ABSTRACT. Objective. The appropriate timing, as well as the type of intervention, for the treatment of empyema in children is controversial. The advent of video-assisted thoracic surgery (VATS) has changed the way we treat these children. Therefore, we reviewed our experience with the early use of VATS in the treatment of empyema and formulated a treatment algorithm.

Methods. We retrospectively reviewed medical records of all patients undergoing VATS for empyema at Arkansas Children's Hospital from December 1994 to February 1997. All patients were treated by the pediatric surgical service and had the diagnosis of empyema confirmed at surgery. Results are reported as means, unless otherwise noted.

Results. Twenty-five children with empyema were treated with VATS during the review period. Their age was 48.3 months, and the duration of symptoms was 7.4 days. All the patients had parapneumonic empyemas and had received preoperative antibiotics for 10.1 days. Preoperative imaging included chest radiography in 25 (100%), ultrasonography in 20 (80%), and computed tomography in 10 (40%). All patients with documented loculated parapneumonic fluid collections underwent VATS within a mean of 2 days of hospitalization. Chest tubes were removed in 3.2 days, resulting in a postoperative length of stay of 4.9 days. Total length of stay was 7.3 days. One patient required conversion to minithoracotomy and required a transfusion. There were no other complications or deaths. Follow-up was available for 22 (88%) children, and there was resolution of symptoms in all children with no recurrences.

Conclusions. Earlier intervention with VATS in the treatment of empyema in children is safe and may reduce hospital charges by shortening hospital stay. A treatment algorithm based on early use of VATS is also described.

METHODS

We reviewed retrospectively medical records of all patients undergoing VATS for empyema at Arkansas Children's Hospital from December 1994 to February 1997. All patients were treated by the pediatric surgical service. The diagnosis of empyema was considered in all patients with parapneumonic effusions on chest radiography, ultrasonography, or computed tomography (CT). If thoracentesis was performed, a diagnosis was made if there was frank pus, positive Gram stain, or culture of pleural fluid. Additional diagnostic criterion were pleural fluid pH <7.0, pleural fluid glucose <40 mg/dL, and pleural fluid LDH >1000 IU/dL. All patients had the diagnosis of loculated empyema confirmed at surgery.

All patients had to have evidence of loculated fluid on a radiographic or sonographic imaging study before undergoing VATS. We preferred chest ultrasonography as the imaging modality of choice. It allows adequate imaging of the pleural space, shows the presence of loculated areas, and does not expose the child to radiation. If an imaging study revealed loculated pleural fluid, thoracentesis or chest tube placement was not required before surgery.

VATS was performed using general anesthesia; a single lumen endotracheal tube was used in the majority of patients, with selective bronchial intubation if possible. Arterial or central lines were not used routinely. The patient was positioned in the lateral decubitus position with the involved side up. Trocar placement was dictated by the location of the loculated empyema; usually one laparoscopic trocar (which allows carbon dioxide insufflation if the lung does not collapse) was used for the telescope, and this was placed in the 6th intercostal space in the mid- or posterior axillary line. A 5- or 10-mm 0° or 30° telescope was used. Before insufflation, pleural fluid or pus should be aspirated with a large bore suction aspirator. After pneumothorax is induced and the lung is collapsed, additional incisions in the intercostal space are made under thoroscopic visualization to allow placement of instruments directly into the thoracic cavity. These skin incisions should be placed so that they can be incorporated in a formal thoracotomy incision, if needed. A variety of curved and straight, ring, stone, and dressing forceps then can be used. The pleural cavity is debrided of all fibrinous and purulent material. All treatment options exist. They include intravenous antibiotics with repeated thoracentesis, chest tube drainage, image-directed drainage, fibrinolytic therapy, video-assisted thoracic surgery (VATS), minithoracotomy, open drainage, and formal thoracotomy with decortication. The timing and type of surgical intervention are controversial as well.

The advent of minimally invasive VATS in adults has resulted in the adoption of these techniques by pediatric surgeons. Following the description of the use of VATS to treat empyema in children, we have utilized this technique increasingly in our practice. In addition, we have intervened earlier in the course of the disease. Therefore we reviewed our experience with VATS to evaluate its safety and efficacy in the treatment of empyema in children and formulated a treatment algorithm.

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RESULTS

Twenty-five children with empyema were treated with VATS during the review period of 27 months. The mean age was 48.3 months (1 month to 14 years), there were 13 males and 12 females. The most common symptoms were fever (96%), cough (92%), and respiratory distress (60%). The duration of symptoms was 7.4 ± 4.2 days before hospitalization. All the patients had parapneumonic empyemas and had received antibiotics for 10.1 ± 7.5 days before surgery.

Laboratory evaluation revealed a white blood cell count of 17 ± 9.2 thousand/mm³. Thoracentesis was performed in 12 patients. Gram stain was positive in 3, and cultures grew Streptococcus pneumoniae in all 3. Pleural fluid white blood cell count was 3826 ± 4105/mm³. Mean pleural fluid pH was 7.8, LDH was 2769 IU/dL, and glucose was 35 mg/dL. Blood cultures were positive in 4 of 13 patients (cultures grew Streptococcus pneumoniae). The bacteriology results, including one intraoperative culture, thus showed growth in cultures from only 8 patients (32%), all which grew Streptococcus pneumoniae.

