

Drainage Volume as an Indicator for Surgery in Pediatric Empyema

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Abstract

Purpose: Empyema has a high prevalence in children, with a mortality rate of 10% - 27%. Accurate staging of the exudative, fibrinopurulent, and organizing phases is crucial for effective treatment. This study aimed to improve the pre-operative staging of empyema to enhance treatment outcomes. **Methods:** Pediatric patients with empyema who were initially treated with tube thoracostomy between January 2014 and December 2023 were retrospectively analyzed. The primary outcome was the comparison of drainage volume on the first day (DV1st) between the tube thoracostomy and surgical conversion groups. The secondary outcome was the comparison of the DV1st-to-body weight ratio (DV1st/BW) between the two groups. **Results:** A total of 31 patients were treated, with 15 undergoing initial tube thoracostomy. The tube thoracostomy group had a significantly higher median DV1st (155.5 mL) than that of the surgical conversion group (20.0 mL, $p = 0.04$). The receiver operating characteristic curve analysis identified DV1st and DV1st/BW cutoffs of 20 mL and 6.90 (area under the curve = 0.84 for both), indicating that higher initial drainage volumes may predict successful non-surgical treatment. **Conclusion:** DV1st and DV1st/BW may be effective indicators for determining the need for surgical intervention, potentially enabling earlier and more accurate treatment decisions.

Keywords

Drainage Volume, Empyema, Indication for Surgery, Tube Thoracostomy

1. Introduction

Empyema, which often results from pneumonia, is particularly prevalent in pedi-

atric patients and is associated with a high mortality rate of 10% - 27%, necessitating appropriate treatment strategies [1] [2]. This progressive disease is categorized into three stages: the exudative phase (Stage 1), the fibrinopurulent phase (Stage 2), and the organizing phase (Stage 3). Stage 1, the early exudative phase, is characterized by the accumulation of thin reactive fluid and a few cells in the pleural space. Stage 2, the fibrinopurulent phase, involves large numbers of white blood cells and fibrin deposition, leading to the formation of loculations. Stage 3, the organizing phase, is marked by the development of a thick fibrinous peel that encases the lung and restricts its mobility [3]-[7]. Effective treatment depends on the accurate identification of the disease stage, underscoring the importance of precise staging in empyema management.

Current guidelines recommend video-assisted thoracoscopic surgery as initial treatment from Stage 2 onward [3]. However, stage classification primarily depends on the condition of the pleural cavity. Although it is often estimated by the number of days since onset, disease progression rates differ among individuals due to differences in local disease activity, rendering accurate preoperative staging challenging [6] [7].

Ozel *et al.* reported that 89.6% of pediatric empyema cases can be managed conservatively, such as with drainage [8]. Paraskakis *et al.* recommend tube thoracostomy as an initial approach in children, with surgical intervention reserved for cases that show no improvement after 1 week [4]. Thus, tube thoracostomy is often chosen for pediatric empyema. The aforementioned guidelines recommend a tube thoracostomy for Stage 1 empyema [3] because this stage is believed to have minimal fibrosis progression, enhancing the effectiveness of drainage. As such, we hypothesized that on this basis, effective drainage might indicate Stage 1 empyema, whereas ineffective drainage may correspond with Stage 2 or 3 disease, which is an indication for surgery. In addition, minimizing delays associated with decision-making for surgery may lead to a shorter hospital stay and treatment period. Therefore, the objective of this study was to investigate whether drainage volume on the first day (DV1st) can help indicate the treatment effect of drainage.

2. Methods

2.1. Study Design and Setting

This case-control study was conducted at a single institution between January 2014 and December 2023 and conformed to the STROBE reporting guidelines [9]. Data were retrospectively collected from medical records.

2.2. Inclusion and Exclusion Criteria

This study included pediatric patients with a diagnosis of empyema who were initially treated with tube thoracostomy. Empyema was defined as the presence of pus-containing drainage fluid from tube thoracostomy. Patients with serous effusions, those diagnosed with empyema based on imaging but initially treated solely with antibiotics, and those who underwent surgery as the initial treatment were

excluded.

