

Strategy for surgical treatment of acute thoracic empyema in adults

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Abstract: This review summarized the surgical management of empyema and treatment strategy by comparing the results of surgical and non-surgical therapies for empyema. Despite improvement in healthcare practices, mortality from pleural infection remains high. Treatment for thoracic empyema depends on its stage at diagnosis, and suggested options involve the administration of antibiotics and drainage of pleural effusion. Prevalence of patients requiring either fibrinolytic treatment into the thoracic cavity or surgical decortication was also reported. Prompt response and initial surgical treatment to empyema could reduce the severity and complications, shorten the hospital stay, and reduce medical costs.

Keywords: Acute thoracic empyema; treatment strategy; thoracoscopic surgery

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Introduction

Acute thoracic empyema is defined as active inflammation and effusion between the parietal and visceral pleural space. Despite improvement in healthcare practices, mortality from pleural infection remains high (1). Guidelines state that treatment for thoracic empyema depends on its stage at diagnosis (2-4). Suggested treatment involves the administration of antibiotics and drainage of pleural effusion (2-5).

A recent systematic review of 134 articles (totaling 227,898 patients) reported that patients with thoracic empyema had long inpatient hospital stay [median 19 days, interquartile range (IQR) 13-27 days], and the median (IQR) in hospital or 30-day mortality was 4% (1-11%, totaling 179,031 patients) (6). The prevalence of patients requiring either fibrinolytic treatment (median 31%, IQR 17-57%; 30,071 patients) or surgery (median 20%, IQR 1-32%; 37,330 patients) was also reported. Empyema should be addressed promptly. Prompt response can reduce

the severity and complications, shorten the hospital stay, and reduce medical costs (7,8).

For drainage of pleural effusion, some trials proceeded directly to surgical management if the initial pleural fluid aspirate was thick pus or there were extensive loculations on imaging (7,9,10). However, to the best of our knowledge, there is currently no clear consensus on the most effective method: primary surgical intervention versus non-surgical management.

Thus, this review aimed to introduce surgical management for empyema and reconcile the treatment strategy by comparing the results between surgical and non-surgical therapies for empyema.

Treatment strategy

Treatment of empyema includes administration of antibiotics, thoracic drainage with closed tubing thoracostomy, intrathoracic administration of fibrinolytic agents, and surgery.

The British Thoracic Society Pleural Disease Guideline 2010 indicated selecting patients for pleural fluid drainage in pleural infection (2). Patients with frankly purulent, turbid, or cloudy pleural fluid on sampling by thoracentesis should receive prompt chest tube drainage of the pleural space. The presence of organisms identified by positive Gram stain and/or culture from a non-purulent pleural fluid sampling indicates pleural infection and should lead to prompt chest tube drainage (2).

The mortality benefit from intrathoracic administration of fibrinolytic agent for empyema has not been reported; thus further study was needed to explore this effect on mortality (2,6,11-14). This procedure is a known possible cause of pneumothorax or hemothorax (15,16).

Patients who fail chest tube drainage are also additional candidates for surgical drainage. Delays in initiating surgical drainage when indicated prolongs hospital stay and worsens clinical outcome. The goals in selecting a surgery are to rapidly establish an effective pleural drainage and to promote lung re-expansion to obliterate the empyema space.

Operative indication

In surgical treatment for empyema, “drainage and dilatation of the lungs” is a basic concept. Pneumonia-induced empyema is classified into three stages according to its progression as stage I, parapneumonic effusion with exudative effusion; stage II, fibrinopurulent stage marked by fibrinopurulent effusion; and stage III, chronic organizing stage forming granulation tissue (pleural peel) (3).

Surgery is performed mainly for stages II and III and consists of aspiration of pleural effusion, destruction of the fibrin septum in the pleural cavity and single cavitation, removal of purulent pleural effusion and inflammatory substances, adequate pleural lavage, and placement of drainage tubes. In stage III, additional removal of the thickened pleura and promotion of reinflation are performed.

Patients in whom chest tube drainage was unsuccessful are also candidates for surgical intervention. Conservative treatment of empyema is challenging owing to host factors and factors determining the disease stage, which possibly cause multiplication of the empyema cavities and decreased drainage. If the pleural effusion develops in the multiple loculae of the septum, medical treatment becomes difficult. Performing drainage promptly during thoracoscopic surgery will help improve results.

