Thoracic Empyemas Necessitating Surgical Management: CT Criteria

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Introduction

Thoracic empyemas are usually classified into 3 stages (1-4). Stage 1 empyemas are exudative, characterized by thin pleural fluid with a low white blood cell count. Stage 2 empyemas are fibrinopurulent, characterized by thicker, more turbid fluid with the appearance of fibrin on the pleural surfaces that begins to form a peel around the lung. Stage 2 empyemas are chronic, characterized by a thickened pleural peel with infiltration of the fibroblasts, entrapment of the lung, and restriction of lung motion.

Patients with stage 1 empyemas are usually treated with antibiotics alone, while patients with stage 2 empyemas can be managed with thoracentesis, percutaneous catheter drainage (PCD), or tube thoracostomy (1,4). Multiloculation of empyemas, usually formed during the late period of stage 2 when fibrin is deposited on the pleural surface, is a major cause of failure of closed drainage including PCD and tube thoracostomy. In our previous study, we suggest that multiloculated empyemas can be treated with intracavitary instillation of urokinase using PCD (5). Surgery, including decortication and open drainage with a large-bore chest tube or flap procedure (Eloesser method), has been regarded as the treatment of choice for chronic empyemas (6-9).

Clinically it is regarded that it takes 6 to 12 weeks for a pleural peel to become dense scar tissue after the onset of empyema symptoms (6-9), but the exact timing of this evolution of dense scar tissue in stage 3 empyemas is difficult.

Computed tomography (CT) is well suited for differential diagnosis of a pleural disease and for differentiation between empyema and peripheral lung abscess (10,11), but to our knowledge, accurate identification of chronic empyemas is not yet possible even with advanced imaging techniques including CT, and there has been no CT criteria of surgery for empyemas. In this study, we tried to find out the possible CT criteria of surgical management for thoracic empyemas by analyzing the CT findings of empyemas managed with multiple treatment modalities.

Materials and Methods

Between January 1989 and December 1990, 33 patients with loculated thoracic empyemas were treated with various modalities including multiple needle thoracentesis (n=3), tube thoracostomy (n=3), PCD (n=6), intracavitary urokinase instillation
through either PCD (n=11) or tube thoracostomy (n=2), decortication (n=7), and open drainage with flap procedure (n=1). They were 24 men and 9 women ranging in age from 7 to 76 years (average: 52). Thirty-two patients had parapneumonic empyemas and 1 had posttraumatic empyema. Patients with tuberculous pleural effusion or chronic tuberculous empyemas were excluded in this study. All the patients met the criteria of empyemas according to biochemical, microbiological, and clinical studies.

**Grouping of the patients**

These patients were classified into 3 groups: Group I (N = 12) included the patients treated by multiple thoracentesis, tube thoracostomy, or PCD; Group II (N = 13) the patients treated by intracavitary urokinase instillation through either PCD or tube thoracostomy; and group III (N = 8) the patients treated by surgery due to treatment failure with modalities of groups I and II.

In the Group II patients, 100,000 units of urokinase in 100cc of 5% D/W were instilled into the pleural cavity in each instillation either through PCD or tube thoracostomy. Then the empyema was drained by connecting the catheter or the tube to the water seal suction of negative pressure of 20cm H2O after overnight clamping. Irrigation of the catheter or the tube was done 2 to 3 times a day with 30-50ml of normal saline in each irrigation. Instillation was repeated until complete drainage of the empyema. The total amount of instilled urokinase ranged from 100,000 to 700,000 units (average: 333,000 units) case by case. PCD was done under fluoroscopic guidance because the empyema cavities were large. An 8-Fr catheter (Medi-tech®, Watertown, MA) was inserted into the empyema cavities in all patients. There were no complications during or after instillation of urokinase in all the patients.

Among the 8 patients of Group III, 4 were treated with decortication due to failure of tube thoracostomy and 3 due to failure of urokinase instillation through PCD or tube thoracostomy. The one remaining patient was treated with open drainage using the flap procedure. In 3 patients of Group III who had decortication due to failure of intracavitary urokinase instillation, 700,000 units of urokinase was instilled into the empyema cavity only to fail to dissolve the pleural peels and to reexpand the entrapped lung.

