum to procedure heading totals because of missing data.

comes as defined by greater than 10% change in the adjusted β coefficients for linear regression or in the adjusted odds ratios for logistic regression.[34] Multivariate linear regression with logarithmic transformation was used to yield regression slope estimates for the association between the pleural drainage procedure type and the LOS. The coefficients resulting from these models can be interpreted as the proportional changes in the dependent measure (ie, LOS) associated with the original scale of measurement (ie, days).

All regression analyses were clustered by hospital to account for increased variability caused by clustering of individuals within hospitals.[35] Two-tailed $P < .05$ was considered statistically significant. Actual P values and 95% confidence intervals are reported. Data were analyzed using commercially available software (STATA, version 9.2; StataCorp LP, College Station, Texas).

RESULTS

CHARACTERISTICS OF SUBJECTS

Complicated pneumonia was noted in 2862 of 49 574 patients (5.8%) diagnosed as having pneumonia. A pleural fluid drainage procedure was performed within 48 hours of hospitalization in 961 (33.6%) of the patients diagnosed as having complicated pneumonia; these patients comprised the study sample. The patient population is summarized in **Table 1**. The median number of study subjects per hospital was 29 patients (IQR, 18-51 patients). The median age of the study population was 4.0 years (IQR, 2.0-8.0 years). Systemic corticosteroids were administered to 14.5% of patients with asthma. There was considerable variability between hospitals in the types of drainage procedures performed (**Figure**). At some hospitals, only chest tube placement was used for early pleural drainage, while at other hospitals more than half of the patients undergoing early pleural drainage received VATS or thoracotomy.

DISTRIBUTION OF OUTCOMES

The overall median LOS was 10 days (IQR, 7-14 days); 7.0% of patients had a LOS exceeding 28 days. The median LOS varied considerably across hospitals (range, 6-13 days). At least 1 additional drainage procedure was performed during the index hospitalization in 298 patients (31.0%); 44 patients (4.6%) required 3 pleural fluid drainage procedures, and 19 patients (2.0%) required 4 or more pleural fluid drainage procedures. There was considerable variation in the requirement for additional pleural fluid drainage procedures between hospitals. At some hospitals, less than 10% of patients required an additional procedure, while at other hospitals more than half of the patients required an additional pleural fluid drainage procedure. The median total hospital billing charges were $37 597 (IQR, $35 609-$62 288) per patient discharge. Sixty-seven patients (7.0%) had bronchopleural fistula, with no significant differences by initial procedure type. Sixteen patients (1.7%) had a pneumonia-related additional hospitalization within 14 days of the index hospitalization discharge; the median time to readmission was 6 days. Eight patients (0.8%) died during the index hospitalization.

