Pediatric empyema: Outcome analysis of thoracoscopic management

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Objective: Thoracoscopy has become a favored modality in treating pediatric empyema. However, the factors affecting the outcome of thoracoscopic management remain unclear. In this study, we report our experience using thoracoscopy to treat empyema in pediatric patients and investigate the factors affecting outcome.

Methods: We retrospectively reviewed the demographic data, clinical presentation, radiographic findings, laboratory studies, and hospital course of 101 pediatric patients who underwent thoracoscopy for empyema between 1995 and 2008.

Results: Empyema was due to pneumococcus infection in 64 patients (63.4%), and 69% of the cultured microorganisms were penicillin nonsusceptible. Chest computed tomography scan was performed in 96 patients, in whom necrotizing pneumonia was noted in 35 (36.5%). Preoperative intensive care unit admission was required for 33 patients (32.7%). Preoperative chest tube drainage was performed in 36 patients (35.6%), and thoracoscopy was used as the primary treatment in the remaining 65 patients. Complications occurred in 10 patients (9.9%); there were no mortalities. The median postoperative hospital stay was 13 days. Multivariate analyses showed that necrotizing pneumonia was significantly associated with the presence of complications, and that necrotizing pneumonia, preoperative intensive care unit admission, and preoperative chest tube drainage were independent risk factors for a longer postoperative hospital stay.

Conclusion: The clinical presentations of empyema in children requiring thoracoscopy are diverse. Patients with necrotizing pneumonia and those requiring preoperative intensive care unit admission and undergoing preoperative chest tube drainage are at high risk for developing complications and requiring longer hospital stay after thoracoscopy.

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The incidence of empyema in children is increasing worldwide.[1,2] Empyema is most often treated with primary nonoperative therapy, such as antibiotics and thoracentesis/chest tube drainage. When this approach is not effective, salvage operative interventions are required and may result in prolonged hospitalization.[3,4]

Although no clear consensus has been reached concerning the optimal therapeutic strategy for pediatric empyema, a meta-analysis showed that the in-hospital mortality rate was lower and that the duration of hospitalization was shorter after primary operative therapy than after nonoperative treatment.[5] With the advent of thoracoscopy, pleural debridement or decortication of empyema has become more common. Thoracoscopy is a minimally invasive procedure with many advantages over traditional open surgery, such as minimal morbidity, hastened recovery, high safety, and good efficacy, leading many experts to recommend an early surgical approach to drain the pleural space.[6-13]

Although thoracoscopy leads to satisfactory results, approximately 5% to 30% of patients develop complications after thoracoscopy that require prolonged hospitalization, additional thoracotomy, or even lobectomy.[3,5,12,14,15] The factors associated with the outcome of thoracoscopy, however, have rarely been investigated.[3,12] The aim of this study was to identify the clinical, bacteriologic, and radiologic prognostic factors for complications and hospital stay in pediatric patients with empyema after thoracoscopic treatment.

MATERIALS AND METHODS

Study Design and Patient Selection

Medical records of all pediatric patients (aged < 16 years) who were discharged with a diagnosis of empyema associated with community-acquired pneumonia at National Taiwan University Hospital during the period from January 1995 to February 2008 were reviewed retrospectively. An empyema was defined as a loculated or septated effusion by radiographic study or finding of pus or loculated effusion at the time of surgical intervention. Only patients who underwent thoracoscopic management were included for this study. Exclusion criteria included *Mycobacterium tuberculosis* or fungi infection, immunocompromised state, or infection originating from extrapulmonary sites.

Information collected included demographic features, clinical presentation, microbiologic and laboratory data, radiographic studies, hospital course, and follow-up outcome. Most patients underwent chest computed tomography (CT) scans to evaluate the extent of the empyema and the severity of pulmonary parenchyma lesions. Necrotizing pneumonia was defined as multiple small lucencies or cavities of nonenhancement on

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Abbreviations and Acronyms
CT = computed tomography
ICU = intensive care unit

a contrast-enhanced CT image, determined by the radiologic report made at the time of care.[16,17] Pneumococcus infection was established on the basis of a positive result of a blood or pleural fluid culture or the detection of antigens in the pleural fluid by latex agglutination testing.[16] All patients received thoracentesis and varying courses of intravenous antibiotics before thoracoscopy, with some having had preoperative chest tube drainage, depending on the attending or referral physician's preference. Antibiotics were adjusted according to the culture results or clinical course. A penicillin-nonsusceptible isolate was defined as that for which a minimal inhibitory concentration of penicillin was more than 2 μg/mL. Indications for preoperative intensive care unit (ICU) admission included respiratory distress, organ failure, or unstable vital signs requiring use of inotropic agents. Duration of preoperative or postoperative fever was defined as the number of days that the patient was febrile (>38°C) before or after thoracoscopic treatment. Duration of preoperative empyema was defined as the number of days from the diagnosis to thoracoscopic treatment. Duration of total hospital stay was defined as the number of days that the patient was hospitalized, including hospital stay at the referral hospitals and the National Taiwan University Hospital.