The stage of empyemas in each group was determined by biochemical, microbiological, and clinical studies. Group I contained 3 stage 1 (pH > 7.2, Glucose > 40mg/dL, and sterile exudate with increased polymorphonuclear leukocyte), 2 early stage 2 (7.0 < pH < 7.2, Glucose > 40mg/dL, infected empyema microbiologically), and 7 late stage 2 (pH < 7.0, Glucose < 40 mg/dL) empyemas. Group II contained 1 stage 1, 5 early stage 2, and 7 late stage 2 empyemas. Group III contained 2 late stage 2 and 6 stage 3 empyemas. Patients were regarded as having stage 3 empyemas on clinical base when the patients had a history of pleurisy for more than 6 weeks and met the criteria of empyema biochemically or microbiologically. Except for 4 patients with stage 1 empyemas and 2 patients with early stage 2 empyemas who had previous antibiotic therapy, microorganisms were smeared or cultured from pleural aspirates.

All 33 patients had loculated effusion. In the patients of Group I, uniloculation was seen in 7 and multiloculation in 5, whereas uniloculation appeared in 2 and multiloculation in 11 in Group II patients. All patients of Group III showed uniloculated empyemas except 1. Group III contained 4 patients with a previous history of tuberculosis, but these patients were included because of negative acid-fast bacilli on smear and culture of sputum and pleural fluid and no pathologic evidence of tuberculosis in pleural specimens from decortication.

**CT study and analysis**

CT scans were performed mainly with a CT-W 700 scanner (Hitachi Medical Corp., Tokyo). All CT scans were done within 2 weeks after symptom onset of pleurisy. The exact time interval between the symptom onset and CT scanning could not be defined exactly in 6 patients of group III. Pre-and postcontrast scans were done in 15 patients and only postcontrast scans in 18 patients. Intravenous contrast medium (68.3% meglumine iohexolate [Rayvist®, 300, Schering Korea]) was given for postcontrast study (50ml in bolus and 50ml in drip infusion during scanning). CT scans were analyzed with the main interest focused
on the same entities used by Waite et al. (12) These were the thickness of the parietal pleura, the degree of enhancement of the parietal pleura with intravenous contrast medium, the thickness and CT attenuation of the extrapleural subcostal tissue, and the presence or absence of calcification in the pleura. The thickness of the parietal pleura and extrapleural subcostal tissue was measured in the subcostal area lateral to the paravertebral space. The maximum thickness was recorded. Intercostal space was excluded in the measurement due to variations in thickness. The degree of enhancement of the parietal pleura is graded as marked when its attenuation is the same or greater than that of the surrounding vasculature, no when less than that of the surrounding musculature, and moderate when between the vasculature and surrounding musculature. No enhancement is also regarded when there was no change in attenuation value with pre-and postcontrast scans. CT attenuation of extrapleural subcostal tissue was classified into fatty and intermediate attenuation compared with that of subcutaneous fat. Differences in these CT findings among the 3 groups were compared with chi-square analysis for discontinuous data. The statistical significance was given when the p value was less than 0.05.

**Results**

The thickness of the parietal pleura.

Eleven out of 12 (91%) patients in Group I and 10 out of 13 (78%) in Group II had parietal pleura less than 2mm in thickness (Fig. 1), but (93%) 7 out of 8 patients in Group III had parietal pleura more than 5mm in thickness (Table 1). So the patients of Group III had thicker parietal pleura, and it was statistically significant (p value: 0.0001). One in Group III had parietal

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**Fig. 1.** Multiloculated empyema in a 75-year-old man of group II. This patient was treated completely by PCD with instillation of 300,000 units of urokinase. Postcontrast CT scan at level of tracheal carina shows multiloculated hydropneumothorax. The thickness of enhancing parietal pleura (arrows) is 1mm. Thin extrapleural subcostal tissue (arrowheads) with 1mm thickness is also seen.