FACTORS ASSOCIATED WITH LOS AND SECOND PROCEDURES

In bivariate analysis, the LOS was shorter for patients undergoing primary VATS (median, 7 days; IQR, 6-11 days) than for patients undergoing primary chest tube placement (median, 10 days; IQR, 7-14 days) or primary thoracotomy (median, 10 days; IQR, 7-14 days). In multivariate linear regression analysis, children undergoing primary VATS had a 24% shorter LOS than patients undergoing primary chest tube placement after adjusting for asthma diagnosis, receipt of systemic corticoste-
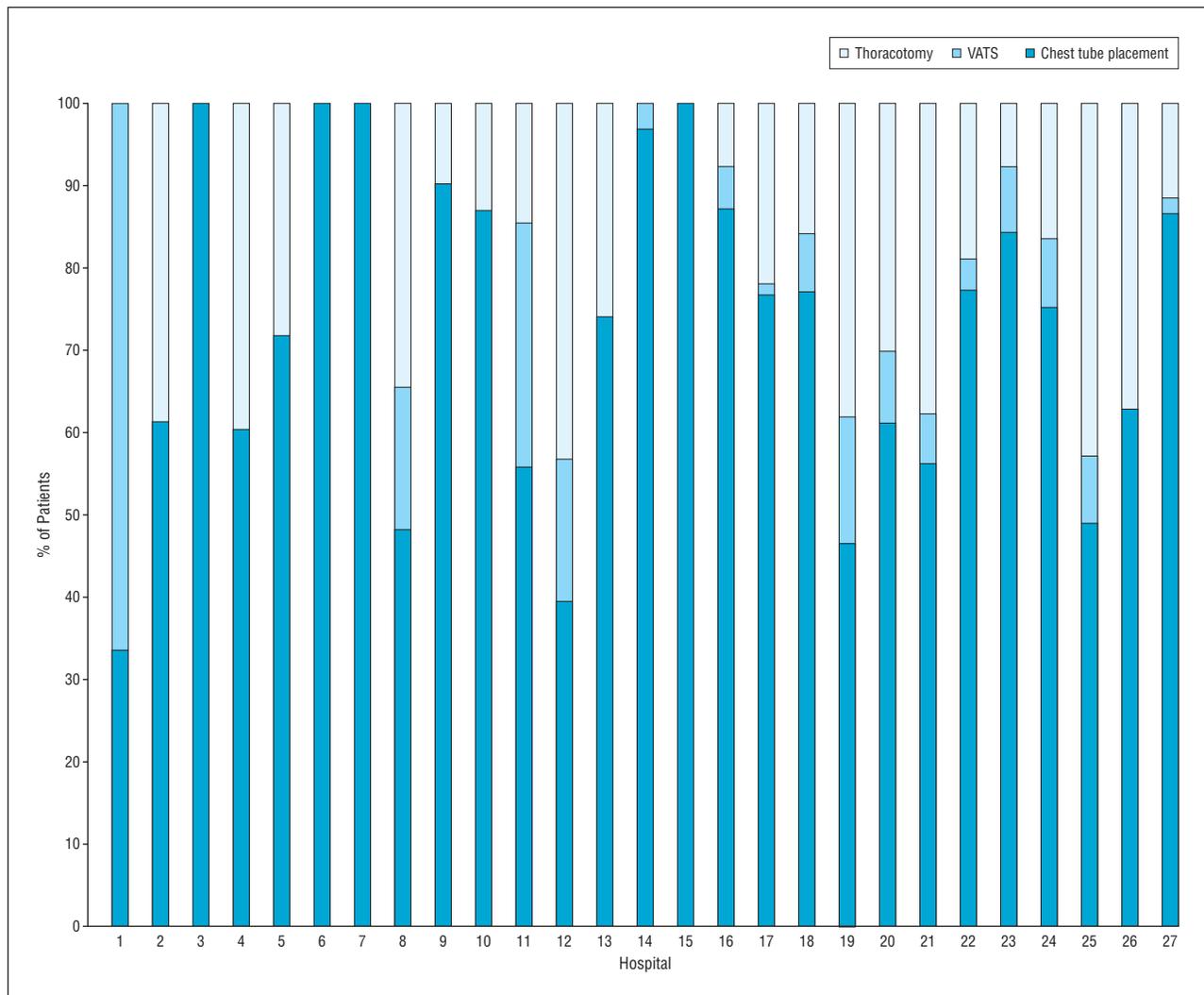
Figure. Distribution of procedure type by hospital. The y-axis shows the percentage of patients undergoing specific pleural fluid drainage procedures. Each bar on the x-axis represents 1 hospital. VATS indicates video-assisted thoracoscopic surgery.

roids, and empirical vancomycin therapy; this translated into a 2.8-day reduction in the LOS for those undergoing early VATS (**Table 2**). In bivariate analysis, additional pleural fluid drainage procedures were required less often for children undergoing primary VATS (8.0%) than for patients undergoing primary chest tube placement (34.5%) or primary thoracotomy (24.4%). In multivariate logistic regression analysis, patients undergoing initial VATS had an 84% reduction in the requirement for additional pleural fluid drainage procedures compared with patients undergoing initial chest tube placement after adjusting for asthma diagnosis, receipt of systemic corticosteroids, and empirical vancomycin therapy (**Table 3**).

COMMENT

In a multicenter study, there was substantial variability among hospitals in initial management and outcomes of children with complicated pneumonia. Furthermore, although VATS has been associated with a shortened LOS compared with chest tube placement among the subset of patients undergoing early pleural fluid drainage, the magnitude of reduction in the LOS in our study was less than that described in single-center studies.[7] In adjusted analysis, initial VATS was also associated with the requirement for fewer additional pleural drainage procedures.

We identified substantial variation in the type of initial procedure among the subset of children with complicated pneumonia undergoing early pleural fluid drainage. Although patients at some hospitals received exclusively primary chest tube placement, patients at other hospitals frequently underwent primary VATS. This heterogeneity in initial management likely reflects the lack of appropriately designed studies and evidence-based guidelines addressing this topic.[36] To date, only 1 randomized trial (to our knowledge) has compared clinical outcomes of children undergoing primary VATS vs primary chest tube placement; this study[23] included 18 patients. Our multicenter study, which includes 961 patients from 27 different children's hospitals, provides additional data to guide the clinical management of children with complicated pneumonia.