2.3. Variables and Measurements

Data on preoperative patient characteristics (age, sex, and BW); duration from symptom onset to presentation; serum leukocyte count, serum C-reactive protein (CRP) level, and oxygen dose at presentation; size of the inserted drain; presence of septa in the chest cavity on ultrasound; presence of air in the abscess on computed tomography (CT); DV1st; and hospitalization duration were collected.

The primary outcome was the comparison of DV1st between the tube thoracostomy and surgical conversion groups. The secondary outcome was a comparison of the DV1st/BW ratio between the two groups.

2.4. Statistical Analysis

Statistical analyses were performed using EZR software (version 1.67) [10]. Descriptive statistics were calculated for all variables. The Mann-Whitney *U* test was used to compare the outcomes, as both datasets were non-normally distributed according to the Shapiro-Wilk normality test. Statistical significance was set at $p < 0.05$. Receiver operating characteristic (ROC) curve analyses were conducted to determine the area under the curve (AUC) and establish optimal cutoff values.

2.5. Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board of Saitama Prefectural Children's Medical Center. Informed consent was obtained from the parents or guardians of all participants. Data confidentiality was maintained in accordance with institutional guidelines and regulations.

3. Results

A total of 31 patients were hospitalized and treated for empyema between January 2014 and December 2023, of whom 15 underwent tube thoracostomy as the initial treatment. The other 16 patients were excluded from the study because they were initially treated with antibiotics alone. All patients who chose only antibiotics for initial treatment did not undergo tube thoracostomy because there was only a small amount of abscess accumulation, and there was no safe drainage space. None of the patients chose surgery as the initial treatment. In the end, 10 patients were able to complete treatment with only a tube thoracostomy, and 5 patients were converted to surgery (**Figure 1**). There were no clear criteria for conversion to surgery; instead, surgery was performed in cases judged to be treatment-refractory based on a comprehensive assessment of various findings, including physical examination, blood test results, and imaging findings.

3.1. Patients

The patient characteristics are summarized in **Table 1**. The groups did not differ significantly in terms of demographics (age, sex, BW), leukocyte count, serum

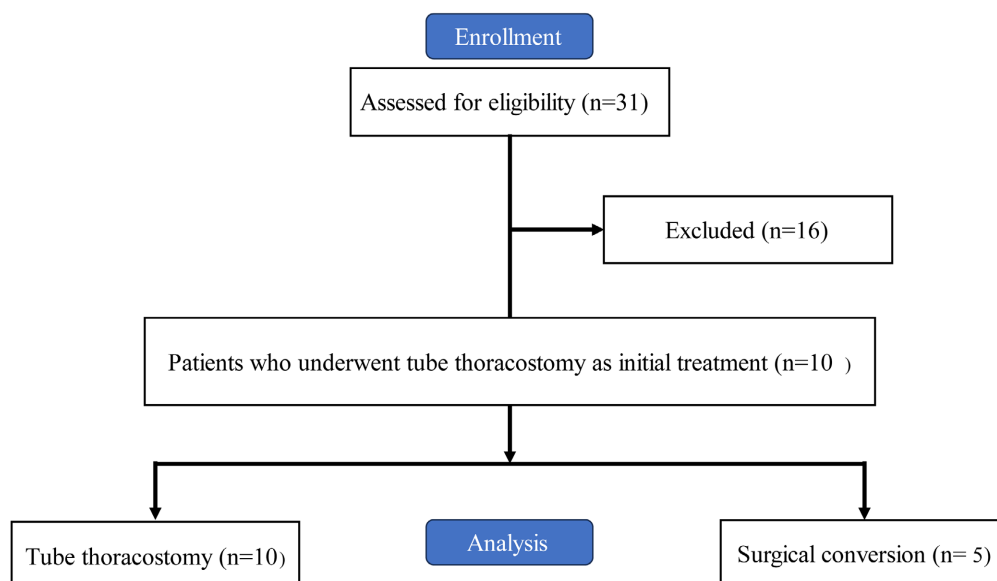


Figure 1. Flowchart of patient selection for this study.

Table 1. Patient characteristics.