Preoperative imaging included chest radiography in 25 (100%); the most common findings were parapneumonic pleural effusion in 17 (68%), loculated fluid in 7 (28%), and complete opacification of the hemithorax in 1 (4%). Ultrasonography was performed in 20 (80%) and was the most accurate in imaging loculated pleural fluid, identifying loculations or fibrinous septations in all 20 (100%). Ultrasonography was not as accurate as computed tomography in imaging the underlying lung. Computed tomography was performed in 10 (40%) children. It showed pleural fluid in all 10, but it did not show loculations in 5 (50%). However, it was more accurate, compared with ultrasonography, in identifying an underlying lung abscess in 1 patient.

Preoperative chest tubes inserted in only 5 patients before surgical consultation were present for 2 ± 1.6 days. Seven patients were admitted directly to the intensive care unit for respiratory distress. All patients with documented loculated parapneumonic fluid collections underwent VATS. The preoperative LOS was 2.2 ± 2 days (median, 1 day). All patients underwent VATS within 2 weeks of the onset of symptoms.

The operative time was 80 ± 42 minutes. Three patients (12%) had associated lung resection or biopsy performed. One patient with a lung abscess had a central line placed. One patient (4%) had conversion of VATS to thoracotomy secondary to inadequate visualization because of bleeding along the chest wall; this also was the only patient who needed a blood transfusion. Only one operative culture result was positive, and all specimens for which pathology examination was performed were consistent with inflammatory tissue, peel, or empyema. Two patients (8%) required postoperative ventilation (for <24 hours) and were admitted to the intensive care unit for a mean of 1.8 days. Postoperative supplemental oxygen was required for 2.3 ± 2 days. Chest tubes were removed in 3.2 ± 2.2 days, resulting in a postoperative LOS of 4.9 ± 2.7 days (median, 5 days).

There were no postoperative complications, returns to the operating room, or deaths. All patients were afebrile before discharge, and 24 (96%) were discharged on oral antibiotics (usually clindamycin). One patient with a lung abscess was discharged on home intravenous antibiotics for 21 days. Total LOS for the entire group was 7.3 ± 4 days (median, 7 days).

Follow-up data were available for 22 (88%) children. Symptoms had resolved in all the children followed. Chest radiography also showed marked resolution of previous radiographic abnormalities. There were no recurrences and no hospitalizations of discharged patients.

DISCUSSION

Childhood empyema usually is secondary to direct spread of infection to a parapneumonic effusion. Approximately 0.6% of pneumonias in children are complicated by empyema, and the incidence of parapneumonic empyema in children ranges from 0.4 to 6 per 1000 admissions. The definition of empyema is the presence of pus in the pleural space, and various criterion exist to define and classify parapneumonic pleural effusions and empyema. Traditionally, empyemas have been divided into three stages: 1) the exudative stage, characterized by a thin, sterile, pleural exudate; 2) the fibrinopurulent stage in which the fluid is now turbid and loculated, with a fibrinous, pleural peel; and 3) the organizing stage, with a thick exudate and an organized, pleural peel, encasing the lung and rendering it immobile.

The microbiology of childhood empyema dictates appropriate antibiotic selection. Haemophilus influenzae, Staphylococcus aureus, and Streptococcus pneumoniae remain the most common pathogens cultured in empyema. In our patients, Streptococcus pneumoniae was the only pathogen isolated. A majority of our patients (68%) did not have any positive culture results, and this may be explained by the fact that all our patients had been receiving antibiotics before obtaining cultures. In our patients, the most com-

...
monly chosen antibiotic for empirical treatment was clindamycin; this gave adequate coverage against the most common pathogens and addressed the problem of drug-resistant *Streptococcus pneumoniae* as well.

In addition to using antibiotics to sterilize the pleural cavity, the goal of treating empyema is to drain and obliterate the pleural space, thus allowing the lung to expand and function normally. The timing and method of attaining these goals is controversial. During the initial exudative stage, the fluid is thin and free-flowing, and its removal by thoracentesis or chest tube drainage may result in cure.5,8,11,13–15

However, most patients are managed initially with antibiotics by their primary care physicians and, in our experience, they have treated them for a mean of 10 days before presenting to us. Thus, by the time they are admitted to the hospital, the empyema usually has progressed to the loculated, fibrinopurulent, or organizing stage. It is therefore crucial to document the presence of free-flowing pleural fluid before embarking on pleural drainage. We recommend initial chest ultrasound rather than CT to image the pleural cavity for the presence or absence of loculations. Park and associates have shown sonography to be superior to CT in evaluating the nature of pleural fluid in their study of 31 patients.16 Another recent study in children has shown that CT is not specific in diagnosing empyema.17 Although chest tube drainage may be successful in some patients in the fibrinopurulent or loculated stage, this usually results in prolonged hospital stay. Hoff and colleagues reported a mean hospital LOS of 20.7 days in patients treated with chest tube drainage.11 McLaughlin and co-workers treated 11 of 16 patients with chest tube drainage and had an average hospital LOS of 22.6 days. A recent report from Montreal Children's Hospital showed an average hospital LOS of 27 days for children with acute empyema.13 If there are loculations on imaging, we proceed to VATS, as outlined in our treatment algorithm (Fig 1).

