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Sonographic Septation:
A Useful Prognostic Indicator of Acute Thoracic Empyema

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The aim of this study was to identify sonographic predictors of patient outcomes or need for surgical intervention of acute thoracic empyema. All patients with a clinical diagnosis of thoracic empyema underwent transthoracic ultrasonographic examination and thoracentesis at admission. According to the presence or absence of septa in sonographic images, the patients were classified into two groups: septated and nonseptated. Sonographic findings were analyzed with respect to duration of hospital stay, chest tube drainage, and treatment efficacy. A total of 163 consecutive patients were included in the study (83 patients with septated and 80 with nonseptated sonographic images). The mean duration of hospital stay (35.4 versus 27.0 days, $P = 0.009$) and chest tube drainage (13.1 versus 7.6 days, $P < 0.001$) for the patients with septa were significantly longer than for those without septa. The patients with septa were more likely to undergo intrapleural fibrinolytic therapy (63.8% versus 38.8%, odds ratio 2.79, $P = 0.001$) and surgical intervention (24.3% versus 7.5%, odds ratio 3.92, $P = 0.004$). We concluded that sonographic septation is a useful sign to predict the need for subsequent intrapleural fibrinolytic therapy and surgical intervention in cases of acute thoracic empyema. Early fibrinolytic therapy or even surgical intervention may be indicated in patients with sonographic septations. KEY WORDS: Thoracic empyema; Empyema, acute thoracic; Septation, pleural; Streptokinase; Ultrasonography.

Despite improvements in antimicrobial therapy and multiple options for drainage of the infected pleural space, thoracic empyema continues to cause significant morbidity and mortality.[1] This may be due to delayed diagnosis and inadequate treatment of pulmonary infection, alterations in the immune status of the patients, and the emergence of resistant organisms. In patients with well-organized, chronic empyema, the optimal management consists of formal thoracotomy and decortication or prolonged open drainage.[2] For thoracic empyemas in the fibrinopurulent phase,[3] the optimal timing of receiving tube thoracotomy with intrapleural fibrinolytic therapy, thoracoscopic pleural debridement, or thoracotomy with decortication remains controversial. Early aggressive surgical intervention after a short trial of tube drainage can achieve a high success rate with low morbidity and mortality.[1,4] However, because of the intraoperative and postoperative risks, surgical intervention remains the last resort for patients with failure to control the infection by chest tube drainage and fibrinolytic therapy.

In our previous study, sonographic examination was helpful in evaluation of the disposition of fibrin

ABBREVIATIONS

VATS, Video-assisted thoracoscopic surgery; SEM, Standard error of the mean; CT, Computed tomography

Received May 8, 2000, from the Departments of Internal Medicine (K.-Y.C., Y.-S.L., H.-C.W., P.-C.Y) and Laboratory Medicine (K-T.L.), National Taiwan University Hospital, Taipei, Taiwan. Revised manuscript accepted for publication August 5, 2000.

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clotting and fibrin membranes of the pleural cavity and also to gain information on the nature of effusion.[5] Transthoracic ultrasonography has been shown to be a helpful diagnostic tool for the characteristics of pleural effusion, but it is seldom used to predict the outcomes of pleural diseases. Thus, we analyzed the sonographic images of patients with acute thoracic empyema treated over a 10 year period to determine whether sonographic evidence of septation can predict a prolonged duration of hospital stay, chest tube drainage, and the need for surgical intervention.

PATIENTS AND METHODS

All patients with a clinical diagnosis of parapneumonic effusion admitted to National Taiwan University Hospital from January 1989 to May 1998 were screened for possible enrollment in this study. Patients were enrolled if (1) the thoracentesis recovered thick, purulent-appearing (puslike) pleural fluid and (2) microscopic examination of pleural effusion revealed a white blood cell count of more than 15000 cells/μl with neutrophil predominance and identification of microorganisms by microscopic examination or culture.[6] Patients were excluded if a diagnosis of chronic thoracic empyema with or without bronchopleural fistula was established or if thoracic empyema was caused by any invasive procedure, such as trauma or surgery.