**Fig. 2.** Uniloculated empyema in a 37-year-old man of group III.

a. Postcontrast CT scan at ventricular level shows ovoid large pleural effusion in right lower hemithorax. The parietal pleura shows high attenuation with 3mm in thickness (arrows). Precontrast scan showed the same attenuation in the parietal pleura. Pleural calcification (arrowheads) is noted in visceral and parietal pleura. Marked thickening of the extrapleural subcostal tissue (12mm) is noted with pure fat attenuation (small arrows) compared with that of subcutaneous fat (open arrows).

b. CT scan at same level after closed thoracostomy with 28-Fr tube shows incomplete expansion of the right lung and incomplete decompression of the pleural cavity. The curvilinear soft tissue attenuation (arrows) in the posterior aspect of the extrapleural subcostal tissue was regarded as a subcostal muscle. Chest tube (arrowhead) is noted in the right lateral chest wall. This patient needed decortication ultimately.
pleura of 3mm thickness, but calcification was noted in the visceral and parietal pleura (Fig. 2).

The degree of enhancement of the parietal pleura
Five out of 12 (42%) patients in Group I and 5 out of 13 (46%) in Group II showed marked enhancement in the parietal pleura (Fig. 1), but 1 out of 8 (12%) in Group III revealed marked enhancement in it (Table 1). In other words, more parietal pleural enhancement was noted in Groups I and II than in Group III patients. But the degree of enhancement of the parietal pleura among the 3 groups was not so different as to have any statistical significance (p value: 0.057).

The thickness of the extrapleural subcostal tissue
Ten out of 12 (83%) patients in Group I and 9 out of 13 (69%) patients in Group II had extrapleural subcostal tissue less than 2mm in thickness. None of the Groups I and II patients had extrapleural subcostal tissue of more than 5mm in thickness, but 7 out of 8 (87%) in Group III had it more than 5mm (Fig. 3) (Table 2). So patients in Group III had thicker extrapleural subcostal tissue, and it was statistically significant (p value: 0.0001).

Attenuation of the extrapleural subcostal tissue
Nine out of 12 (75%) patients in Group I and 12 out of 13 (92%) patients in Group II had extrapleural subcostal tissue of intermediate attenuation, but 4 out of 8 (50%) in Group III had it of fat attenuation (Fig. 2 & 3) (Table 2). But the difference of these attenuation values of the extrapleural subcostal tissue among the 3 groups was not statistically significant (p value: 0.089).

Calcification
None of Groups I and II had pleural calcification, but 6 out of 8 (75%) patients in Group III had pleural calcification either in the visceral and/or parietal pleura.

Table 1. Thickness and Degree of Contrast Enhancement of the Parietal Pleura

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<tr>
<th>Group</th>
<th>Thickness</th>
<th>Enhancement</th>
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<tr>
<td></td>
<td>&lt;2mm</td>
<td>3-5mm</td>
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<tr>
<td>Group I (N=12)</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Group II (N=13)</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Group III (N=8)</td>
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<td>1*</td>
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* 3mm in thickness and contains pleural calcification

Fig. 3. Loculated empyema in a 32-year-old man of group III.

a. Precontrast CT scan at subcarinal level shows thick pleural fluid with marked thickening of the parietal pleura (arrows) and extrapleural subcostal tissue (arrowheads). The thickness of the parietal pleura and extrapleural subcostal tissue was 17mm and 15mm, respectively. Extrapleural subcostal tissue shows intermediate attenuation.
b. Postcontrast scan at same level shows marked enhancement of the parietal pleura (arrows). Lung parenchymal consolidation and collapse is also noted.
Fig. 4. Empyema with bronchopleural fistula in a 44-year-old woman of group III.

a. CT scan at ventricular level shows loculated effusion in the left hemithorax. Air densities are noted in the empyema cavity due to bronchopleural fistula. The thickness of the parietal pleura (arrows) is 6mm and that of extrapleural subcostal tissue (arrowheads) is 5mm. The fat attenuation of extrapleural subcostal tissue is seen. Fine calcifications (small arrows) are noted in the visceral pleura.

b. CT scan at same level after instillation of 700,000 units of urokinase through PCD shows complete drainage of empyema, but no expansion of the lung. Urokinase instillation began after cessation of expectoration of foul-odoured sputum for fear of pouring of urokinase into bronchial trees. Extrapleural subcostal tissue shows change in its attenuation (into intermediate attenuation). Decortication was performed to expand the entrapped lung.