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Thoracoscopy Technique

Video-assisted thoracoscopy was performed in the operating room in a standard fashion as described previously.[11] Briefly, each patient underwent general anesthesia and single- or double-lumen endotracheal intubation with either 1- or 2-lung ventilation, depending on the size of the child. The patients were positioned in either the left or right lateral decubitus position depending on the involved side. A 5-mm 30-degree telescope was inserted through the sixth or seventh intercostal space at the mid-axillary line. Two additional ports for insertion of instruments were made under thoracoscopic guidance. The free fluid was evacuated and loculations were drained, the fibrinous adhesions were separated, and the pleural debris was removed from the pleural lining using ring forceps. Necrotic lung tissue caused by necrotizing pneumonia was carefully preserved to prevent postoperative air leakage. At the completion of the operation, 1 or 2 chest tubes were inserted under thoracoscopic visualization. Pleural fluids and fibrinous tissues were sent for Gram stain, acid-fast stain, microbiological culture, and pathologic examination. After the operation, most patients were sent to the ICU for postoperative care. The chest tubes were removed when there was minimal drainage. Patients were discharged after removal of chest tubes and completion of intravenous antibiotic treatment at the discretion of the attending pediatrician.

After discharge, patients were monitored at the outpatient clinic at 1 week, 1 month, 3 months, and 6 months, at which times chest radiography was performed. Patients were instructed to come back to the clinic or visit the emergency department whenever they had fever, chest pain, dyspnea, or any signs related to the recurrence of empyema.

Outcome Variables and Data Analysis

The outcome variables assessed in this study included the presence of complications (yes/no), duration of postoperative hospital stay (days), and duration of total hospital stay (days). Potential factors affecting the postoperative outcome after thoracoscopic management for pediatric empyema included age, gender, duration of preoperative empyema, presence of necrotizing pneumonia, operation time, preoperative chest tube drainage, preoperative ICU admission, *Pneumococcus* infection, status of bacterial culture, and penicillin susceptibility. Univariate analysis was performed to assess the association between each risk factor and one of the outcome variables. Variables with P values less than .1 in the univariate analysis were included in the multivariate analyses. For the dichotomous outcome variable, presence of complications (yes/no), the logistic regression models were used to calculate the odds ratio and 95% confidence interval. For the continuous outcome variables, the duration of postoperative stay and total hospital stay, the general linear regression models were applied to calculate the change of dependent variables, hospital stay (days), for 1 unit change of the independent variables. All data analyses were conducted with the Statistical Package for the Social Sciences release 15 (SPSS Inc, Chicago, Ill), and all statistical tests were 2-sided.

RESULTS

From 1995 to 2008, a total of 131 pediatric patients with empyema were managed at the National Taiwan University Hospital. Among them, 106 patients underwent thoracoscopic management. Five patients were excluded because of fungal infection (2), immunocompromised state (2), and empyema caused by mediastinitis (1). Therefore, data on 101 pediatric patients were analyzed. The algorithm for patient selection in this study is shown in Figure 1. There were 52 boys (51.5%) and 49 girls (48.5%), and the mean age was 4.4 ± 2.7 years. Empyema was right sided in 47 patients and left sided in 53 patients. One patient had bilateral disease, and thoracoscopy was performed on both sides. The clinical presentations, radiographic studies, and laboratory data are shown in Table 1. Chest CT scans were available in 96 patients, in whom necrotizing pneumonia was noted in 35 (36.5%). The median duration from diagnosis to thoracoscopic treatment of empyema was 4 days. Thirty-six patients (35.6%) underwent chest tube drainage followed by thoracoscopy for treatment of empyema, and 65 patients underwent thoracoscopy as the primary treatment. The median duration of chest tube drainage before thoracoscopy was 6 days (range, 1–28 days). Preoperative ICU admission was required in 33 patients (32.7%).