On the first day of admission, all patients underwent transthoracic sonography with an Aloka SSD 200 (Aloka, Tokyo, Japan) or Toshiba 270A (Toshiba, Tokyo, Japan) ultrasonic scanner with a 3.5 to 5.0 MHz linear or sector probe. The patients were examined while supine or sitting, with the transducer scanning through the intercostal space. The sonographic images were recorded on Polaroid film (Polaroid, Cambridge, MA) or terminal prints (Video Graphic Printer, UP-890MD, Sony, Tokyo, Japan) for further analysis. The echogenicity of bile in the gallbladder was used as a reference for anechoic lesions. The echogenicity (hypoechoic, isoechoic, or hyperechoic) of the effusion was compared with the echogenicity of the liver. The pleural effusions were classified on the basis of sonographic findings as septated or nonseptated.[5] Strand formation was defined as the presence of hyperechoic lines in the pleural cavity. Septa formation was defined as the presence of strands, which may be weblike or branching. Septated effusions were those with fibrin strands or septa floating inside the anechoic pleural space (Fig. 1), whereas nonseptated effusions were those with anechoic, homogeneously echogenic, or complex appearances on the internal echo image, but no evidence of fibrin strands or septa formation in the pleural cavity (Fig. 1).

Standing chest radiographs were obtained on admission and evaluated by at least one pulmonologist and one radiologist. The chest radiographs were classified into two groups according to the extent of opacification shown in the posteroanterior view. Severe opacification was defined as pleural effusion above the level of the hilum or the presence of multiple loculated effusions. The opacification was defined as not severe if pleural effusion was below the level of the hilum without multiple loculations. Multiple loculated pleural effusions were defined as the presence of more than one well-defined area of opacity in the chest radiographs, without evidence of air bronchogram.