Table 2. Risk Factors Affecting Length of Hospital Stay[a]

| Variable | β Coefficient (95% Confidence Interval) | | P Value |
	Unadjusted	Adjusted[b]	
Male sex	−0.09 (−0.17 to −0.02)	. . .	. . .
Age category, y			
1-5	1 [Reference]	1 [Reference]	
>6-13	−0.09 (−0.19 to 0.01)	. . .	. . .
>14-18	−0.08 (−0.17 to 0.01)	. . .	. . .
White race/ethnicity	−0.14 (−0.22 to −0.06)	−0.13 (−0.21 to −0.04)	.002
Initial procedure			
Chest tube placement	1 [Reference]	1 [Reference]	
VATS	−0.28 (−0.46 to −0.11)	−0.24 (−0.41 to −0.07)	.007
Thoracotomy	−0.06 (−0.16 to 0.04)	−0.04 (−0.14 to 0.06)	.44
Asthma[c]	0.07 (−0.08 to 0.22)	0.04 (−0.11 to 0.19)	.60
Systemic corticosteroids	0.30 (0.12 to 0.48)	0.24 (0.07 to 0.42)	.007
Empirical vancomycin therapy	0.22 (0.14 to 0.30)	0.19 (0.12 to 0.28)	<.001
Chemical fibrinolysis	−0.08 (−0.52 to 0.38)	. . .	. . .

Abbreviation: VATS, video-assisted thoracoscopic surgery.
[a]Multivariate linear regression with logarithmic transformation of the outcome (ie, length of hospital stay).
[b]The following variables were insignificant on adjusted analysis and were left out of the final model: sex, age category, and chemical fibrinolysis.
[c]Although not statistically significant, asthma remained in the final multivariate model because of our a priori hypothesis of the effect of asthma on the length of hospital stay.

In our multicenter study, primary VATS was associated with a 24% shorter LOS compared with primary chest tube placement after adjusting for potentially confounding variables. In a systematic review, Gates et al[37] found that the LOS was approximately 35% shorter for children undergoing primary VATS (mean LOS, 10.5 days) than for children undergoing primary chest tube placement (mean LOS, 16.4 days). In a meta-analysis[7] of the subset of studies published since 1999, the LOS was 1 week longer for nonoperatively treated patients compared with operatively treated patients, with LOS values of 18 days vs 11 days. However, direct comparison with our study results is difficult because in the meta-analysis the nonoperative group included patients undergoing needle thoracentesis or chest tube placement, while the operative group included patients undergoing VATS or thoracotomy. Furthermore, the timing of the procedures was not specified in all of the studies reviewed, and adjustment for potentially confounding variables was not performed.[7,37] Kurt et al[23] conducted a randomized clinical trial of 18 patients with complicated pneumonia. The mean LOS was 13.3 days for the chest tube placement group and 5.8 days for the VATS group; although this difference was statistically significant, the median values were not available for more direct comparison of the magnitude of the difference for nonparametric LOS data.[23]

Receipt of vancomycin and systemic corticosteroids was also independently associated with increased LOS, while white race/ethnicity was associated with shorter LOS. Vancomycin concentration in the epithelial lining fluid of the lung can be substantially less than that in serum.[38] However, these levels are typically higher than the vancomycin minimum inhibitory concentrations for staphylococci and pneumococci, making it unlikely that the longer LOS in patients receiving vancomycin is caused by ineffective or suboptimal antibiotic therapy.[38] We sus-

Table 3. Risk Factors for Second Pleural Fluid Drainage Procedure[a]

| Variable | Odds Ratio (95% Confidence Interval) | | P Value |
	Unadjusted	Adjusted	
Male sex	0.82 (0.68-1.01)	. . .	. . .
Age category, y			
1-5	1 [Reference]	. . .	. . .
>6-13	0.82 (0.60-1.12)	. . .	. . .
>14-18	0.79 (0.56-1.12)	. . .	. . .
White race/ethnicity	0.77 (0.54-1.11)	0.78 (0.54-1.13)	.20
Initial procedure			
Chest tube placement	1 [Reference]	1 [Reference]	. . .
VATS	0.16 (0.06-0.42)	0.16 (0.06-0.42)	<.001
Thoracotomy	0.61 (0.31-1.18)	0.60 (0.31-1.16)	.13
Asthma[b]	1.28 (0.81-2.02)	1.27 (0.79-2.04)	.31
Systemic corticosteroids	1.08 (0.61-1.88)	0.96 (0.52-1.74)	.90
Empirical vancomycin therapy	1.16 (0.82-1.63)	1.14 (0.79-1.64)	.47
Chemical fibrinolysis	0.31 (0.01-2.46)	. . .	. . .