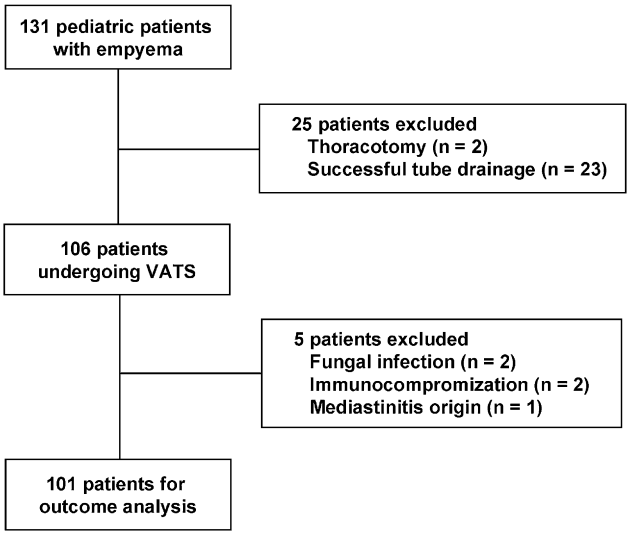

FIGURE 1. Algorithm for patient selection. *VATS,* Video-assisted thoracic surgery.

TABLE 1. Clinical characteristics of 101 pediatric patients with empyema who underwent thoracoscopy

Variable	Median (range)
Age (y)	4.5 (0.5–15.0)
Male, no. (%)	52 (51.5%)
Duration of preoperative fever (d)	11 (3–47)
Duration of preoperative stay (d)	7 (0–42)
Duration of preoperative empyema (d)	4 (0–30)
Necrotizing pneumonia, no. (%)[a]	35 (36.5%)
Preoperative chest tube drainage, no. (%)	36 (35.6%)
Preoperative ICU admission, no. (%)	33 (32.7%)
Positive bacterial culture, no. (%)	48 (47.5%)
Causing organisms, no. (%)	
Streptococcus pneumoniae[b]	64 (63.4%)
Others	27 (26.7%)
Unknown	10 (9.9%)

ICU, Intensive care unit. [a]Data were available in 96 patients. [b]By positive culture or latex agglutination testing.

Empyema was due to pneumococcal infection in 64 patients (63.4%); the diagnosis was based on positive culture in 27 patients and on positive latex agglutination test results in 37 patients. Forty-eight patients (47.5%) had positive blood or pleural effusion cultures for bacterial pathogens. The most frequent cultured pathogen was *streptococcus pneumoniae,* followed by methicillin-resistant *Staphylococcus aureus* (Table 2). Among these isolates, penicillin-nonsusceptible pathogens were noted in 33 patients (68.8%).

Treatment outcomes are shown in Table 3. The mean operation time was 80.6 minutes. Conversion to an open procedure was necessary in 2 patients (2.0%) because of dense adhesions after prolonged chest tube drainage. The mean operation time was longer in patients with preoperative chest tube drainage than in those who underwent thoracoscopy as primary treatment (94.0 vs 73.2 minutes, $P = .006$ by Wilcoxon rank-sum test). The mean blood loss was 33 mL. The median postoperative hospital stay was 13 days, and the median total hospital stay was 21 days. There were no mortalities. Postoperative complications developed in 10 patients (9.9%). Among them, large

TABLE 2. Microorganisms isolated from cultures of 48 patients

Isolate(s)	No. cases (%)
Streptococcus pneumoniae	27 (56.3%)
MRSA	11 (22.9%)
MSSA	2 (4.2%)
Enterobacter cloacae	2 (4.2%)
Acinetobacter baumannii	1 (2.1%)
Alpha-streptococcus	1 (2.1%)
Streptococcus viridans	1 (2.1%)
Group A Streptococcus	1 (2.1%)
Pseudomonas aeruginosa	1 (2.1%)
Staphylococcus cohnii	1 (2.1%)

MRSA, Methicillin-resistant *Staphylococcus aureus; MSSA,* methicillin-susceptible *Staphylococcus aureus.*

TABLE 3. Treatment outcome of 101 pediatric patients with empyema who underwent thoracoscopy

Variable	Median (range)
Duration of postoperative fever (d)	5 (0–29)
Duration of postoperative chest tube (d)	6 (1–49)
Duration of postoperative stay (d)	13 (6–75)
Duration of total hospital stay (d)	21 (11–92)
Complication, no. (%)	10 (9.9%)
Mortality, no. (%)	0 (0%)

pneumatoceles causing respiratory distress developed in 3 patients. One of them had tension pneumatoceles and underwent chest tube decompression and subsequent lobectomy. The remaining 2 patients improved after conservative treatment. One patient had recurrent empyema that required additional thoracotomy for thorough debridement. Bronchopleural fistula developed in 1 patient, and additional lobectomy was performed. The other complications included prolonged air leaks (2), superimposed respiratory syncytial virus infection (1), red man syndrome caused by vancomycin infusion (1), and septic arthritis (1); all of these complications were managed conservatively.

