中 國 醫 藥 大 學
臨床醫學研究所
碩士學位論文

使用超音波鑑別具有氣液界面的肺膿瘍及膿胸

Ultrasound in Peripheral Pulmonary Air-fluid Lesions: Color Doppler Imaging as an Aid in Differentiating Empyema and Abscess

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論文題目

中文：**使用超音波鑑別具有氣液界面的肺膿瘍及膿胸**

英文：**Ultrasound in Peripheral Pulmonary Air-fluid Lesions: Color Doppler Imaging as an Aid in Differentiating Empyema and Abscess**

本論文係 陳鴻仁 於中國醫藥大學臨床醫學研究所完成之碩士論文，經考試委員審查及口試合格，特此證明。

考試委員

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中文摘要

背景：此實驗的目的是試圖以超音波影像（特別是都卜勒彩色超音波的運用）來鑑別診斷肺部週邊的氣液界面病灶究竟是由肺膿瘍或膿胸所引起。

方法：在2003年一月至2007年十月的回朔性資料庫裏，尋找具有氣液界面病灶而且接受過彩色超音波檢查的病患。共有34位肺膿瘍及30位膿胸。有四項超音波影像的特徵特別被觀察分析：1. 氣液界面病灶的外圍特徵（包括壁的厚度，內緣外緣是否平整，以及氣液界面與邊界所形成的角度）；2. 壁層及臟層肋膜是否能以超音波看出分離； 3. 氣液界面病灶的裏面特徵（包括是否有懸浮的微小氣泡、複雜分隔的肋膜積液或肺塌陷）；4. 以都卜勒彩色超音波觀察包圍氣液界面的血管是屬於肺部實質化或塌陷所有。

結果：在超音波的影像裏，複雜分隔的肋膜積液以及肺塌陷是膿胸的專屬特徵，但敏感度分別只有40% (12/30)及 47% (14/30)。但是假若以都卜勒彩色超音波觀察氣液界面，**發現所包圍的血管是肺部實質化所有，那此氣液界面就是肺膿瘍。**此特徵的敏感度，專一性，陽性預測率以及陰性預測率分別為94%，100%，100%以及94%。

結論：以都卜勒彩色超音波鑑別肺部週邊的氣液界面病灶究竟是肺膿瘍或膿胸所引起，具有高度專一性而且沒有危險性。

關鍵字：肺膿瘍、膿胸、氣液界面、都卜勒彩色超音波

英文摘要

Background: The aim of this study was to re-evaluate the clinical significance of sonographic appearances, in particular the application of color Doppler ultrasound (US) imaging, in discriminating peripheral air-fluid lung abscess from empyema.

Methods: We retrospectively collected those patients who had had peripheral air-fluid lesions due to empyema or lung abscess, and undergone color Doppler US and gray-scale US examinations between January 2003 and October 2007. A total of 34 patients with confirmed lung abscess and 30 patients with empyema were identified. Four sonographic characteristics were observed and analyzed: 1. the wall characteristics of the lesions (wall width, luminal margin, outer margin and chest wall angle); 2. split pleura sign; 3. internal echogenicity (suspended microbubble sign, complex-septated effusions and passive atelectasis); 4. identification of color Doppler US vessel signals in peri-cavitary lesions (consolidation or atelectasis).

Results: Among the sonographic characteristics, complex-septated effusions and passive atelectasis were specific for empyema, but the sensitivity was only 40% (12/30) and 47% (14/30), respectively. Identification of color Doppler US vessel signals in peri-cavitary consolidation was the most useful and specific for lung abscess. In our series, if we define the identification of color Doppler US vessel signals in peri-cavitary consolidation as a predictor for peripheral lung abscess, we can achieve sensitivity, specificity, positive predictive value and negative predictive value of 94%, 100%, 100% and 94%, respectively.

Conclusions: Color Doppler US is powerful in differentiating the peripheral air-fluid abscess from empyema, with high specificity and without any risk.