	Tube thoracostomy n = 10	Surgical conversion n = 5	<i>p</i> -value
Age, years; Median (IQR)	7 (2 - 24)	8 (0 - 27)	0.854*
Sex; N (%)			0.251†
Female	2 (20)	3 (60)	
Male	8 (80)	2 (40)	
Body weight, kg; Median (IQR)	19.2 (11.7 - 64.3)	22.4 (2.9 - 33.1)	0.759*
Duration until presentation after symptoms, days; Median (IQR)	7 (2 - 30)	15 (6 - 30)	0.354*
Serum leukocytes count at presentation, / μ L; Median (IQR)	20780 (13,500 - 30,200)	17800 (12,800 - 32,690)	0.462*
Serum C-reactive protein level at presentation, mg/dL; Median (IQR)	21.7 (5.4 - 45.9)	13.4 (2.2 - 25.7)	0.462*
Oxygen dose at presentation, L; Median (IQR)	3.0 (0.0 - 8.0)	3.0 (0.0 - 5.0)	0.950*
Size of inserted drain, Fr; Median (IQR)	11.0 (8.0 - 24.0)	10.0 (3.5 - 16.0)	0.619*
Presence of septum in the chest cavity on ultrasound; N (%)	7 (70)	4 (80)	1.000†
Presence of air in the abscess on CT; N (%)	2 (20)	3 (60)	0.251†

IQR: interquartile range; n: number; SD: standard deviation; *: Mann-Whitney *U* test; †: Fisher's exact test.

CRP level, or oxygen dose at presentation; size of inserted drain; presence of septum in the chest cavity on ultrasound; presence of air in the abscess on CT; or duration of hospitalization.

3.2. Outcomes

The results are shown in **Table 2**. The median DV1st was significantly larger in the tube thoracostomy group compared to that in the surgical conversion group

(155.5 mL vs. 20.0 mL, $p = 0.04$). A ROC curve was constructed to assess the relationship between sensitivity and 1-specificity for different DV1st thresholds to determine the optimal cutoff value for successful treatment with tube thoracostomy alone (Figure 2). The optimal cutoff value for DV1st was identified as 20 mL according to the Youden index, yielding an AUC of 0.84. The tube thoracostomy group had a significantly higher median DV1st/BW value than that in the surgical conversion group (7.95 mL/kg vs. 2.45 mL/kg, $p = 0.04$). The optimal cutoff for DV1st/BW was 6.90 mL/kg, with an AUC of 0.84 (Figure 2).

Table 2. Outcome data.

	Tube thoracostomy n = 10	Surgical conversion n = 5	<i>p</i> -value
DV1st, mL; Median (IQR)	155.5 (72.5 - 582.5)	20.0 (10.0 - 82.0)	0.04
DV1st/BW, mL/kg; Median (IQR)	7.95 (4.94 - 14.4)	2.48 (0.45 - 6.25)	0.04

DV1st: drainage volume on 1st day; IQR: interquartile range; n: number.