Table 2. Thickness and Attenuation of Extrapleural Subcostal Tissue

<table>
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<th>Group</th>
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<th>Attenuation</th>
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<tr>
<td></td>
<td>&lt;2mm</td>
<td>3-5mm</td>
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<tr>
<td>Group I (N = 12)</td>
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</tr>
<tr>
<td>Group II (N = 13)</td>
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<td>4</td>
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<tr>
<td>Group III (N = 8)</td>
<td>0</td>
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pleura.

Other findings

One patient with multiloculated empyema manifesting multiple air-fluid levels was treated with intracavitary urokinase instillation through PCD (Fig. 1). Bronchopleural fistula was noted in 1 patient in group III. This patient had air in the pleural space, pleural calcification, and thickened parietal pleura and extrapleural subcostal tissue (Fig. 4). An initial PCD was performed, and bronchopleural fistula was occluded during catheter drainage. 700,000 units of urokinase was instilled into the pleural cavity to dissolve the pleural peel, but only to fail. So decortication was performed.

Discussion

Empyema is a common problem occurring most frequently after infection, trauma, or surgery. Standard therapeutic options include antibiotics, thoracentesis, drainage via PCD or tube thoracostomy, excision of the ribs for open drainage, and decortication. Since the successful treatment of thoracic empyemas with PCD by vanSonnenberg et al. in 1984, PCD has been regarded as a primary treatment modality of acute thoracic empyemas with a cure rate of 80-90% (1, 13-15). But some thoracic surgeons still advocate surgery, such as open drainage or decortication, as a treatment modality for stage 2 empyemas (16, 17). The study of Neff et al. (18) suggests that early pleural peels can resolve after PCD if they are treated before dense and organized collagen peels are formed. Intracavitary urokinase instillation can expedite the drainage of loculated empyemas (5, 19). Group II in this study contained 10 patients of our previous study treated with intracavitary urokinase instillation through PCD [5]. We could treat 13 patients with multiloculated empyemas by intracavitary instillation of urokinase.
mainly through an 8-Fr PCD catheter. Thus we think
multiloculated empyema (mostly late stage 2 empyemas) may no longer be an indication of surgery.

Stage 3 empyemas are chronic, characterized by
the pleural peel becoming organized, entrapping the lung, and restricting its movement. Chronic empyemas usually result from delay in seeking medical attention, along with inadequate antibiotic therapy, persistence in conservative management with inadequate drainage, the presence of intrapleural foreign body, and a chronic pulmonary infection such as tuberculosis or interstitial pulmonary disease that prevents re-expansion of the lung to obliterate the pleural space. Decortication, multiple rib resection and removal of the thick fibrous tissue covering the lung (pleural peel), or open drainage have been regarded as treatment modalities for chronic empyemas. But it is difficult to detect the exact time of evolution of early pleural peel (late stage 2) into the dense scar of chronic empyema (stage 3) using clinical and/or biochemical studies. Patients with stage 3 empyemas were those who had pleurisy symptoms of more than 6 weeks clinically and who satisfied the biochemical criteria of empyemas. Actually 2 patients of Group III in this study had pleurisy symptoms of less than 6 weeks, but they needed decortication eventually. In this sense it is very important to determine objectively the accurate criteria of empyemas which need thoracotomy. Waite et al. (12) contend that CT evaluation of the parietal pleura and extrapleural subcostal tissue cannot accurately differentiate patients with late stage 2 empyema from those who ultimately needed decortication (stage 3) because of overlapping of the CT findings between the stages. But in our study, the CT findings of the parietal pleura and extrapleural subcostal tissue in Group III patients, who ultimately needed decortication, were different from those of Groups I and II patients (who were patients mainly with stage 2 empyemas). The different observations between our study and that of Neff et al. cannot be explained simply.

There was no mention of pleural calcification in
the study of Waite et al. Calcified effusions are usually from chronic tuberculous empyema, thoracic empyema secondary to penetrating trauma, and traumatic hemothorax (20). Our case in Group III contained 6 patients with pleural calcification. One patient had posttraumatic empyema, and the remaining 5 had empyemas of long duration.