Operative technique

Before surgery, chest computed tomography should be performed to obtain anatomical information about the location, size, extent of the empyema, and pleural surface thickness (17).

Video-assisted thoracic surgery (VATS)

VATS, which is currently popular (18), consists of evacuation by suction, disruption of fibrous pleural septations and peeling off adhesions until the empyema cavity becomes a single space. Chest tubes were inserted at the end of the procedure through separate incisions for thoraco-ports. The advantages of VATS are visualization of the entire thoracic cavity, removal of the purulent pleura, and accurate placement of the thoracic drain with less surgical trauma, improved postoperative pain control, less respiratory compromise and reduction in postoperative complications including 30-day mortality.

However, despite effective placement of drainage tubes, improvement of empyema cannot be achieved if the drain is obstructed. In the past, we have used porous 24–32 Fr tubes; however, they drain pus only through their tips, which should be washed to clear the blockage when occluded. Recently, a drain has been developed with a drainage hole at the tip and a longitudinal groove at the side; this has the advantages of both drains and is useful for drainage of empyema. It is made of silicone and is soft; further, drainage of empyema may have a longer indwelling period, which may reduce pain.

We placed the aforementioned drainage tube on the dorsal side and on the diaphragm (near the pulmonary ligament) at the time of thoracoscopic surgery and another drain on the ventral side in cases with extensive empyema.

Open thoracotomy (OT) approach

In the OT approach, decortication removes fibrous tissue and peels from the parietal and visceral pleura and pus from the pleural cavity (19). Theoretically, complete decortication can improve intrathoracic infection and expand the lungs. However, it should not be performed solely to remove pleural thickening because pleural thickening disappears spontaneously over several months (20,21). In a previous study, improving the numerical value of the respiratory function at discharge and at 6 months had no significant effect on patients with or without residual pleural thickening, although pleural thickening markedly reduced with regard to time at discharge and 6 months (21).

Outcome of surgical treatment for empyema

Surgical treatment versus non-surgical treatment for empyema

Recently, three studies using observational large-scale databases also revealed the actual clinical aspects of empyema treatment (*Table 1*) (22–24).

Of the 17,533 patients treated for empyema in North America from 1987 to 2014 and in Canada from 1996 to 2015, 8,097 (VATS 4585 and OT 3512) in the surgical treatment group and 9436 in the non-surgical treatment group were retrospectively examined for treatment results. The average age of patients was significantly higher in the non-surgical treatment group (61–62 years) than in the surgery group (53–56 years) ($P < 0.001$). The initial treatment success rate was 85% for VATS, 73% for OT, and 59% for non-surgical treatment. The mortality rate was 6–14% for VATS, 8–20% for OT, and 21–32% for non-surgical treatment ($P < 0.001$). The relapse rate of empyema was 4% for VATS, 3–6% for OT, and 5–9% for non-operative treatment.

These studies demonstrated that the surgery group has higher the initial treatment success rate and mortality rate than the non-surgical treatment group although there was age difference and some degree of selection bias. By reducing the burden of patients from surgery and anesthesia, if early surgical intervention can be added to patients who had to be limited to non-surgical treatment, improvement of treatment results for empyema might be expected.

Surgery versus non-surgical treatment in randomized control trials (RCTs)

There were four RCTs of treatment in stage II/III empyema comparing initial VATS or OT versus chest tube drainage with or without fibrinolytic agents on a total of 208 patients (*Table 2*) (7,9,10,25).

The treatment success rate was 83–98% for surgery and 44–86% for non-surgical treatment. The mean duration of postoperative hospital stay was 8–12 days and 13–17 days in the surgery and non-surgery groups. The mortality rate was 2–9% in the surgery group and 3–11% in the non-surgery group.

Results of RCTs showed that initial surgical treatment had significantly better outcomes in primary treatment success rate and length of hospital stay than non-surgical treatment in stage II/III empyema, although RCTs were limited by the small sample size, with 20–78 cases. No

significant difference was found in the mortality rate between the two groups because patients who suffered from treatment failure after the chest tube drainage were subsequently treated by surgical drainage and had successful resolution of their empyema.