Key words: Lung abscess, empyema, air-fluid level, color Doppler ultrasound

誌謝辭

入學前我對所謂的分子實驗室沒有任何概念，也對“Bench”，中譯“長檯子”為何會跟實驗室扯上邊百思不解，但是卻想像也許有一天，一個平凡無奇的午後，那時我的細胞培養陷入困境，一隻生理實驗課脫逃的青蛙突然就從水槽裏跳出來。立時，尖叫聲與追捕聲混雜的分貝數就要破百。三十分鐘過後，青蛙又跳進牆角的雜物堆裏從此消失了。我收拾桌面，看著青蛙三趾、四趾交雜的腳印與打翻的試劑，卻發現細胞有著驚人的變化……

這個揉合「幽門桿菌發現過程」與「老鼠報恩」的故事當然沒有在我的碩班學年中發生，而我那白髮愈拔愈多的腦袋瓜也作不出更驚人的白日夢來。生活，就是一早進實驗室，看門診，查房，聽老師上課或去學校幫學生上課，回家管小孩或被小孩管，讀書，煩惱，如此更迭順序，日復一日。去年，爸爸生病，又多了一項：查房完開車回嘉義，三小時後又從嘉義趕回台中。

謝謝徐武輝教授，我的胸腔超音波技術及論文寫作都由他啟蒙，直到現在我仍留有他四年前幫我改得密密麻麻的論文初稿。我對他最由衷感激的是：爸爸重病時，他晚上七點多來探望，在病房浴室外等了爸爸近二十分鐘，之後，坐下來聽爸爸說了好長一串話；幾天後，他出國開會前又特地來了一次，只可惜爸爸那時肝昏迷又發作。

謝謝佘玉萍及顧正崙老師，指導一個先前對基礎醫學沒有任何概念的學生是累人的；對愚笨的問題不厭其煩的回答而且帶著微笑顯示修養良好。特別是佘老師，初始為了建立實驗流程，花兩、三個小時處理一個肋膜積液檢體，之後一代又一代的細胞培養及老鼠皮下腫瘤種植所花費的時間更是難以計數。只因我的基礎實驗成果尚待充實而不克在此碩士論文中呈現，但是佘老師對學生的指導及努力必須在此強調說明。

謝謝張君銘對於實驗技術的指導，三不五時還要在我為病人的事情焦頭爛額時扮演救火隊。謝謝慷慨提供肋膜積液的病人。謝謝默默支持的爸爸、媽媽、太太以及我所有的家人好友。

當初讀碩士班的目的是看不懂 New England Journal Medicine 裏那些寫給醫學生看的轉譯論文，而肺癌新藥的發展又如火如荼，假如我對藥物機轉都一知半解怎麼解釋給病人聽？碩士班兩年，儘管實驗技術仍舊稚嫩，神奇的青蛙也沒有出現，還好，我大致看得懂“CNS”(Cell, Nature, Science)的論文了。也了解，基礎科學家長時間窩在一只“工作檯”(Bench)上反覆實驗只為了探究一個細胞裏成千上萬個訊號的其中一個謎團，是多麼讓人佩服的事情。

第一章 前言

第一節 研究背景

The differentiation between lung abscess and empyema is important. Prolonged antibiotic therapy and postural drainage are appropriate for lung abscess, but early external drainage is essential therapy for empyema. Nevertheless, the differentiation by chest radiograph alone is difficult when the empyema presents with an air-fluid level.[1,2] Friedman and Hellekant[3] found the most helpful features for distinguishing lung abscess from empyema are the shape and the relationships of the air-fluid level to the chest wall: empyema is fusiform and over posterior costophrenic angle location; abscess tend to be spherical and farther from the ribs. However, the method does not work when the air-fluid lung abscess attached to the chest wall.[4] In selected cases, lung abscess and empyema may coexist, further complicating the clinical interpretation.

