Utility of Pleural Fluid Analysis in Predicting Tube Thoracostomy/Decortication in Parapneumonic Effusions*

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Recommended criteria for surgical drainage of parapneumonic effusions include evidence of frank purulence, a glucose level <40 mg/dl, a pH of <7.00, or an LDH >1,000 IU/L. To test the utility of these criteria, we reviewed the three-year experience of three Rochester, NY, hospitals. We identified 133 patients undergoing thoracentesis for putative parapneumonic effusions. Of 91 patients with neutrophilic exudates, 43 met one or more criteria for tube thoracostomy; 48 did not. Twenty-one of the 43, including 9 with frank empyema, underwent immediate drainage. Of the 22 who did not, 11 eventually required tube thoracostomy and/or decortication. Of the 45 not meeting any of the criteria, 7 also came to surgery. Using whether the patients eventually underwent surgery as a measure of outcome, we calculated for those patients not undergoing immediate drainage the sensitivity, specificity, positive predictive values, and negative predictive values for each of the criteria. The four criteria have relatively high specificity ranging from 82 to 96 percent, but have low sensitivity varying from only 18 percent for a positive Gram stain to 53 percent for a fluid LDH >1,000 IU/L. We conclude that these criteria have limited usefulness in predicting the need for eventual chest tube drainage/decortication. Patients not meeting the criteria require close follow-up as well. (Chest 1991; 100:963-67)

Pleural effusion is commonly associated with bacterial pneumonia. The parapneumonic effusion results from an increased permeability of the visceral pleura due to inflammation. As many as 40 percent of patients with pneumonia will develop pleural fluid during the course of their illness. Early diagnosis is important and delay in instituting appropriate treatment is believed to increase both complications and morbidity.

Many parapneumonic effusions resorb eventuantly with early treatment of the pneumonia. If too much time passes, the inflammatory process may result in pleural sepsis and a prolonged period of recovery ensues usually necessitating surgical drainage. Thoracostomy is often necessary. The clinician faces a challenge in identifying effusions that will resolve with antibiotic treatment alone vs those that behave like empyemas and require tube thoracostomy for drainage and/or eventual parietal pleurectomy.

Examination of the pleural fluid appears to be of fundamental importance in determining whether tube thoracostomy needs be performed. The diagnostic thoracentesis ideally consists of withdrawal of 30 to 50 ml of pleural fluid that is analyzed for glucose, lactate dehydrogenase (LDH), and protein levels, pH, total WBC count, and differential. Gram stain and both aerobic and anaerobic cultures should also be performed on this fluid. Any finding of gross purulence or organisms on Gram stain, a pH of <7.00, or a glucose level of <40 mg/dl have been recommended as the criteria for the immediate insertion of a chest tube. Additionally, if the pleural fluid pH is >7.00 but <7.20 or the LDH level is >1,000 IU/L, consideration of a chest tube vs repeated thoracentesis has been recommended on an individual basis. We have observed that these criteria have not uniformly identified patients who need immediate tube thoracostomy; when these criteria are not met, not all patients recover without surgery. To define better the operating characteristics of the recommended criteria, we reviewed our recent experience in the community hospital setting with their application in patients presenting with pneumonia and parapneumonic effusions.

Patients and Methods

We reviewed the records of patients with pleural effusions undergoing thoracentesis at three Rochester, NY, community teaching hospitals over a 36-month period ending in December 1989. We identified 144 patients believed to have possible parapneumonic effusions. Information obtained from each record included the following: (1) the size of the effusion (small effusions were defined as obscuring less than one half of the hemidiaphragmatic silhouette on the posteroanterior [PA] chest roentgenogram; (2) if the fluid was free flowing or loculated on a decubitus roentgenogram; (3) the quantity of fluid obtained by thoracentesis; (4) a description of the

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fluid; (5) fluid and serum protein levels; (6) fluid and serum LDH levels; (7) fluid glucose level; (8) fluid pH; (9) WBC count with the predominant cell; (10) Gram stain result; (11) culture results for both aerobic and anaerobic organisms; (12) whether tube thoracostomy and/or pleurectomy were performed; (13) interval in days between initial thoracentesis and surgery if performed; (14) the outcome of each. Immediate drainage was defined as tube thoracostomy within 24 hours of thoracentesis. If the outcome was not apparent from the medical record, the patient and/or the attending physician were contacted.