According to the study by Waite et al., (12) the
average thickness of the parietal pleura and extrapleural subcostal tissue in the 8 patients who needed decortication was 4 and 4.5mm, respectively. With intracavitary urokinase instillation, late stage 2 empyemas with parietal pleura of 3-5mm thick resolved without surgery in our study.

In this study, although this event had no significant statistical significance, Group III empyemas showed less enhancement of the parietal pleura with infusion of constrast medium on CT. This lesser enhancement may be related to the obliteration of the microvasculature in the inflamed pleura by fibrosis with dense collagen tissue.

Anatomically the parietal pleura is composed of
4 major layers. From the deepest layer these are: (1) a single layer of mesothelial cells, (2) a thin supportive fibroelastic layer, (3) a layer of loose connective tissue, and (4) the endothoracic fascia that adheres the pleura to the overlying rib (12, 21). The loose connective tissue layer is made up of adipose tissue and varies in thickness. This layer has been designated as an extrapleural layer, although it is regarded as a component of the parietal pleura. Thickening of this adipose tissue of the extrapleural fat layer may occur in patients with chronic pleural disease (22). In our study, the thickness of the extrapleural subcostal tissue in patients who ultimately needed surgical treatment was more than 5 mm in all but 1 patient. Fat attenuation in the extrapleural subcostal tissue was more frequently noted in the patients of Group III. This phenomenon corroborates the findings of previous studies (20, 22) where fat attenuation of extrapleural subcostal tissue was seen in chronic empyemas.

Decortication is successful when the fibroelastic peel that traps the lung leaves the visceral pleura relatively normal and the lung itself expansible so
that the empyema space can be obliterated by pulmonary re-expansion when the peels are removed (7). So it is very important for surgeons to see the state of the visceral pleura and the lung parenchyma. But to evaluate the visceral pleura exactly with CT is usually difficult because there are accompanying lung lesions (atelectasis or parenchymal infiltration) in the vicinity of or next to the visceral pleura. So we excluded the visceral pleura from the entities of CT evaluation.

In summary, we conclude that CT can determine the surgical criteria for thoracic empyemas, and multiloculated empyema may no longer be an indication of surgical treatment. The CT criteria of surgical treatment of thoracic empyemas are pleural calcification, more than 5mm in thickness of the parietal pleura, and more than 5mm in thickness of the extrapleural subcostal tissue, although more prospective studies should be done.

REFERENCES

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수술적 치료를 요하는 농흉 : CT상의 기준

이경수·황선희·김용훈·노중기·이병호

저자들은 수술적 치료를 요하는 농흉의 전산화단층촬영 (이하 CT)상의 기준을 알아 보기 위하여 소방이 형성된 농흉을 가진 33명의 환자의 CT 소견을 후향적으로 분석하였다. 33명의 환자를 치료 방법에 따라 3개군으로 나누어 이들 3개군의 CT 소견상 차이를 알아 보았다 : 제 1군은 세침 흉강천자 (needle thoracentesis), 경피적 도관배액술 (percutaneous catheter drainage) 혹은 삽관 흉곽 개구술 (tube thoracostomy)로 완치된 12명, 제 2군은 경피적 도관이나 흉막수관을 통하여 urokinase를 주입하여 완치받은 다소방 농흉을 가진 13명, 제 3군은 제 1군 혹은 제 2군의 시술로 완치가 불가능하여 수술을 받은 8명이었다.

CT상 제 1군과 제 2군간의 차이는 없었다. 제 3군은 제 1군이나 2군과는 CT상 엄격한 차이를 보였는데 이들은 내장흡막 혹은 체벽흡막의 석회화, 체벽흡막의 심한 비후 (> 6 mm, p 값: 0.0001) 그리고 흉막 외부 늑골하조직의 비후 (> 6 mm, p 값: 0.0001) 등이었다.

결론적으로 저자들은 농흉의 수술적 치료의 기준은 늑막의 석회화, 체벽흡막의 심한 비후 및 흉막외부 늑골하조직의 비후이며 다소방성 농흉은 수술없이도 치료가 가능하다고 사료된다.