Thoracic computed tomography (CT) proves valuable in differentiating lung abscess from empyema.[5,6] However, the problems of radiation exposure and contrast-induced renal failure sometimes limit its application. Furthermore, CT is still a relatively expensive imaging examination. With the advances in imaging technology and computerized functions, chest ultrasound (US) examination has been widely used in the diagnosis and management of lung cancer, uncommon pulmonary consolidations, mediastinal tumors, and pleural diseases.[7,8] As reported, the sonographic features of the wall characteristics, shape, chest wall angle and split pleura sign (thickened visceral and parietal pleural layers separated by empyema) [6] are helpful in differentiation of lung abscess and empyema.[4,9] Lin et al[9] also showed that the curtain sign (the movement of air-fluid level synchronized with respiration in ultrasonography) is valuable in distinguishing pyopneumothorax from lung abscess.

In our daily practice, the split pleura sign was hardly observed in sonography. The sensitivity of the curtain sign in air-fluid empyema may be lower due to lesion-pleura adhesion resulting from strong inflammation. Furthermore, lung abscess has not revealed specific imaging signs in previous reports, whether with CT or US.

第二節 研究目的

The role of color Doppler US in this issue remains undetermined. Herein, we collected and analyzed the sonographic appearances of peripheral air-fluid lesions in empyema or lung abscess in our hospital. The aim was to re-evaluate the clinical significance of the sonographic appearances of peripheral air-fluid lung abscess and empyema, in the hope that the sonographic images, in particular the application of color Doppler US imaging, may be helpful in the differential diagnosis between lung abscess and empyema.

第二章 研究方法

第一節 研究材料

We retrospectively collected and carefully reviewed the medical records of those patients who had had peripheral air-fluid lesions due to empyema or lung abscess, and undergone color Doppler US and gray-scale US examinations between January 2003 and October 2007 (58 months) in our hospital. A mixed diagnosis of empyema and lung abscess were excluded (n =2). A total of 34 patients with confirmed lung abscess and 30 patients with empyema were identified: all had demonstrated peripheral air-fluid lesions on their chest radiography and/or CT. A diagnosis of lung abscess or empyema was accepted based on an appropriate clinical course, thoracic CT images,[6] serial follow-up of chest radiographs performed, and response to standard therapy. The study was approved by the Institutional Review Board in our hospital.

Of the 34 patients with lung abscess, 29 were men and 5 were women, with ages ranging from 33 to 79 years (mean, 58 years). The lesion was on the right in 25 and on the left in 9 patients. All 30 patients with empyema were men. Their ages ranged from 26 to 86 years, with a mean age of 50 years. The lesion was on the right in 20 and on the left in 10 patients.

第二節 研究設計

Chest US Examination

All patients underwent chest sonographic examinations with an Aplio-80 US machine (Toshiba Medical Systems Co, Ltd, Tokyo, Japan) equipped with a 3.75-MHz convex transducer under the fixed parameter settings such as power, gain setting of 80 decibels and transmitted focus at a depth of 6 cm in routine practice. Without prior knowledge of the definite diagnosis, chest US was performed by 3 well-trained pulmonologists with more than five-year experiences under the following standard procedures.

The patients were examined in supine or sitting positions, as clinically appropriate. Gray-scale US was

first used to localize the whole lesion and then a color Doppler US examination was added. Before the start of the color Doppler US examination, the Doppler filter was usually set at 100 Hz to eliminate low-frequency signals from vessel wall motion, and to avoid interference from respiratory and cardiac movement.[10] The color Doppler window was focused on the whole wall of air-fluid lesion to detect flow signals; if no signals were detected, the steering angle of the color Doppler window was adjusted to -45° or +45° to avoid the false-negative results. The blood flow in a vessel was seen as a persistent area of color signal with a tubular, curvilinear, or branching distribution on real-time images; color signals that persisted in the same location during the respiratory cycle were considered to be blood flow signals and not due to interference.[11] The sonographic appearances were recorded regularly on the hard disc of the commercial US machine.

