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RESEARCH ARTICLE

Paediatric Empyema Thoracis: Roles and Outcomes of Surgical Intervention in Advanced Disease

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Abstract

Aim: Empyema thoracis has become increasingly common in paediatric population. Antibiotics and thoracostomy have been the cornerstones in managing stage 1 empyema, where as management of stage 2-3 empyema remains controversial. Surgical intervention is perceived to be associated with high morbidity and protracted recovery. This paper reviews the roles and outcomes of surgical decortication, and to provide data for comparison with other treatment modalities.

Methods: Thirty children (median age 5.2 years, range 2 months to 12 years) with stage 2-3 empyema who underwent surgical decortications in our unit from September 2017 to September 2019 were included. The medical records and clinical outcomes were reviewed.

Results: Most children were admitted on day 5 ± 3 of illness. They were referred for decortication by day 8.8 ± 4 of admission, and the median time from referral to surgery was 2.2 ± 2 day. All patients have tube thoracostomy done and 17% of patients (n = 5) underwent fibrinolysis prior to surgery. Pre-operative paediatric intensive care unit admission was required for 70% of patients (n = 21). Post-operatively, all patients were extubated on day 2.5 (range 1-4 days), with chest tubes removed on day 3.8 (range 1-7 days). Most were discharge by day 6.2 (range 4-10 days). Post-operative air leak occurred in 6% of patients (n = 2). There was no mortality or reoperation.

Conclusion: Surgical decortication remains an excellent modality in managing stage 2-3 paediatric empyema. The procedure has low morbidity and provides rapid resolution of symptoms with good clinical outcomes and shorter hospital stay if it was done promptly. Delayed referrals may result in a more protracted clinical course. Nevertheless, this study shows that surgery provides considerably positive clinical outcomes even in severe and advanced disease.

Keywords

Paediatric empyema thoracis, Outcomes, Surgical decortication, Thoracotomy, Video assisted thoracoscopic surgery (VATS)

Introduction

Empyema thoracis, defined as purulent pleural effusion, describes the presence of collection of pus in intrapleural cavity. It has become increasingly common in paediatric population in recent years, which usually complicates community or hospital acquired pneumonia [1,2]. As many as 28% of children admitted for community acquired pneumonia was complicated with pleural empyema, and another study reported a 5-10% risk of parapneumonic effusion progressing to empyema [3,4]. Also, there is raising incidence of multi-resistant organisms found in empyema [3]. In developing countries, paediatric empyema remains a serious health issue with significant morbidity and mortality [5]. Classically empyema thoracis is classified into 3 different phases which describe the progression of disease, namely purulent phase, fibrinopurulent phase and organizing phase based on the contents of pleural cavity [6]. Despite recent advances, optimal treatment for empyema in children remains controversial in term of the choice and duration of parenteral antibiotics, the timing and duration of tube thoracostomy, as well as the role and timing of surgical decortication. Recently, the newer therapies of intrapleural fibrinolysis and Video-assisted thoracoscopic surgery (VATS) further compounded this issue in finding the ideal manage-

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ment of empyema thoracis in children. Early empyema (stage 1) may respond to parenteral antibiotics with or without tube thoracostomy. However, when loculation and septae developed (stage 2) with the formation of thick fibrous cap and thickened pleural (stage 3), surgical decortication may be needed for symptoms resolution. Certain guidelines have outlined the administration of parenteral antibiotics and tube thoracostomy as the mainstay treatment in stage 1 empyema thoracis, but the optimal management of stage 2 and 3 empyema remains debateable [3,5,7]. Often children with stage 2 and 3 empyema underwent a trial of nonsurgical treatment such as tube thoracostomy with/without intrapleural fibrinolytic therapy, fearing that surgical decortication will result in higher morbidity with protracted outcomes. This inadvertently leads to delay in receiving appropriate treatment and thus progression and worsening of disease. This study was conducted to study the role and outcome of surgical intervention in advanced paediatric empyema, cited by the growing incidence of empyema in children, the continuous uncertainty of its most appropriate management and the expressed concerns for possible adverse effects of thoracotomy, highlighting the urgency of early surgical referral for decortication.