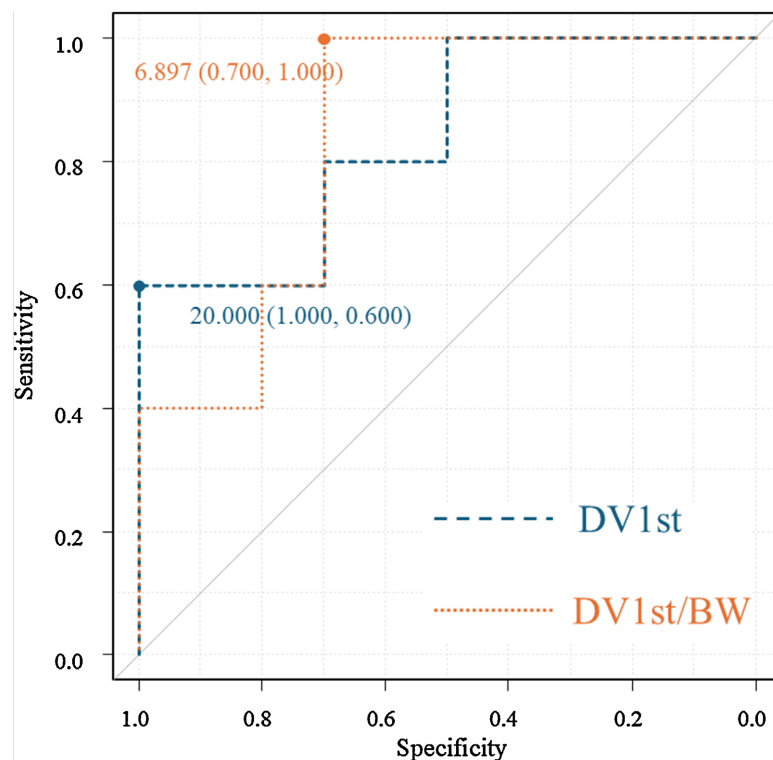


Figure 2. Receiver operating characteristic curves for surgical conversion after tube thoracostomy for empyema.

4. Discussion

The results of this study demonstrate that patients who were successfully treated with tube thoracostomy alone had a significantly larger DV1st than that of patients who required surgical conversion. The secondary outcome, DV1st/BW, was also significantly larger in the tube thoracostomy group. Furthermore, the ROC

curve analysis suggests that the likelihood of requiring surgery increases if DV1st is <20 mL or DV1st/BW is <6.90 mL/kg.

Previous studies have examined the use of preoperative tests to determine patients' suitability for surgery. Chen *et al.* compared 163 patients with empyema and found that those with a septum in the pleural cavity (83 patients) were significantly more likely to undergo surgical intervention than those without a septum (24.3% vs. 7.5%, $p = 0.004$) [11]. However, in the present study, no significant differences were found between the groups regarding the presence of a septum on ultrasound or air in the abscess on CT. To our knowledge, no reports to date have examined the relationship between drainage volume and surgical indication in empyema; however, Mowery *et al.* and Yap *et al.* have suggested the utility of drainage volume in determining surgical intervention in hemothorax and lobectomy, respectively [12] [13]. These findings support the hypothesis that drainage volume may be a reasonable factor to consider when deciding on a treatment strategy for empyema.

Nandesh *et al.* reported that early surgical intervention in pediatric patients with Stage 2 empyema can shorten hospitalization duration [14] [15]. Avansino *et al.* also found that patients who chose surgery as initial treatment showed shorter hospital stays (10.8 vs. 20.0 days), briefer antibiotic use (12.8 vs. 21.3 days), equivalent complication rates (5% vs. 5.6%), and better cost-effectiveness than those who chose tube thoracostomy [7]. Therefore, early surgical intervention may be beneficial even in children. However, tube thoracostomy also demonstrates advantages as a minimally invasive procedure. The approach used in this study will enable the determination of the need for surgical intervention at an early stage, allowing clinicians to plan and implement an appropriate treatment strategy that minimizes the duration of treatment and degree of invasiveness to the extent possible.

The strength of this study is that, to the best of our knowledge, this is the first report to show that the amount of drainage for empyema can be a factor in determining whether surgery is indicated. Secondly, it is possible to determine whether surgery is indicated at an early stage, on the first day of drainage, which could contribute to shortening the treatment period and hospital stay. Finally, in contrast to the guideline that determines the stage of empyema and the indication for surgery based on intrapleural characteristics, it is possible to determine the indication for surgery based on an objective indicator: the drainage volume. However, its limitations include its retrospective nature, small sample size, and the use of only univariate analysis. As more cases are accumulated, multivariate analysis could provide stronger evidence. Furthermore, we believe that conducting a prospective study using the DV1st and DV1st/BW cutoff values obtained in this study will further contribute to the development of evidence.