Pleural fluid pH determinations at the three hospitals utilized blood gas methodology, immediate icing, and anaerobic technique. Patients with a systemic acidosis or for whom the fluid pH methodology was questioned were excluded from the study as were those with a diagnosis of carcinoma. Patients with pleural effusions defined as a transudate by protein and LDH in the pleural fluid and serum or with non-neutrophilic exudates were also excluded from the study. Additionally, patients having a chest tube inserted for reasons other than the previously described criteria based on pleural fluid analysis, eg, for a pneumothorax complicating thoracentesis or dying within 24 hours of presentation due to comorbidity, were not considered for the study.

In those patients who did not undergo immediate tube drainage, we compared the results of pleural fluid analysis with the clinical outcome, ie, whether or not a surgical procedure was eventually performed. We were able to analyze these data in this fashion because at the three hospitals, there is no consensus on the approach to treating these patients. The decision for chest tube drainage is at the discretion of the attending physician or consulting surgeon. Using a decision matrix, we calculated the true positive ratio (sensitivity), true negative ratio (specificity), and both positive and negative predictive values4 for the fluid Gram stain, glucose, pH, and LDH determinations.

RESULTS

Ninety-one patients with neutrophilic exudates were included in the study. There were 56 men and 35 women ranging in age from younger than 1 year to 94 years (mean, 51 years). Sixty-eight patients had large pleural effusions and 23 had small effusions. Thirty-nine of the 91 effusions were confirmed as loculated by a lateral decubitus chest roentgenogram. The four pleural fluid criteria were not recorded in the medical record for all 91 patients. Fifty-four of the 91 patients had all four criteria measured. No patient had less than two. Sixty-six patients had a pleural fluid Gram stain, 58 had a glucose level, 54 had a correctly collected pH determination, and 66 had an LDH measurement. The bacterial cause of an empyema in 66 patients was not apparent. Often the patients had received prior treatment with antibiotics and the culture of the pleural fluid revealed no growth. Twenty-five cultures were positive; seven grew Staphylococcus species; five, Streptococcus pneumoniae; five, other Streptococcus species; three, Gram-negative bacilli; four, anaerobic organisms; and one, a Nocardia species.

The eventual outcomes for the 91 patients included in the study are shown in Figure 1. Twenty-one of 43 patients with pleural fluid meeting one or more of the criteria underwent immediate open drainage. Nine of the 21 had frank empyema. The remaining 12 met one or more of the four previously determined pleural fluid criteria for chest tube placement. Of the 22 patients meeting one or more of the same pleural fluid criteria, yet not demographically different by age, size of effusion, severity of pneumonia, or bacteriology from the others, but not undergoing immediate open drainage, 11 eventually required chest tube placement within a period of several weeks. This was prompted by a worsening clinical state, including increasing pleural fluid volume, recurrent fever, and/or persistent

FIGURE 1. Eventual outcome for 91 patients with pneumonia and a neutrophilic exudative pleural effusion.
leukocytosis despite antibiotic therapy. Five of the 11 ultimately came to decortication and one to rib resection in order to recover. Four of the 22 patients not undergoing immediate drainage had a pleural fluid LDH level in excess of 1,000 IU/L as the only criteria. Three of the four recovered uneventfully, although one had a repeated thoracentesis. The fourth patient was one who came to decortication. Figures 2 to 4 illustrate the distribution of the pleural fluid pH, glucose, and LDH values, respectively, as related to outcome. No clearly defined pattern of distribution is identified for those patients not undergoing immediate chest tube placement.

We attempted to identify which clinical feature might predict the outcome for these 22 patients. Of 16 patients who had loculated effusions, 11 eventually required surgery while only one of six with free-flowing effusions had a surgical outcome. Three patients had *Staphylococcus aureus* cultured from their pleural fluid; all three ultimately came to surgery. Three of four patients with *S pneumoniae* had a benign course. We were unable to identify any pattern to the outcome based on choice of antibiotic therapy.