Materials and Methods

The medical records of 30 children with empyema thoracis who was referred to Department of Cardiothoracic Surgery, Hospital Pulau Pinang for surgical decortication over 2 years period (September 2017-September 2019) were reviewed retrospectively. The diagnosis of empyema thoracis was confirmed by imaging modalities, including ultrasound and/or CT Thorax, and by percutaneous aspiration of pus from the pleural cavity. Only children underwent surgical decortication were included in this study. Exclusion criteria include children with tubercular empyema, children without thoracocentesis or pleural fluid analysis and cultures. Children with fungal infection or immunocompromised state were also excluded in this study.

Details regarding baseline demographic features, clinical presentations, days of illness prior to admission to healthcare facilities, treatment received before referring to Cardiothoracic Surgery Unit (intravenous antibiotics, intercostal drainage tube insertion, intrapleural fibrinolysis), laboratory investigations (full blood count, renal profile, serum albumin, C-reactive protein (CRP), blood culture, pleural fluid analysis and pleural fluid culture), imaging investigation (Chest X-ray, Ultrasonography, Computed tomography (CT) scan of thorax if performed) and surgery details (types of surgery, duration of surgery, any difficulties encountered intraoperatively) were noted. Of the 30 children that were referred to Cardiothoracic Surgery, 83% (n = 25) of them were diagnosed of stage 3 empyema thoracis, and 17% (n = 5) were diagnosed of stage 2 empyema thoracis.

All of the patients have Intercostal drainage tube (ICDT) inserted and received varying courses of parenteral antibiotics prior to surgery. Antibiotics were adjusted according to culture and sensitivity result of pleural fluid or blood culture report. Indications for preoperative Paediatric intensive care unit (PICU) admission included severe respiratory distress, organ dysfunction or failure, septic shock requiring inotropic support. Duration of total hospital stay was defined as the number of days that patient was hospitalized in both referral hospitals and Hospital Pulau Pinang. The clinical outcomes of surgical decortication, including duration of intercostal drainage tube, incidence of air leak, duration of intubation and days of hospitalization of these patients were reviewed.

Results

Demographic and clinical presentation

The mean age of children was 5.8 ± 5.2 years, with the youngest being 2 months old and the oldest being 12-years-old. 23% (n = 7) of patients were below 1-years-old, 20% (n = 6) between 1-years-old to 3-years-old, 14% (n = 4) between 3 to 5-years-old, and 43% (n = 13) above 5-years-old. In this study, male and female distribution was 18 and 12 respectively. 40% of them had left sided disease while 60% had right sided disease. None of the patients have bilateral disease. The duration of illness was 5 ± 3 days prior to hospital admission. The most common presentation was fever (100%), cough (100%) and respiratory distress (80%). All of the patients received parenteral antibiotics and all of them have intercostal drainage tube inserted prior to surgery, with the mean duration of antibiotics administration and duration of intercostal drainage tube being 10.1 days and 4.5 days. 10% of children were not vaccinated and 13% of them had recurrent pneumonia (Table 1).

Intrathoracic pathology and microbiological profile

Pleural fluid culture was positive in 11 (37%) patients, from which *Streptococcus pneumoniae* was the most common organism isolated, accounted for 81% of cases, followed by *Staphylococcus aureus*, which account for 19% of the cases. 1 pleural fluid grew *Klebsiella pneumoniae* which has extended spectrum beta-lactamase resistant strain. Similarly, blood culture was positive in 5 (6%) patients, again with *Streptococcus pneumoniae* being the most common pathogen isolated. 2 cases were complicated with pseudomonas bacteraemia. 16% (n = 5) of children have both positive pleural fluid and blood cultures result.

Pleural fluid analysis for all of the children showed exudative in nature using Lights' criteria. Both the total white cell count and C-reactive protein (CRP) were

significantly raised on hospital admission, with marked reduction after surgical decortication.

Associated conditions

Of the total number of cases, 7 (23%) children was associated with other organ dysfunction or organ failure. The following organs were involved: Kidney (57%), bone marrow suppression (42%), meningitis (14%) and venous thrombosis (14%). Septic shock was present in 11 (36%) of cases. 21 (70%) children were admitted to PICU prior to surgery in which 16 (53%) of them required mechanical ventilation.