5. Conclusion

Drainage volume in empyema may be a useful factor in determining the indication

for surgery.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Reichert, M., Hecker, M., Witte, B., Bodner, J., Padberg, W., Weigand, M.A., et al. (2017) Stage-Directed Therapy of Pleural Empyema. *Langenbeck's Archives of Surgery*, **402**, 15-26. <https://doi.org/10.1007/s00423-016-1498-9>
- [2] Kercher, K.W., Attorri, R.J., Hoover, J.D. and Morton, D. (2000) Thoracoscopic Decortication as First-Line Therapy for Pediatric Parapneumonic Empyema. *Chest*, **118**, 24-27. <https://doi.org/10.1378/chest.118.1.24>
- [3] Shen, K.R., Bribiesco, A., Crabtree, T., Denlinger, C., Eby, J., Eiken, P., et al. (2017) The American Association for Thoracic Surgery Consensus Guidelines for the Management of Empyema. *The Journal of Thoracic and Cardiovascular Surgery*, **153**, e129-e146. <https://doi.org/10.1016/j.jtcvs.2017.01.030>
- [4] Paraskakis, E., Vergadi, E., Chatzimichael, A., and Bouros, D. (2012) Current Evidence for the Management of Paediatric Parapneumonic Effusions. *Curr Med Res Opin*, **28**, 1179-1192. <https://doi.org/10.1185/03007995.2012.684674>
- [5] Scarci, M., Abah, U., Solli, P., Page, A., Waller, D., van Schil, P., et al. (2015) EACTS Expert Consensus Statement for Surgical Management of Pleural Empyema. *European Journal of Cardio-Thoracic Surgery*, **48**, 642-653. <https://doi.org/10.1093/ejcts/ezv272>
- [6] Ozcelik, C., Ulku, R., Onat, S., Ozcelik, Z., Inci, I. and Satici, O. (2004) Management of Postpneumonic Empyemas in Children. *European Journal of Cardio-Thoracic Surgery*, **25**, 1072-1078. <https://doi.org/10.1016/j.ejcts.2003.12.025>
- [7] Avansino, J.R., Goldman, B., Sawin, R.S. and Flum, D.R. (2005) Primary Operative versus Nonoperative Therapy for Pediatric Empyema: A Meta-Analysis. *Pediatrics*, **115**, 1652-1659. <https://doi.org/10.1542/peds.2004-1405>
- [8] Ozel, S.K., Kazez, A., Kilic, M., Koseogullari, A.A., Yilmaz, E. and Aygun, A.D. (2004) Conservative Treatment of Postpneumonic Thoracic Empyema in Children. *Surgery Today*, **34**, 1002-1005. <https://doi.org/10.1007/s00595-004-2859-5>
- [9] von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gøtzsche, P.C., et al. (2007) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies. *Lancet*, **370**, 1453-1457. [https://doi.org/10.1016/S0140-6736\(07\)61602-X](https://doi.org/10.1016/S0140-6736(07)61602-X)
- [10] Kanda, Y. (2012) Investigation of the Freely Available Easy-to-Use Software 'EZR' for Medical Statistics. *Bone Marrow Transplantation*, **48**, 452-458. <https://doi.org/10.1038/bmt.2012.244>
- [11] Chen, K.Y., Liaw, Y.S., Wang, H.C., Luh, K.T. and Yang, P.C. (2000) Sonographic Septation: A Useful Prognostic Indicator of Acute Thoracic Empyema. *Journal of Ultrasound in Medicine*, **19**, 837-843. <https://doi.org/10.7863/jum.2000.19.12.837>
- [12] Mowery, N.T., Gunter, O.L., Collier, B.R., Diaz, J.J., Haut, E., Hildreth, A., et al. (2011)

Practice Management Guidelines for Management of Hemothorax and Occult Pneumothorax. *Journal of Trauma: Injury, Infection & Critical Care*, **70**, 510-518.

<https://doi.org/10.1097/ta.0b013e31820b5c31>

- [13] Yap, K.H., Soon, J.L., Ong, B.H. and Loh, Y.J. (2017) The Safe Volume Threshold for Chest Drain Removal Following Pulmonary Resection. *Interactive CardioVascular and Thoracic Surgery*, **25**, 822-826. <https://doi.org/10.1093/icvts/ivx161>
- [14] M., N. (2013) ICD versus VATS as Primary Treatment in Fibrinopurulent Stage of Empyema Thoracis. *Journal of Clinical and Diagnostic Research*, **7**, 2855-2858. <https://doi.org/10.7860/jcdr/2013/7228.3776>
- [15] St. Peter, S.D., Tsao, K., Harrison, C., Jackson, M.A., Spilde, T.L., Keckler, S.J., *et al.* (2009) Thoracoscopic Decortication vs Tube Thoracostomy with Fibrinolysis for Empyema in Children: A Prospective, Randomized Trial. *Journal of Pediatric Surgery*, **44**, 106-111. <https://doi.org/10.1016/j.jpedsurg.2008.10.018>