Outcomes of VATS and open thoracic surgery for empyema

Expert clinical opinion recommends that VATS should be the first line approach (4). Experts mentioned that VATS and OT are logically parallel.

Two prospective and seven retrospective studies of surgical treatment for stage II and III empyema involved a total of 1,954 patients. VATS and decortication by OT were performed on 1,087 (56%) and 867 (44%) patients, respectively (*Table 3*) (26–34). The treatment success rate was between 38% and 100% for VATS and 89% and 100% for OT. VATS had shorter operation time (64–153 *vs.* 137–228 min), and shorter postoperative hospital stay (5–16 *vs.* 7–21 days) than OT. The morbidity rate of treatments was 0–52% for VATS and 0–57% for OT, and mortality rate was 0–10% for VATS and 0–16% for OT. The relapse rate of empyema was 0–5% for VATS and 3–12% for OT.

Compared with OT, VATS for stage II/III empyema could reduce the operative time and length of hospital stay without compromising the primary treatment success rate and complications and mortality after surgery. Initial VATS therapy was indicated not to be inferior to OT and might be tried as an initial surgical intervention for thoracic empyema.

Discussion

Dr. Satoshi Shiono: What kind of devices do you use for VATS surgery for acute empyema?

Answer: The surgical procedure for acute empyema was performed using a 1-cm flexible thoracoscope and Pulsavac Plus (Zimmer Biomet G.K., Tokyo, Japan) (*Figure 1*). The entrapped or septational purulent pleural effusion is curetted and dissected using a grasping forceps of a general thoracoscopic surgical instrument and a cotton swab called the Naruke-type Thoraco-cotton (KENZMEDICO CO., LTD., Saitama, Japan) (*Figure 2*). After removing the purulent material and decortication, a device called the Pulsavac was used to wash the thoracic cavity with 10 L of normal saline (*Figure 1*). Pulse lavage can be performed in the thoracic cavity using this device; cleaning the thoracic cavity was difficult using conventional techniques. Soft

Table 1 Characteristics of adult patients in retrospective population-based cohort studies of thoracic empyema

Study	Year	Study period	Region, country	Stage of empyema	Number of patients	Procedure, number of patients [%]	Age, year [IQR]	Time to intervention, days [IQR]	Single-procedure treatment success [%]	Initial treatment success [%]	Length of hospital stay, days [IQR]	30-day mortality [%]	Total mortality [%]	Readmission for empyema [%]	90-day re-intervention [%]	
Farjah (22)	2007	1987–2004	Washington, USA	Stage 2/3	4,424	OP 2,281 [52]	53±18	NA	NA	NA	16±13	123 [5]	NA	68 [3]	NA	
						Non-OP 2,143 [48]	62±19									
							P<0.001									
Semenkovich (23)	2018	2009–2014	New York, USA	Stage 2/3	4,095	VATS 1,313 [32]	56 [45–69]	3 [1–5]	415 [55]	648 [85]	12 [9–19]	71 [5]	83 [6]	55 [4]	37 [3]	
						Open 1,219 [30]	57 [47–69]	3 [1–5]	322 [58]	404 [73]	15 [10–21]	83 [7]	91 [8]	63 [6]	45 [4]	
						CT ± FL 1,563 [38]	64 [52–79]	2 [1–5]	1,030 [37]	1,633 [59]	14 [9–22]	286 [18]	322 [21]*	113 [9]	113 [9]	
			P<0.001	P<0.001												
Nayak (24)	2019	1996–2015	Ontario, Canada	Stage 2/3	9,014	VATS 991 [32]	56±16	NA	NA	NA	16	35 [3]	144 [14]	40 [4]	NA	
						Open 2,293 [30]	56±16									
						CT±FL 5,730 [38]	61±17									

*, in 90-day mortality; **, in 1-year mortality. CT, chest tube; FL, fibrinolytics; IQR, interquartile range; NA, not available; Non-OP, nonoperative treatment; OP, operative treatment; VATS, video-assisted thoracoscopic surgery.