The majority of the 48 patients in whom the pleural fluid did not meet any of the four criteria for tube thoracostomy recovered uneventfully. However, seven eventually required surgery. Four had tube thoracostomy within a week when repeated thoracentesis showed a decrease in the pleural fluid pH, one of whom developed a frank empyema. Three patients ultimately required decortication of the parietal pleura up to several months later with the development of thick pleural peels. These seven patients had a mean pleural fluid pH of 7.41 (range, 7.20 to 7.49), a mean pleural fluid glucose level of 114 mg/dl (range, 84 to 211 mg/dl), and a mean pleural fluid LDH value of 394 IU (range, 194 to 933 IU) on initial thoracentesis. An additional patient of the 48 who did not undergo surgery died and at postmortem examination had a thick pleural peel entrapping the lung. Yet another patient in this group had a fluid pH between 7.0 and 7.20. Chest tube placement was considered, but on repeated thoracentesis, the pleural fluid pH had increased to 7.40. Medical therapy resulted in full

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**Figure 3.** Glucose levels in patients with pneumonia and pleural effusions.

**Figure 4.** Lactate dehydrogenase levels in patients with pneumonia and pleural effusions.
recovery without surgery.

By including clinical outcome, ie, whether or not surgery was eventually performed, we calculated for those patients not undergoing immediate open drainage the sensitivity, specificity, positive predictive values, and negative predictive values for each of the four pleural fluid criteria. Table 1 shows the operating characteristics for each of the criteria: a positive Gram stain, a glucose level <40 mg/dl, a pH of <7.00, and an LDH value >1,000 IU/L. Each of the four criteria has a fairly high true-negative ratio (specificity), but only a modest true-positive ratio (sensitivity) in predicting the need for immediate chest tube placement. Both the positive predictive value, ie, given that empyema was present, and the negative predictive value, ie, that empyema was unlikely, were only moderately useful for these patients except perhaps if the pleural fluid pH was >7.00 or the LDH value was <1,000 IU/L. Under those conditions, there was an 80 percent chance that a complicated effusion or empyema would not develop. Using χ² analysis, the p value is significant for both pH and LDH criteria. This results from the relatively large number of patients in the study with a negative test, the majority of whom do not come to surgery. Hence, a higher negative predictive value is evident as well.

Our data were also analyzed for 43 of the 54 patients for whom all four pleural fluid parameters had been measured and immediate tube thoracostomy not performed to determine if the outcome could be predicted based on any 1, 2, 3, or all 4 criteria being positive. Table 2 shows the result. No clear prediction of outcome is possible by this approach.

DISCUSSION

There are three types of parapneumonic effusions. At one extreme is the sympathetic collection of fluid that clears spontaneously with treatment of the pneumonia. At the other extreme is empyema. While the adage of "draining the pus" has been challenged by the discovery of new and more potent antibiotics, frank purulence within the pleural space still calls for surgical drainage. Likewise, the presence of a positive Gram stain in the absence of pus also constitutes an adequate diagnosis of empyema. This finding suggests a heavy bacterial inoculation of the pleural space and most often requires surgical drainage. What about other cases in which medical management continues to fail? The key issue remains patient selection and the major question is which patient requires surgical drainage.

Clinical grounds for patient selection is difficult. There is no easy way to identify patients with a simple sympathetic effusion from those who will progress to complicated effusion with loculation and empyema. Each group has a similar incidence and degree of pleuritic chest pain, fever, and leukocytosis. Neither the size of the effusion nor rapidity of reaccumulation clearly differentiates the patient who requires drainage. Pleural effusions of less than 10 mm on a decubitus chest roentgenogram usually resorb during antibiotic therapy.

We were unable to identify any demographic feature that consistently predicted outcome. Patients with loculated effusions not undergoing immediate drainage more frequently came to surgery than those

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Surgery</th>
<th>Predictive Values</th>
<th>Test Result</th>
<th>Surgery</th>
<th>Predictive Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Positive Gram Stain p&gt;0.05*</td>
<td>Eventual</td>
<td>None</td>
<td>B. Glucose &lt;40 mg/dl p&gt;0.10*</td>
<td>Eventual</td>
<td>None</td>
</tr>
<tr>
<td>(n = 17)</td>
<td>(n = 17)</td>
<td>(n = 49)</td>
<td>(n = 20)</td>
<td>(n = 38)</td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>3</td>
<td>5</td>
<td>60%</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Negative</td>
<td>14</td>
<td>15</td>
<td>77%</td>
<td>33</td>
<td>25%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>18%</td>
<td>25%</td>
<td>96%</td>
<td>50%</td>
<td>69%</td>
</tr>
<tr>
<td>Specificity</td>
<td>94%</td>
<td>92%</td>
<td>96%</td>
<td>87%</td>
<td>82%</td>
</tr>
</tbody>
</table>

*χ² test.