Table 1: Demographic and clinical presentation.

Clinical profile	N = 30
Sex (M:F)	18:12
Age (years)	
< 1, n (%)	7 (23)
1-3, n (%)	6 (20)
3-5, n (%)	4 (14)
> 5, n (%)	13 (43)
Duration of illness in days, mean (range)	5 (1-8)
Clinical features	
Fever, n (%)	30 (100)
Cough, n (%)	30 (100)
Respiratory distress, n (%)	24 (80)
Anorexia, n (%)	20 (66)
Chest pain, n (%)	18 (60)
GI symptoms, n (%)	12 (40)
Site of involvement	
Left, n (%)	12 (40)
Right, n (%)	18 (60)
Bilateral, n (%)	0 (0)
Prior surgery	
Antibiotics, n (%)	30 (100)
Antibiotics duration in days, mean (SD)	10.1 (2.8)
Intercostal drainage tube, n (%)	30 (100)
Intercostal drainage tube duration in days, mean (SD)	4.5 (2.3)
Predisposing factors	
Not vaccinated, n (%)	3 (10)
Recurrent pneumonia, n (%)	4 (13)

Treatment details and surgical decortication

All children have closed chest tube drainage on referral for surgical decortication. The mean duration from hospital admission to surgical referral was 8.8 (4-16) days, whereas the duration from surgical referral to surgical intervention was 2.2 (1-4) days. The mean duration of surgical decortication was 2.4 hours, and all of the children underwent a limited thoracotomy with adhesiolysis and breakdown of loculations, followed by drainage of intrapleural space (Table 2).

Out of the 30 children who underwent surgical decortication, 5 (17%) children in the study was diagnosed of stage 2 empyema, with intrapleural fibrinolysis done which has failed to provide symptomatic relieve and thus referred for surgical intervention. The other 25 (83%) children have stage 3 empyema and underwent surgical procedure without intrapleural fibrinolysis.

Outcomes of surgical intervention

Rapid improvements were observed in all the children following surgical intervention. The children became afebrile within 2.2 (1-3) days and most of the patients were extubated on 2.5 (1-4) days post operation. By day 2-5 days these children were able to be transferred out from PICU to general paediatric ward for further monitoring. Intercostal chest tube was removed on 1-8 days post operation. Complication of surgery was observed in 1 child who developed air leak postoperatively. The majority went home 4-10 days after surgery. The follow up period range from 2 to 6 months. All of the children were doing well, with improved aeration and expanded lungs on follow-up chest X-rays. There was no recurrence of empyema thoracis in any of the patients discharged. None has clinically significant restrictive disease and functional limitation.

Discussion

Bacteriological profile of empyema

Table 2: Treatment details and surgical decortication.

Variable	Median (range)
Duration from start of symptoms to hospital admission, day(s)	4.8 (1-8)
Duration from hospital admission to surgical referral, day(s)	8.8 (4-16)
Duration from surgical referral to surgical intervention, day(s)	2.2 (1-4)
Duration of chest tube post operatively, day(s)	3.8 (1-7)
Duration of PICU stay post operatively, day(s)	3.3 (2-5)
Total duration of hospital admission	
Duration from hospital admission to surgery, day(s)	9.8 (5-18)
Duration from surgery to discharge, day(s)	6.2 (4-10)
Complication, no. (%)	1 (3)
Mortality, no. (%)	0 (0)

Pleural fluid culture positivity was lower in this study compared to the studies by Suresh, et al. and Baranwal, et al. (37% *vs*. 40% *vs.* 48% respectively) [3,5]. This could be due to a higher number of children receiving parenteral antibiotics and early administration of antibiotics. Late referral was another possibility of lower culture yield. More recent studies show a wider range of pleural fluid culture positivity rate of 17-40% [5].