Table 2 Characteristics of patients in randomized controlled trials comparing surgical and medical therapy

Study	Year	Stage of empyema	Number of patients	Procedure, number of patients [%]	Age, year [range]	Anesthesia, number of patients [%]	Duration of tube drainage, days	Number of tubes	Length of hospital stay, days [range]	Primary treatment success [%]	Mortality [%]	Complication [%]	Detail of complication	Costs [USD]
Wait (7)	1997	Stage 2/3	20	VATS 11 [55]	42±20	General anesthesia	6±1	2±0	9±1	10 [91]	1 [9]	0	Diaphragm damage by CT	16,642±2,841
				CT+FL 9 [45]	43±13		10±1	2±1	13±1	4 [44]	1 [11]	1 [11]		24,052±3,466
							P=0.03	P=0.009	P=0.009	P=0.05	P=0.009	P=0.009		
Bilgin (9)	2006	Stage 2/3	70	VATS 35 [50]	48 [29–68]	Local anesthesia +sedation 29 [83]	NA	NA	8 [7–11]	29 [83]	0	1 [3]	Bronchopleural fistula	NA
				CT + FL 35 [50]	47 [41–69]	General anesthesia 6 [17]			13 [10–18]	22 [63]	1 [3]	1 [3]		
									P<0.05	P<0.05				
Bagheri (25)	2013	Stage 2/3	40*	VATS 20 [50]	51 [17–72]	NA	NA	NA	21±3**	18 [90]	0	2 [1]	Intraoperative bleeding, wound infection, atelectasis	NA
				CT 20 [50]	54 [22–65]				45±3	12 [60]	0	1 [1]		
									P=0.001	P=0.028				
Ahmed (10)	2016	Stage 2/3	78	OT 43 [55]	56±9	NA	NA	2	12±2	42 [98]	1 [2]	NA	NA	NA
				CT + FL 35 [45]	56±8									
									P<0.001	P=0.04	P=0.43			

*, randomization after 2 weeks with administration antibiotics; **, hospital stay from the day that empyema was diagnosed. CT, chest tube; FL, fibrinolytics; NA, not available; OT, open thoracotomy; VATS, video-assisted thoracoscopic surgery.

Table 3 Characteristics of patients in prospective studies analyzing surgical treatment

Study	Year	Study design	Stage of empyema	Number of patients	Procedure, number of patients	Age, year [range]	Operative time, min [range]	Tube drainage, days [range]	Length of postoperative hospital stay, day	Primary treatment success [%]	Conversion [%]	Mortality [%]	Morbidity [%]	Recurrence of empyema [%]
Chan (26)	2007	Prospective	Stage 2/3	77	VATS 41 Open 36	46±15 49±16	150±58 228±84	8±6 9±4	16±7 21±14	41 [100] 36 [100]	0	0	9 [22] 8 [22]	NA
Muhammad (27)	2012	Prospective	Stage 2/3	49	VATS 25	NA	85±24	6±3	8±5	23 [92]	2 [8]	0	0	NA
Angelillo (28)	1996	Retrospective	Stage 2/3	64	Open 24 VATS 31 Open 33	49±18 51±18	137±27 NA	7±2 4+2 6±2	9±3 7±3 [2-16] 12±9 [3-54]	24 [100] NA	0 NA	0 1 [3] 1 [3]	0 5 [16] 5 [15]	0 4 [12]
Roberts (29)	2003	Retrospective	Stage 2/3	172	VATS 66 Open 106	53 54	NA	11	15	66 [38] 103 [97]	106 [62]	0	6 [9] 22 [21]	5 [3] NS
Luh (30)	2005	Retrospective	Stage 2/3	234	VATS 194 Open 40*	49±6 52±12	64±23 NA	7 [2-65] NA	7±3 [2-42] 20±12 [9-158]	202 [86]	24 [10]	4 [2]	11 [6] 8 [20]	NA
Lardinois (31)	2005	Retrospective	Stage 2/3	328	VATS 178 Open 150	NA	NA	NA	NA	99 [56] 146 [97]	79 [44]	5 [3] 6 [4]	30 [9] NA	4 [2] 4 [3]
Tong (32)	2010	Retrospective	Stage 2/3	420	VATS 326 Open 94	55±17 53±17	97 155	4 6	7 10	300 [92] 84 [89]	37 [11]	24 [8] 14 [16]	NA	NA
Marks (33)	2012	Retrospective	Stage 2/3	393	VATS 116 Open 277	53 [37-69]	NA	NA	5 [4-9]	374 [95]	17 [15]	22 [6]	98 [25]	NA
Reichert (34)	2018	Retrospective	Stage 3	217	VATS 110 Open 107	61±16 54±16	153±68 172±71	7±4 7±3	10 [3-230] 12 [2-193]	95 [86] 97 [91]	5 [5]	10 [10] 7 [7]	55 [52] 61 [57]	5 [5] 3 [3]

* , open conversion 24+ reoperation 16. NA, not available; NS, not significant; VATS, video-assisted thoracoscopic surgery.