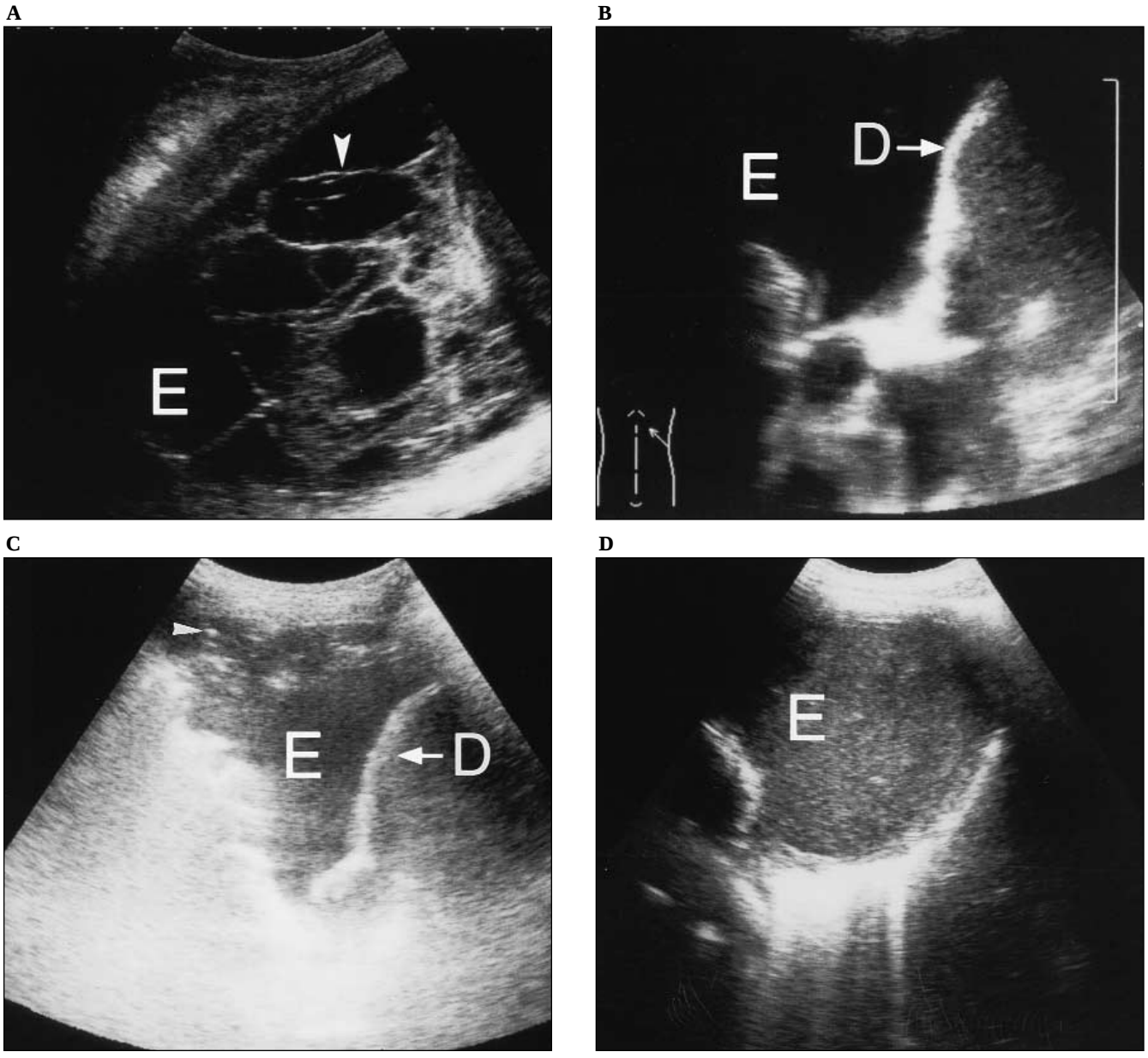
The pleural effusions were aspirated after sonographic evaluation and transferred under aseptic conditions, were processed according to a standard procedure,[7] and were cultured for both aerobic and anaerobic bacteria. The infections were classified into four types according to the types of organism that were cultured from the pleural effusions: aerobic and facultative gram-positive, aerobic gram-negative, anaerobic, and mixed. Mixed infection was defined as the isolation of more than one type of organism from the pleural effusion.

Patients with empyema underwent standard tube thoracotomy or continuous closed drainage with an indwelling pigtail catheter, unless the clinical condition or small size of effusion ruled out the use of invasive procedures. All patients initially received antibiotics in accordance with the type of organisms found by microscopic examination of pleural effusion or were treated empirically with a broad-spectrum penicillin (ampicillin or amoxicillin) with a beta-lactamase inhibitor and an aminoglycoside. The antibiotic regimen was adjusted according to the species and the antibiotic sensitivity profile of the isolate or isolates. Patients were reevaluated on the third day by means of chest radiography. If radiographic evidence revealed loculation of pleural effusion with poor drainage and the clinical condition suggested the presence of persistent inflammation (fever, leukocytosis, and so forth), the patients received instilled streptokinase, 250,000 units via the chest tube daily for 3 to 7 days. If the effusions failed to be drained by tubal thoracotomy with intrapleural fibrinolytic therapy, VATS or open thoracotomy was performed for further decortication and drainage. All of the patients received at least 2 weeks of parenteral antibiotic therapy. The antibiotics were then

shifted to oral form for at least 1 more week after fever and clinical symptoms and signs of infection subsided. The patients were then discharged.