Of the positive pleural fluid culture, the most common organism isolated was *Streptococcus pneumoniae* which is a major cause of pneumonia, a finding similar to the studies by WHO and Krenke, et al. [4,8,9]. *Streptococcus pneumoniae* might not be the most common cause of pneumonia in children. But it is the most common cause of pneumonia complicated with effusion and empyema [9,10]. This is in contrast to studies done by Surest, et al. and Baranwal, et al. which showed Staphylococcus aureus as the most common pathogen isolated, followed by *S. pneumoniae*. Goyal, et al. also showed a similar finding [11]. Although the data on aetiology of empyema thoracis in children vary in different countries, *S. pneumoniae* has been reported as a leading pathogen. This wide variation in different countries might be due to the mandatory vaccination policy or the availability of vaccine, with other issues such as malnutrition and low social-economic status.

Non-surgical management of empyema

Antibiotics were prescribed routinely for children presented with parapneumonic effusion and empyema thoracis. Anti-microbial therapy should be initiated empirically for these patients, and adjusted accordingly to culture and sensitivity results. Duration of antibiotic therapy depends on types of pathogen isolated, the clinical and laboratory response to therapy, and progression to complication such as empyema. However, the optimal duration of antibiotics remains debatable [1]. Intercostal drainage tube (ICDT) insertion is the cornerstone in managing Stage 1 empyema, to allow for lung re-expansion, and prevent the formation of thickened pleural and progression of disease. Many studies described the successful resolution of symptoms with radiological improvement with conservative management alone, particularly in uncomplicated and early empyema thoracis (stage 1) [3,5]. Baranwal, et al. reported successful treatment with antibiotics and pleural space drainage in 78% of patients, and Suresh, et al. reported a success rate of ICDT as high as 60-100%. Numerous studies also documented the role of intrapleural fibrinolytics to increase drainage in multiloculated effusion and stage 2 empyema [12,13].

Uncomplicated free-flowing parapneumonic effusion may resolve without surgical intervention. However, surgical literature supports the use of thoracotomy and decortication to remove the thick pleural peel if the children do not respond promptly to non-surgical treatment. Length of stay and long term morbidity are reduced by this aggressive approach. Nonetheless, the management of such advanced empyema remains controversial, particularly in terms of indications for and timing of surgery, and the uncertainty as to how long the duration of the trial of non-surgical intervention should be done. All these considerations inadvertently lead to delay in surgical referral, often result in progression of disease and worsening of empyema with subsequent increase in morbidity and mortality which we frequently observed today. Randomized trials of chest tube drainage with fibrinolytics versus surgical therapy need to be undertaken to fully assess the clinical outcomes in more complicated patients, particularly in stage 2 empyema.

Role of surgery

As mentioned above, numerous studies have shown that antibiotics and intercostal chest tube drainage are the keystones in managing stage 1 empyema, supported by clinical and experimental experience. However, the most appropriate treatment for stage 2 and 3 disease is more ambiguous without a definitive and elaborated treatment details. To date, there are still lack of controlled trials and studies ventured in this area to compare the merit of each therapy. As a result, each institution often practises and manages patients based on the available expertise and resources locally.

Several studies have been done to justify the effectiveness and outcomes of surgical approach in managing empyema thoracis in children. Some authors recommend an aggressive surgical approach, whereas some are more conservative [14,15]. Some literatures suggested that surgical approach only reserved for those with persistent pleural sepsis and persistent pleural collection despite antibiotics and ICDT insertion and/or intrapleural fibrinolysis, as well as organizing empyema (stage 3 empyema) [5,6]. In contrary, some studies propose surgical intervention as a first line treatment before tube thoracostomy [16,17].

We favour the early surgical decortication in children with stage 2 and 3 empyema, similar to a Turkish study of 79 cases by Gun, et al. which showed a quick resolution of symptoms after decortication [18]. A study from Liverpool of 47 children also showed a positive shift in management towards early thoracotomy due to prompt symptomatic recovery [19]. Alexious, et al. reported the benefit of earlier and timely surgical consultation for advanced empyema [20]. Several retrospective studies showed higher complications, longer hospital stay, more procedures and radiographs in delayed referral for surgery [11,21]. No complications were observed in other studies as well [22,23].