Abbreviation: VATS, video-assisted thoracoscopic surgery.
[a]The following variables were insignificant on adjusted analysis and were left out of the final model: sex, age category, and chemical fibrinolysis.
[b]Although not statistically significant, asthma remained in the final multivariate model because of our a priori hypothesis of the effect of asthma on the length of hospital stay.

pect that critically ill children were more likely to receive vancomycin and were more likely to have a longer LOS than less severely ill children. Systemic corticosteroids did not modify the effect of asthma on the LOS. The reason is unclear but may be related to illness severity, with the most critically ill patients receiving corticosteroid therapy. Patients of white race/ethnicity had a shorter

LOS compared with patients of other races/ethnicities. This difference remained significant after adjustment for procedure type and for clustering by hospital. Although this difference could not be explained by differences in insurance status, it is possible that such variation is merely a surrogate for health care access constraints facing individuals of different races/ethnicities. For example, delays in receiving care, which could not be measured in this study, may be associated with race/ethnicity and with worse outcomes. Previous investigations have shown that substantial variation exists with respect to patterns of care for pneumonia among different racial/ethnic groups.[30] Further research should define the contribution of such variation to differences in the LOS among patients of different racial/ethnic backgrounds.

We found substantial variability in the LOS among hospitals. Interhospital variations in the LOS have been described previously for adults hospitalized with uncomplicated pneumonia.[39] In children, Srivastava and Homer[40] found that the LOS was shorter for nonteaching hospitals compared with teaching hospitals for several common pediatric conditions, including bacterial pneumonia. In a review of pediatric complicated pneumonia, Avansino et al[7] found that single centers reported an LOS ranging from 6.5 to 46 days for children undergoing needle thoracentesis or primary chest tube placement and an LOS ranging from 5 to 24.5 days for children undergoing primary VATS or thoracotomy. Some differences in the review can be attributed to changes in systems of medical care and to trends toward shorter LOS for many common pediatric conditions, as studies published more than 2 decades ago were included. However, these differences also likely reflect local or regional variation in the treatment of a common infection for which formal management guidelines do not exist.

In our study, just over one-third of children undergoing primary chest tube placement required an additional pleural fluid drainage procedure. This proportion is similar to that found in reviews by Gates et al[37] (25.0%) and by Avansino et al[7] (23.6%). The magnitude of reduction in additional procedures associated with primary VATS compared with primary chest tube placement in our study was similar to that found in a previously published meta-analysis[7] (risk ratio, 0.09; 95% confidence interval, 0.04-0.23), despite the fact that patients undergoing primary chest tube placement or thoracentesis were combined into a single category for meta-analytic purposes.

This study had several limitations. First, as with any study using administrative data, diagnosis codes may be inaccurate. We attempted to minimize the effect of such miscoding by limiting the study population to patients with a primary diagnosis code for pleural effusion and an additional diagnosis code for pneumonia. It is possible that patients with metastatic dissemination of infection (eg, endocarditis) had these infections rather than pleural effusion listed as the primary diagnosis, potentially leading to the disproportionate exclusion of the most severely ill patients. However, the effect of such exclusions is probably minimal because the metastatic infection rather than the initial procedure is likely to be the primary determinant of the LOS in such cases. Few patients in this study were prescribed chemical fibrinolysis. We suspect that our methods for detecting intrapleural administration underestimated the proportion of patients receiving these agents. If chemical fibrinolysis is beneficial, such misclassification should also bias our results in favor of chest tube placement because patients undergoing primary VATS rarely receive adjuvant intrapleural fibrinolysis. Second, several factors such as duration of symptoms, prior antibiotic therapy, and effusion size and character that may influence the decision to perform a specific procedure could not be measured in this study. It is likely that patients with protracted symptoms and more severe disease would be most likely to undergo surgical therapy (ie, VATS or thoracotomy). These differences in baseline disease characteristics would likely lead to an underestimation of the benefit of primary VATS compared with primary chest tube placement. In contrast, the results of our study favor primary VATS, making it likely that the actual effect of primary VATS is more dramatic than that found in our study. Third, because this study was limited to freestanding children's hospitals, it is unlikely that these data are generalizable to community settings. Because VATS requires specialized surgical training, most community hospitals do not have surgeons with the technical training and expertise to perform this procedure. Therefore, any benefit of primary VATS to patients with complicated pneumonia initially evaluated at community hospitals should be balanced against the delays in pleural drainage that could result from the transfer process. However, this study is generalizable to tertiary care children's hospitals that are not included in the PHIS database. The strength of this multicenter study lies in the inclusion of a racially/ethnically and geographically heterogeneous population.

In conclusion, our large retrospective multicenter study demonstrates that, compared with primary chest tube placement, primary VATS is associated with a shorter LOS and with fewer additional procedural interventions. Although these immediate short-term outcomes are important considerations, longitudinal studies of long-term functional outcomes of patients undergoing different initial drainage procedures are necessary to help determine the optimal management strategies.

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