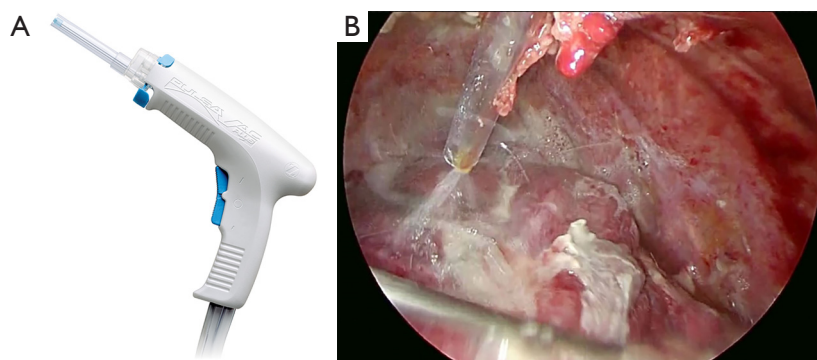


Figure 1 Pulsavac Plus™ (Zimmer Biomet G.K., Tokyo, Japan). (A) Washing device with pulsation to allow for debridement and suction in the thoracic cavity. The tip of the device is 9 mm in size; (B) Pulsavac Plus™ was used for pulse lavage in the purulent thoracic cavity. The lung coated with purulent content was washed with gentle water pressure, and the bony thorax can be washed with powerful water pressure; therefore, the purulent tissue can be removed quickly and efficiently.



Figure 2 Naruke-type Thoraco-cotton™ (KENZMEDICO CO., LTD., Saitama, Japan). Cotton stick for the dissection of the tissue and structures in the thorax.

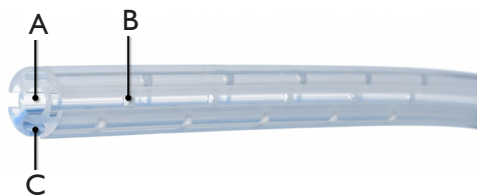


Figure 3 Smart Coaxial Drain (REDAX®, SENKO MEDICAL INSTRUMENT Mfg. CO., LTD., Tokyo Japan). (A) Inner lumen; (B) small pores at the tube tip, 20 holes in total; (C) outer slit.

organs, such as the lung, mediastinum or diaphragm can be washed with gentle water pressure, and the bony thorax can be washed with powerful water pressure; therefore, the purulent tissue can be removed quickly and efficiently.

Dr. Satoshi Shiono: When do you remove the chest tubes after surgery?

Answer: The chest drain can be removed after radiological confirmation of successful pleural drainage, that is, on observing a decrease in the size of the pleural collection on the chest radiograph or computed tomography and obtaining objective evidence of infectious resolution, negativity of the pleural effusion culture for bacteria, and decreasing levels of inflammatory markers (e.g., white

blood cell count and C-reactive protein levels). Patients are observed for 24 h after drain removal is routinely performed.

Dr. Satoshi Shiono: Could you show us the picture of the chest tube which you recently use?

Answer: Yes, I could. I have shown the Smart Coaxial Drain (REDAX®, SENKO MEDICAL INSTRUMENT Mfg. CO., LTD., Tokyo Japan) in *Figure 3*. The drain has a drainage hole at the tip and a longitudinal groove on the side.

Conclusions

With the surgical treatment of complicated parapneumonic effusions and empyema, the treatment period will be shortened and medical cost will be reduced. However, there are only small studies of immediate surgical treatment versus chest tube drainage with fibrinolytics at the start of empyema treatment, but RCTs with increased number of cases are needed to draw definite conclusion.

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Footnote

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