Table 2—Number of Positive Pleural Fluid Criteria* Present vs Outcome

<table>
<thead>
<tr>
<th>No. of Positive Criteria Present</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
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<tr>
<td>Chest tube/decortication</td>
<td>Yes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Totals</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>28</td>
</tr>
</tbody>
</table>

*The four criteria are a positive Gram stain, pH <7.00, glucose <40 mg/dl, and LDH level >1,000 IU.
without. For the several patients from whom *S pneumoniae* was identified in the pleural fluid and not undergoing immediate drainage, a favorable outcome usually resulted, whereas those with *S aureus* were not so fortunate. These results are not unexpected. Loculation of pleural fluid has been reported previously to affect outcome in patients with complicated effusions,\textsuperscript{1,5,6} as is the benign course often encountered in effusions secondary to *S pneumoniae*.\textsuperscript{1,7}

Light and associates\textsuperscript{1} have advocated pleural fluid analysis as the only means of identifying the pneumonia patient with a complicated pleural effusion. In an early study of 178 patients, no patient with a pleural fluid pH below 7.20 recovered without surgical drainage and all whose parapneumonic effusion had a pH in excess of 7.20 recovered with antibiotic therapy.\textsuperscript{8} Potts et al\textsuperscript{8} in 1976 concluded that pleural fluid pH was a more sensitive indicator of a complicated effusion than the pleural fluid glucose concentration and recommended that patients with a fluid pH as high as 7.30 would develop loculations and require surgical management. In contrast, a recent study by Berger and Morganroth\textsuperscript{9} found that 13 of 16 patients with complicated parapneumonic effusions defined as a pH below 7.20 or a positive Gram stain or culture without purulence recovered with antibiotic therapy alone.

In a recent study by Light and associates,\textsuperscript{1} either a pleural fluid pH below 7.00 or a glucose value less than 40 mg/dl was reaffirmed as an indication for chest tube placement. Conversely, if the pH exceeded 7.20 or the pleural fluid LDH concentration was less than 1,000 IU/L, antibiotic therapy alone was advocated. Obviously, these guidelines did not address patients whose pleural fluid has a pH between 7.00 and 7.20 or an LDH concentration greater than 1,000 IU/L. Serial thoracentesis was recommended for those patients followed by chest tube placement if the fluid characteristics moved toward levels consistent with a complicated effusion. However, using the latter criteria, only five patients in that study underwent serial thoracentesis and the only patient requiring surgical drainage met the other criteria for chest tube placement on the initial thoracentesis as well.

We have employed the criteria of Light et al\textsuperscript{1} treating patients presenting with pneumonia and pleural effusions and included in the study only those patients whom we believed had an effusion solely on the basis of a bacterial pneumonia.

We are not surprised that the specificity of each of the four criteria is relatively high, with a positive Gram stain the most likely to confirm the presence of an empyema. The Gram stain, however, although prompt, is frequently negative in the absence of a heavy bacterial inoculum and is influenced by previous antibiotic therapy. The result is a large number of false negative stains and a low sensitivity.

About one quarter of patients meeting one or more of the pleural fluid criteria will recover without surgery, hence, the modest positive predictive values for each of the criteria. The negative predictive values, on the other hand, are somewhat better, with fewer patients not meeting one or more criteria eventually requiring surgical drainage or decortication.

Sahn and Light\textsuperscript{10} have recently suggested modification of the original criteria and proposed that if the pH is >7.30, the glucose level is >60 mg/dl, and the LDH value is <1,000 IU/L, the parapneumonic effusion is uncomplicated and surgical drainage is unnecessary. Twenty-two of our patients with a negative fluid Gram stain met these three criteria. While 18 recovered, three eventually came to thoracotomy with decortication and the fourth died with a thick fibrotic pleural peel. Also, 13 of our patients had a pleural fluid pH between 7.10 and 7.30. As is currently recommended, thoracentesis was repeated. Using this approach, a worsening of the fluid pH led to tube thoracostomy/decortication in five patients. Improving pH values resulted in resolution without surgery in the other eight patients.

No laboratory value is ever absolute in dictating a specific clinical action. Clinical judgment and serial observation are obviously of value in these patients. Clearly, close follow-up is required for all patients with a parapneumonic effusion and one should not rely solely on laboratory results in the decision-making process. A prospective randomized study will ultimately be necessary to define the role of tube thoracostomy in the treatment of these patients.

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