The clinical data for these patients were recorded, including age and sex; predisposing factors, clinical symptoms, intervals from the onset of symptoms to the establishment of diagnosis, duration of hospitalization, strains of isolates from culture of pleural effusion, transthoracic sonographic findings, chest radiographic presentations, duration of chest tube insertion with or without intrapleural fibrinolytic therapy, surgical intervention, and mortality directly

Figure 1 A, Sonographic septation in a 45 year old man with acute thoracic empyema. Two-dimensional gray scale scan shows a pleural cavity with many hyperechoic strandlike materials. Note septa formation of strands (*arrowhead*). **B**, Nonseptated sonographic findings in a 52 year old woman with acute thoracic empyema. Two-dimensional gray scale scan shows a relative anechoic pleural cavity. Note the thickened pleura over the diaphragm (*arrow*). **C**, Nonseptated sonographic findings in a 67 year old man with acute thoracic empyema. Two-dimensional gray scale scan shows a heterogeneous pleural cavity. Note some hyperechoic spots (*arrowhead*) inside the pleural cavity and the thickened pleura over the diaphragm (*arrow*). No septa or fibrin strands were seen. **D**, Nonseptated sonographic findings in a 36 year old woman with acute thoracic empyema. Two-dimensional gray scale scan shows a homogeneously echogenic loculated effusion. No septa or fibrin strands are seen. E, Effusion; D, diaphragm.



attributable to thoracic empyema. Data were presented as mean ± SEM. The mean hospital stay, mean duration of chest tube drainage, and mean duration from onset of clinical manifestations to diagnosis in patients with and without septa were compared by means of independent-samples *t*-test. The proportions of patients with and without septation who received fibrinolytic therapy, underwent surgery, and died were compared by means of chi-square test. *P* values of < 0.05 were considered statistically significant.

RESULTS

Clinical Characteristics and Outcomes

From January 1989 through May 1998, a total of 240 patients with a clinical diagnosis of parapneumonic effusion were treated. Of these, 163 met the enrollment criterion of acute thoracic empyema and were included in this study. The mean age was 65 years (range, 1 to 96 years). Sixty-three patients (39%) were over 65 years of age. Males predominated, with a male to female ratio of 122:41. One hundred and nine of the 163 patients (67%) had underlying diseases. The most common underlying condition was diabetes mellitus (35 of 109, 32%). Malignancy was the second most common underlying disease (30 of 109, 28%), of which lung cancer was the most frequently encountered type. Previous lung diseases (mainly with chronic obstructive pulmonary disease) and central nervous system disorders (mainly with previous cerebrovascular accident) also were the major associated medical conditions. The records of periodontal evaluation generally were not available.

The most frequent manifestation was fever (80.3%), followed by cough (69.3%), chest pain (67.4%), dyspnea (60.7%), and expectoration (60.7%). Of the 163 patients, 132 had positive pleural effusion cultures. A total of 154 organisms, including 120 aerobic or facultative bacteria and 34 anaerobic bacteria, were identified. Of the 132 patients, 45 had aerobic or facultative gram-positive, 57 had aerobic gram-negative, 13 had anaerobic, and 17 had mixed infection.

The mean duration of hospitalization of the 163 patients was 31 days, the mean duration between onset of symptoms and diagnosis was 12 days, and the mean duration of chest tube drainage was 10 days. Eighty-four of the 163 patients (51.5%) received intrapleural fibrinolytic therapy for poor response of empyema to simple chest tube drainage. Twenty-six patients (16%) underwent surgical intervention for empyema, including VATS with debridement or open thoracotomy with drainage, or both. The mortality rate of the 163 patients was 13.5%. However, no patient who underwent surgical intervention died.

Sonographic Findings

Sonographic evaluation revealed septated pleural effusion in 83 patients and nonseptated effusion in 8 patients. Those with septa did not differ significantly from those without septa in terms of age, sex, underlying conditions, or clinical manifestations, except that cirrhosis of the liver was more common in those with septation (Table 1). No significant difference in bacteriologic results was found between the septated and nonseptated groups.

The mean hospital stay (35.4 ± 2.7 days versus 27.0 ± 1.6 days, $P = 0.009$) and mean duration of chest tube drainage (13.1 ± 0.9 days versus 7.6 ± 0.6 days, $P < 0.001$) of the patients with septa were longer than those without septa (Table 2). Patients with septation underwent intrapleural fibrinolytic therapy (63.8% versus 38.8%, odds ratio 2.79, $P = 0.001$) and surgical intervention (24.3% versus 7.5%, odds ratio 3.92, $P = 0.004$) more frequently than those without septation. The mortality rates of patients with septa did not differ significantly from those of patients without septa.