As a tertiary specialist cardiothoracic surgical centre, we are often the receiving end of the referral and treatment chain, accepting children who had failed trial of non-surgical management of empyema. In our

experience, patients with stage 2-3 empyema usually presented to hospital early in the course of the disease due to the severity of the symptoms. However, patients do not get referred to the surgeon promptly at an early stage. This inadvertently resulted in progression of disease into more advanced empyema, making surgical decortication extremely difficult and technically challenging. Majority of the patients attending to our centre are in this stage of disease, with massive debris, multi-loculation and thick pleural peel encasing the lung. Fibroblastic invasion usually starts after 2 weeks of disease, causing adherent and thickened pleural cortex [15]. Thereafter it will progress into organizing phase if untreated, making surgical decortication mandatory. A study conducted in Switzerland had similar observation, with increased number of failed thoracoscopic surgery and conversion to thoracotomy decortication in delayed presentation [24]. Undoubtedly surgical intervention in organizing phase (stage 3) poses a greater technical difficulty with higher morbidity compared to surgery in fibroblastic phase (stage 2).

In our settings, reasons for this delay include: Extended duration of trial of parenteral antibiotics and pleural fluid drainage, administration of intrapleural fibrinolysis, as well as optimization of comorbidities and associated conditions such as acute kidney injury requiring dialysis and meningitis. These children are usually referred with advanced and severe empyema with variable duration, who are frequently very sick with multiple comorbidities and multi organ involvement. Nevertheless, our study has shown good outcomes with thoracotomy decortication, even in those with severe advanced disease and multiple comorbidities. Indeed, our study is comparable to a meta-analysis by Avansino, et al. in term of in-hospital mortality rate (0% *vs.* 0%), re-intervention rate (0% *vs.* 2.5%), length of stay (6.2 *vs.* 10.8 days), duration of thoracostomy (3.8 *vs.* 4.4 days) [25]. This meta-analysis also described greater outcomes in patient who underwent primary operative therapy compared to patients who underwent non-operate therapy [25].

Video assisted thoracoscopic surgery (VATS) vs. thoracotomy decortication

Recent studies have shown the superiority of VATS over conventional thoracotomy in managing empyema in children. Fuller, et al. describes the role of early use of VATS decreases the number of procedures and duration of chest tube drainage with reduced pain and hospital stay, less morbidity and better cosmesis compared to thoracotomy [26]. However, studies done in tertiary referral centre in Scotland showed high rate of conversion from thoracoscopic surgery to formal thoracotomy in empyema. Thoracoscopic surgery may be a superior method to remove pus but this approach may not always be the ideal modality to facilitate the complete expansion of the lung by removing visceral pleural peel due to the thickness of the peel, a finding similar to Shah, et al. [23] In our opinion, bleeding due to adhesiolysis in delayed stage is common which can significantly affect visibility in endoscopic view resulting in subsequent conversion to open thoracotomy. Furthermore, compared to VATS, time to apyrexia, duration of chest drainage and hospital stay appear to be more favourable after thoracotomy in a recent report from Newcastle, UK [27]. We may conclude that thoracoscopic approach for paediatric empyema has led to variable outcomes that may reflect the differences in disease severity of the children.

In our tertiary referral centre in a developing country with high number of patients and disease burden, VATS surgery is often not accessible due to limited resources and thus we often adopted a limited thoracotomy approach rather than conventional thoracotomy which has wider incision. A 3 cm to 4 cm incision is usually adopted for such limited thoracotomy. Nevertheless, this study shows evidence that performing limited thoracotomy in these children with advanced and severe empyema has a low morbidity rate with prompt resolution of symptoms and provide clinically and radiologically improvement.

Conclusion

In conclusion, surgical decortication remains an excellent modality in managing stage 2-3 paediatric empyema. We emphasize on timely and promptly referral of these patients to regional cardiothoracic surgical centre for assessment and evaluation. Delayed referrals may result in a more protracted clinical course, with higher morbidity and hospital stay. Alternative strategies may be considered, especially in early stage 2 disease. However, neither fibrinolysis nor pleural drainage alone can achieve more rapid resolution at lower risk, comparable to the benchmark set by results achieved with surgical decortication. We showed that open thoracotomy carries low morbidity and provides rapid resolution of symptoms with good clinical outcomes and shorter hospital stay if it was done promptly. Nevertheless, this study shows that surgery provides considerably positive clinical outcomes even in severe and advanced disease.

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