In an attempt to improve drainage of the pleural cavity and decrease treatment failures, especially once loculations have developed, intrapleural fibrinolytic agents (streptokinase and urokinase) have been used.18–21 In addition, percutaneous catheters for the instillation of fibrinolytics have been placed under CT or ultrasound guidance to obtain more complete drainage.16,21,22 Despite success in treating 50% to 90% of their patients nonoperatively, the mean hospital LOS in these studies has been ~21 days, with a failure rate of 10% to 50%.20,21

Another approach to hasten recovery is to perform open surgical drainage or decortication earlier in the course of the disease, usually within 3 to 5 days of hospitalization, in children not responding to conventional therapy.23–26 Although most patients improved with this approach, there was significant morbidity, including wound infections, persistent air leaks, recurrent empyema, and bleeding, resulting in postoperative hospital LOS of 9 days to 6 weeks.23–25 Some sur-

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**Fig 1.** Treatment algorithm for the management of empyema in children.
geons have used a minithoracotomy or muscle-sparing thoracotomy to minimize morbidity.27

Kern and Rodgers were among the first to report the use of thoracoscopy and VATS in the management of children with empyema.4 They treated 9 children and had 1 death, unrelated to the procedure; the survivors had a mean postoperative LOS of 13.4 ± 2.9 days and did not require any other intervention. In another study that reported 12 children who had VATS for parapneumonic empyema, there was no mortality and the postoperative LOS was 6 to 8 days, resulting in a total hospital LOS of 10 to 14 days.28 Silen and Weber reported success using VATS in 3 patients who were discharged by postoperative day 8.29 Davidoff et al successfully treated 7 of 9 children using VATS; they removed chest tubes in an average of 8.5 days.30 The data available from published results of VATS in pediatric empyema, including the present study are tabulated for comparison (Table 1).

Our experience with 25 patients reported here reflects the success of others using VATS for the treatment of pediatric empyema. We found that earlier intervention (median of 1 preoperative hospital day) resulted in a faster (mean, 80 minutes) and less morbid procedure (no air leaks requiring prolonged chest drainage). We removed chest tubes earlier (3.2 ± 2.2 days), as soon as drainage was <50 mL/d, than reported on other studies4,28-30 (4 to 8.5 days) without an increase in complications or recurrences. We were able to discharge our patients in a median of 5 days postoperatively, and our total LOS of 7.3 ± 4 days was significantly less than that reported in the literature.4,6,7,5,13,14,23-25,26-30

Because early intervention depends on an accurate assessment of the pleural space, we have implemented a treatment algorithm based on early imaging using chest ultrasonography (Fig 1). VATS is indicated if imaging shows the presence of loculated pleural fluid. The algorithm does not require preoperative thoracostomy or chest tube placement, unless the pleural fluid is free-flowing and without evidence of loculation. If thoracostomy is performed, the pleural fluid should be analyzed, and a chest tube should be inserted if there is frank pus or positive Gram stain or culture of pleural fluid, or pleural fluid pH <7.0, pleural fluid glucose <40 mg/dL, and pleural fluid LDH >1000 IU/dL. If there is no improvement in 48 hours with chest tube drainage, we recommend proceeding to VATS.

The implementation of this treatment algorithm, based on our experience using VATS, was 100% successful in curing the disease, resulted in a shorter postoperative stay than that reported in the literature, and was accomplished with minimal morbidity and no mortality (Table 1). Early intervention with VATS in the management of pediatric empyema is safe and is efficient in using health care resources. We recommend adoption of this treatment algorithm in the management of pediatric empyema.

### REFERENCES


### TABLE 1. Results of VATS in the Treatment of Pediatric Empyema

<table>
<thead>
<tr>
<th>Reference</th>
<th>Patients (n)</th>
<th>Preoperative Chest tube days</th>
<th>Postoperative Chest tube days</th>
<th>Postoperative LOS days</th>
<th>Total LOS (days)</th>
<th>Recurrence, Failure or Death</th>
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<tr>
<td>Kern⁴</td>
<td>9</td>
<td>6.9 ± 1.8</td>
<td>8.4 ± 4</td>
<td>13.4 ± 2.9</td>
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<tr>
<td>Stovroff²⁸</td>
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<td>4 to 6</td>
<td>4</td>
<td>6 to 8</td>
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<td>0</td>
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<tr>
<td>Silen²⁹</td>
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<td>4 ± 1</td>
<td>7 ± 1</td>
<td>8 ± 1</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>Davidoff³⁰</td>
<td>9</td>
<td>NA</td>
<td>8.5</td>
<td>NA</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>Present Series</td>
<td>25</td>
<td>2 ± 1.6</td>
<td>3.2 ± 2.2</td>
<td>4.9 ± 2.7</td>
<td>7.3 ± 4</td>
<td>0</td>
</tr>
</tbody>
</table>

* NA indicates data not available.


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