Radiographic Findings

Chest radiographs revealed that 93 patients had right-sided pleural effusions and 70 had left-sided pleural effusions, whereas 14 (8.5%) had an air-fluid level. Sixty-nine patients had severe radiographic opacification and 94 patients were without severe opacification. Patients with and without severe

Table 1: Demographic Features of the Septated and Nonseptated Sonographic Groups of Patients

	Septated (n = 83)	Nonseptated (n = 80)	*P* Value
Age, mean (yr)	56.2	55.2	0.459
Male / Female	58 / 25	64 / 16	0.137
Underlying Condition			
Diabetes mellitus	16	19	0.487
Malignancy	13	17	0.357
Lung disease	12	12	0.922
Central nervous system disease	12	6	0.157
Renal disease	4	7	0.317
Liver cirrhosis	7	1	0.030
Autoimmune disease	2	3	0.620
Alcoholism	2	2	0.970
No underlying disease	29	26	0.742

Table 2: Clinical Course, Treatment, and Outcomes of Empyema Patients with Septated and Nonseptated Sonographic Patterns

	Septated (n = 83)	Nonseptated (n = 80)	95% CI of Difference	Odds Ratio (95% CI)	*P* Value
Mean hospital stay (days)*	35.4 ± 2.7	27.0 ± 1.6	2.12–14.60	—	0.009
Duration before diagnosis (days)*	13.1 ± 1.2	11.6 ± 1.1	–1.49–4.76	—	0.269
Duration of chest tube drainage (days)*	13.1 ± 1.0	7.6 ± 1.0	3.37–7.64	—	< 0.001
Fibrinolytic therapy	53 (63.8%)	31 (38.8%)	—	2.79 (1.48–5.27)	0.001
Surgical intervention	20 (24.3%)	6 (7.5%)	—	3.92 (1.48–10.35)	0.004
Mortality	9 (11%)	13 (16%)	—	0.63 (0.25–1.56)	0.313

CI, Confidence interval.
*Data presented as mean ± SEM.

opacification did not differ significantly in terms of age, sex, underlying condition, bacteriologic findings, and clinical manifestations. No significant differences in mean hospital stay, interval between onset of symptoms and establishment of diagnosis, or duration of chest tube drainage were found between these two groups (Table 3). Patients with severe opacification were more likely to require intrapleural fibrinolytic therapy (62.3% versus 43.6%, odds ratio 2.14, $P = 0.018$) and operation (26.1% versus 8.5%, odds ratio 3.79, $P = 0.007$) than those without severe opacification. In addition, no statistically significant difference was found between the mortality rates for these two groups (Table 3).

DISCUSSION

In this study, sonographic findings in patients with acute thoracic empyema were associated with the clinical course and treatment efficacy. Patients with sonographically demonstrable septation in the pleural cavity on admission had a longer hospital stay and duration of tubal drainage and were more likely to require intrapleural fibrinolytic therapy or surgical intervention.

Effective treatment for thoracic empyema consists of two important parts: (1) appropriate antibiotics and (2) adequate drainage of the infected pleural space. Nevertheless, there is still no definite consensus on the best management for the infected pleural cavity.[8] The fibrinopurulent stage of empyema may develop within 24 to 48 hr if effective antibiotic therapy is not given.[3,9] Thoracic empyema in the fibropurulent stage sometimes progresses rapidly to the organizing stage. Surgical intervention usually is necessary under such circumstances.