All patients were afebrile, and chest tubes had been removed before discharge. The follow-up period ranged from 1 to 12 months (median, 5.0 months). All patients in whom necrotizing pneumonia had been diagnosed had improved aeration on follow-up chest x-rays. There were no recurrences of empyema in any of the patients after discharge from the hospital.

Analyses of factors affecting the presence of complications are shown in Table 4. Multivariate analysis showed that the presence of necrotizing pneumonia is a significant predictor for developing complications (odds ratio = 4.34, 95% confidence interval, 1.02–18.42). In our cohort, complications of pneumatoceles, bronchopleural fistula, and prolonged air leaks were all observed in patients with necrotizing pneumonia. Both univariate and multivariate analyses showed that the presence of necrotizing pneumonia ($P = .020$), preoperative chest tube drainage ($P = .003$), and preoperative ICU admission ($P = .016$) were associated with a longer postoperative hospital stay (Table 5). For factors affecting total hospital stay, univariate analysis showed that preoperative empyema more than 4 days ($P = .001$),

TABLE 4. Logistic regression analysis of risk factors affecting the presence of complication

Associated variable	Odds ratio (95% CI)	*P* value
Univariate analysis		
Necrotizing pneumonia	4.83 (1.16–20.11)	.030
Preoperative ICU admission	3.55 (0.93–13.60)	.064[a]
Multivariate analysis		
Necrotizing pneumonia	4.34 (1.02–18.42)	.047

CI, Confidence interval; *ICU,* intensive care unit. [a]Borderline significant.

TABLE 5. Multivariate linear regression analyses of factors affecting the outcomes

Outcome	Associated variable	B[a] (SE)	*P* value
Postoperative stay (d)	Necrotizing pneumonia	4.0 (1.7)	.020
	Preoperative chest tube drainage	5.2 (1.7)	.003
	Preoperative ICU admission	4.2 (1.7)	.016
Total hospital stay (d)	Preoperative chest tube drainage	11.5 (2.7)	<.001

SE, Standard error; *ICU*, intensive care unit. [a]B denotes the unstandardized coefficient of the multivariate linear regression model.

necrotizing pneumonia ($P = .037$), and preoperative chest tube drainage ($P < .001$) were significant factors, and that preoperative ICU admission was a borderline significant factor ($P = .098$). Multivariate analysis showed that that only preoperative chest tube drainage was significantly associated with a longer duration of total hospital stay ($P < .001$) (Table 5).

DISCUSSION

The clinical presentation of pediatric empyema requiring thoracoscopy is diverse. Empyema can be caused by a variety of multidrug resistant organisms, can vary in clinical severity, and is frequently associated with necrotizing pneumonia. The surgical outcome is also affected by many factors, including the form of pulmonary infection, severity of disease, and mode of primary treatment.

Since 1990, an increase in necrotizing pneumococcal pneumonia has been observed in children, especially in Taiwan, where pneumococcal vaccination is not widely implemented.[16-18] Necrotizing pneumonia represents a more severe form of pulmonary infection and can be caused by a variety of microorganisms, such as *Streptococcus pneumoniae* and methicillin-resistant *S. aureus*.[17,19] In Suchar and colleagues' report,[19] necrotizing pneumonia occurred in 33% of their patients and was found to significantly increase postsurgery stay if patients also had positive intraoperative culture. In our cohort, necrotizing pneumonia was noted in 36.5% of empyemas requiring thoracoscopy, and 20% of these patients developed complications after the operation, including pneumatocele, pneumothorax, and bronchopleural fistula. In addition to a higher complication rate, necrotizing pneumonia is also associated with a longer duration of postoperative stay, probably because the severity of disease and the types of complications required a longer period of treatment.