Interpretation of Sonographic Appearances

The recorded sonographic appearances were analyzed carefully, and the following 4 characteristics were observed: 1. the wall characteristics of the lesion (wall width, luminal margin, outer margin and chest wall angle); 2. split pleura sign; 3. internal echogenicity (suspended microbubble sign, complex-septated effusions and passive atelectasis); 4. identification of color Doppler US vessel signals in peri-cavitary lesions (consolidation or atelectasis).

The suspended microbubble sign was defined as the image scattered with numerous hyperechoic pinpoints that moved synchronously with respiration in various directions.[12] Complex septated effusions were defined as the presence of strands (hyperechoic lines within the effusion) floating inside the pleural space, web-like or branching.[13] Passive atelectasis was defined as homogeneously echoic transformations with band-like shape on the extent of intrapleural fluid.[14,15]

In order to obtain interpretations of the sonographic appearances of the lesion and inter-observer agreement, three chest physicians (the authors: H.-J.C., C.-Y.T., and W.-H.H.) independently interpreted all the static images on the recorded hard discs without knowledge of clinical data, laboratory tests, or pathologic findings. The final interpretations had the concordant agreement of at least two physicians. When there was not unanimity on a case, that case was labeled as one with interobserver variability.

第三節 統計方法

The characteristics of sonographic appearances in air-fluid lung abscess and empyema were compared by chi-square test with the use of SPSS software, version 12.0 (SPSS Inc., Chicago, IL, USA). Statistically, a p value <0.05 was considered to be significant.

第三章 研究結果

第一節 描述性統計分析

The sonographic features of lung abscess and empyema are summarized in Table 1. The differences in wall characteristics (width uniformity, luminal and outer margins), complex-septated effusions, passive atelectasis and identification of color Doppler US vessel signals in peri-cavitary consolidation were significant in the differential diagnosis of these two groups of patients. The chest wall angle, split pleura sign and suspended microbubble sign had limited value in making a differential diagnosis between the two diseases.

第二節 推論性統計分析

In further analyses of wall characteristics, the air-fluid lesions with width uniformity (48% [14/29]), and smooth luminal (52% [15/29]) and outer margins (50% [15/30]) were highly suggestive of empyema (Fig. 1). Lung abscess typically had an irregular wall width (91% [20/22]), irregular luminal margin (91% [21/23]) and blurred outer margin (91% [30/33]) (Fig. 2). However, some wall characteristics could not be evaluated in 20% (13/64) of patients because of a poor acoustic window. The inter-observer variabilities were also higher in the interpretation of the wall characteristics (51% of width uniformity, and 40% of luminal and 32% of outer margins), leading to unreliable conclusions.

On the other hand, the identification of internal echogenicity (suspended microbubble sign, complex-septated effusions and passive atelectasis) and color Doppler US vessel signals in peri-cavitary consolidation had good inter-observer agreement (92%~100%). Suspended microbubble sign could be found in 15% (5/34) of lung abscess and 23% (7/30) of empyema, but without statistical significance. By contrast, complex-septated effusions and passive atelectasis (Fig. 1) were specific for empyema, but the sensitivity was only 40% (12/30) and 47% (14/30), respectively. Among the analyzed sonographic characteristics, identification of color Doppler US vessel signals in peri-cavitary consolidation was the most useful and specific for lung abscess (Fig. 2). In our series, if we defined the identification of color Doppler US vessel signals in peri-cavitary consolidation as a predictor for peripheral lung abscess, then we could achieve the sensitivity, specificity, positive predictive value and negative predictive value of

94%, 100%, 100% and 94%, respectively.