A randomized study for empyema therapy showed that VATS with pleural drainage and debridement is associated with high efficacy, shorter hospital durations, and lower cost than tubal thoracotomy with fibrinolytic therapy.[10] However, patients receiving VATS are subject to the risks associated with general anesthesia as well as the morbidity and mortality related to the invasiveness of this procedure. Proper identification of candidates for early intrapleural fibrinolytic therapy or surgical

Table 3: Clinical Course, Treatment, and Outcomes for Empyema Patients With and Without Severe Opacification of Chest Radiography

	With Severe Opacification (n = 69)	Without Severe Opacification (n = 94)	95% CI of Difference	Odds Ratio (95% CI)	*P* Value
Mean hospital stay (days)*	34.2 ± 3.1	29.2 ± 1.6	–11.47–1.41	—	0.082
Duration before diagnosis (days)*	11.2 ± 0.9	9.8 ± 0.7	–4.42–1.91	—	0.433
Duration of chest tube drainage (days)*	13.2 ± 1.3	12.0 ± 1.0	–3.66–0.97	—	0.856
Fibrinolytic therapy	43 (62.3%)	41 (43.6%)	—	2.14 (1.13–4.03)	0.018
Surgical intervention	18 (26.1%)	8 (8.5%)	—	3.79 (1.54–9.35)	0.007
Mortality	9 (13.0%)	13 (13.8%)	—	0.94 (0.38–2.33)	0.885

CI, Confidence interval.
*Data presented as mean ± SEM.

intervention will help in reducing morbidity and mortality.

Transthoracic sonography is useful for guiding a thoracentesis or placing a chest tube. It is also helpful during sampling of fluid that does not layer on decubitus films and in reducing the prevalence of iatrogenic pneumothorax.[11,12] Intrapleural septa could be detected by sonography in 74% of cases of exudative pleural effusion.[13] Mobility of the septa could sometimes be demonstrated on real-time examination.[14] Because loculated collections require drainage and usually are larger than simple collections, intrapleural septa are of prognostic significance and may predict a more complicated clinical course.[15] The sonographic findings of thoracic empyema and their relationship to treatment outcome have not been analyzed previously. In this study, patients with intrapleural septa on admission had significantly longer durations of hospitalization and chest tube drainage than those without septa. They also had higher rates of treatment failure with simple drainage with or without subsequent fibrinolytic therapy, and they were more likely to require fibrinolytic therapy and surgical intervention. These findings suggest that sonographic evidence of septation may be an indication for early fibrinolytic therapy or even surgical intervention, such as VATS with debridement and drainage.

Chest radiography remains an important initial examination for patients with pleural disease.[16] The level of opacity in chest radiographs, although not representative of the amount of pleural effusion, might indicate the extent of pleuropulmonary infection. Thus, we analyzed the posteroanterior chest films to identify potential prognostic features. Our results show that different chest radiographic presentations that indicate the extent of the empyema might correlate with the need for fibrinolytic therapy as well as operation. Patients with severe opacification had higher rates of treatment failure in this study. Nevertheless, no significant differences were found in mean hospital stay, duration from symptom onset to diagnosis, duration of chest tube drainage, or mortality between groups.

CT also is helpful in establishing the diagnosis of thoracic empyema and differentiating empyema from peripheral lung abscess.[17,18] CT likewise may be used for image-guided drainage.[19,20] The findings of empyema on chest CT include parietal pleura thickening, biconvex configurations, contrast-enhanced pleura, and increased density of uptake of the adjacent subcostal tissue.[3] However, previous studies have found no correlation between the CT findings and the stages of thoracic empyema.[3] Sonography has several advantages over CT, including bedside availability for critically ill patients for whom transport may pose risks, the lack of radiation exposure, and lower cost. Sonography therefore is a very convenient tool for repeated evaluation of patients with acute thoracic empyema in assisting the management and follow-up evaluation and in assessing treatment efficacy. Thus, further study to compare sonography and CT may be warranted.

In conclusion, transthoracic sonography is useful in predicting the clinical course and treatment efficiency of patients with acute thoracic empyema. Sonographic evidence of septa on admission may indicate the need for early intrapleural fibrinolytic therapy or subsequent surgical intervention. The extent of thoracic empyema shown on the chest radiograph also may be related to treatment efficacy. Further studies to compare the efficacy of fibrinolytic therapy and VATS with debridement in patients with sonographic septation are necessary to determine the optimal management.

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