The ideal management of necrotic lung tissue caused by necrotizing pneumonia during thoracoscopy remains unclear. Although some authors reported successful results in removing all necrotic lung tissue,[9] Margenthaler and colleagues' report[3] showed that 7 of 33 surgical patients (21%) had diffuse necrotizing pneumonia requiring lobectomy or pulmonary resection and that prolonged air leaks developed in 4 children (57%).[3] In our patients, we preserved the necrotic lung tissue during the operation. Most of our patients had small pneumatocele after operation, but this resolved spontaneously within 1 to 2 months with excellent results. We suggest that removal of necrotic tissue is unnecessary during thoracoscopy.

The optimal primary management of pediatric empyema remains controversial. This study revealed that the durations of operation and postoperative hospitalization were longer in patients with preoperative chest tube drainage than in patients who underwent thoracoscopy as the primary treatment. Many studies have also demonstrated that primary chest tube drainage is associated with prolonged fever, pleural drainage, and hospital stay when compared with primary operative therapy. This can probably be attributed to ineffective drainage and rapid characteristic changes of the retained empyemic fluid.[5,10,11] The median duration of chest tube drainage before thoracoscopy was 6 days in our patients. Prolonged chest tube drainage not only increased the duration of hospitalization but also made the empyema more fibrotic and the operation more difficult. In our patients, the main reason for prolonged chest tube drainage before thoracoscopy is that many of these patients had been referred from hospitals where pediatric thoracic surgeons were not available. Chest tube drainage was the only method of treatment before being transferred to the National Taiwan University Hospital.

One critical issue concerning *S. pneumoniae* in recent decades is the global emergence of penicillin-nonsusceptible *S. pneumoniae* among children.[20-22] In Taiwan, the incidence of pulmonary infection with *S. pneumoniae* progressing to necrosis or empyema and the incidence of infections due to penicillin-nonsusceptible *S. pneumoniae* in children have increased markedly in recent years.[16] The correlation between bacterial virulence and treatment outcome remains unclear. Although a report showed that bacterial virulence is associated with surgical outcome for complicated pneumonia in children,[3] our results showed that the complication rate and the duration of postoperative stay and total hospital stay are not affected by penicillin susceptibility, positive culture, or pneumococcal infection.

Preoperative ICU admission is also an important predictor of prolonged postoperative hospital stay. The causes of preoperative ICU admission included respiratory distress, unstable general conditions, or presence of organ failure, such as hemolytic uremic syndrome.[23] Patients admitted preoperatively to the ICU usually have more severe forms of illnesses that may be associated with other comorbidities. Although necrotizing pneumonia also represents a severe form of illness, there is no significant correlation between preoperative ICU admission and presence of necrotizing pneumonia.

The timing of surgical treatment was reported as an important prognostic factor for treating pediatric empyema.

Previous studies showed that a delay of more than 4 days between diagnosis of and surgery for pediatric empyema was significantly correlated with more frequent surgical difficulties, longer hospitalization, and more postoperative complications.[4,12] However, our results showed that preoperative empyema more than 4 days was associated with a longer total hospital stay only in univariate analysis. Our explanation is that the diagnosis and true onset of empyema in this retrospective study varied widely, making the estimation of duration of preoperative empyema inconsistent.

In comparison with other studies, the median postoperative hospital stay in our patients (13 days) is longer, although the median durations of postoperative fever and chest tube drainage are comparable.[10,15,19] The possible reasons include that our patients tended to stay in the hospital longer for completion of intravenous antibiotics treatment after subsidence of fever and removal of the chest tube. Other factors, such as difference in disease severity and empyema stage at the time of thoracoscopy, may also play roles.

LIMITATIONS

There are, however, limitations to this study. It is a retrospective study of a group of patients treated by different physicians and surgeons over a 13-year period. Treatment policy was not standardized and might be modified over time. We believe that a prospective study with precise definition of variables and standardized treatment protocol will be helpful in validating our results.

CONCLUSIONS

Although a variety of recent reports have documented the success of thoracoscopy in the treatment of children with empyema, not every patient had uneventful and prompt recovery after thoracoscopy. In this study, we found that necrotizing pneumonia, preoperative ICU admission, and preoperative chest tube drainage are predictors for complications and prolonged hospital stay. We therefore suggest that patients with necrotizing pneumonia and unstable general conditions requiring ICU admission should be informed of the possibility of poorer outcome before thoracoscopy. Prompt surgical intervention is indicated to prevent difficult operation and prolonged hospital stay, especially in patients in whom chest tube drainage is ineffective.

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