第四章 討論

第一節 結果討論

Lung abscess is defined as a localized area of suppuration with destruction of the lung parenchyma. Empyema is a pleural-based lesion. Distinguishing between empyema and lung abscess on the basis of conventional radiographic findings is often difficult (Fig. 3a, 4a, 5a and 6a), because of the inability to resolve adequately the pleural-parenchymal interface; thus, the actual site of the air-fluid level cannot be determined.[3]

Plain film and CT findings emphasizing the shape and wall characteristics have been reported as being useful for differentiating lung abscess from empyema: abscess tends to be round and empyema tends to be lenticular; abscess usually appears with an irregular wall width (irregular luminal and outer margins), and empyema shows width uniformity.[6] Our sonographic study had the same findings. However, exceptions often occur (Fig. 3b). By changing the sonographic plane, the shape may shift from lenticular to oval or round, and vice versa.[4] In our series, the inter-observer variabilities were around 32~51% in the interpretation of the wall characteristics. How smooth should be considered “smooth”? How uniform should be considered “uniform”? Apparently, this differential method is too subjective to be reliable.

Lung compression and split pleura sign were specific features for empyema in CT.[6] Compression of the adjacent lung was identified by noting distorted and bowed bronchi and/or pulmonary vessels around the periphery of the lesion.[6] As empyema progresses, a fibrin peel coats the surfaces of the visceral and parietal pleural layers with ingrowth of capillaries and fibroblasts and subsequent thickening. This forms the basis of the split pleura sign. The split pleura sign is usually seen on contrast material–enhanced chest CT images.[6] In the sonographic exam, it is difficult to differentiate the visceral/parietal pleural layers from lung parenchyma without contrast material enhancement. We could identify only 1 split pleura sign in 30 empyemas. The sonographic appearance of passive atelectasis develops homogeneously echoic transformations with band-like shape on the extent of intrapleural fluid (Fig. 1, 5c and 5d).[15] Passive

atelectasis is specific for empyema in sonography, like lung compression in CT, but was seen in 47% of all empyemas in our series.

Suspended microbubble sign and complex-septated effusions are specific sonographic characteristics. Lin et al[9] found that the suspended microbubble sign might be of value in differentiating empyemic and nonempyemic hydropneumothorax. However, the suspended microbubble sign was not specific for empyema. As reported and from our experience, both empyema and lung abscess could have the suspended microbubble sign, in which the pus was expected to be aspirated (Fig. 3b and 4b).[9,12] On the other hand, the complex-septated appearance was specific for pleural diseases, such as complicated parapneumonic effusions, empyema or tuberculous pleural effusions.[8] Visualization of complex-septated effusions was noted in only 40% of all air-fluid empyemas (Fig. 1).

Of the imaging examinations (chest radiograph, CT, US, magnetic resonance imaging, angiography and fluoroscopy) used in chest medicine, color Doppler US is the only imaging modality capable of assessing the vessel signals in peripheral pulmonary lesions.[10] In pulmonary consolidation, Yang et al[16] found Doppler US was excellent in demonstrating blood flow present in the pulmonary vasculature. The vascular linear echoes could be traced to the hilar region, which may join the pulmonary artery.[16] Lung abscess is surrounded by the consolidated lung parenchyma, so we assume that the air-fluid abscess may be encircled by pulmonary vasculature. Thoracic empyema, by comparison, is defined as pus in the pleural cavity. Compression of the adjacent lung by empyema[6] may cause a local reduction of blood flow.[17] In comparing Figs. 3 and 4, both pictures had almost the same gray-scale sonographic appearance, and we could not distinguish between lung abscess and empyema confidently until the application of color Doppler US. If we define the identification of color Doppler US vessel signals in peri-cavitary consolidation as a predictor for lung abscess, we can achieve sensitivity, specificity, positive predictive value and negative predictive value of 94%, 100%, 100% and 94%, respectively. There were no inter-observer variabilities in our series, because color Doppler vessel signals were easy to recognize.

Although thoracic CT proves valuable in differentiating lung abscess from empyema,[5,6] it has some

limitations. In Figs. 5 and 6, almost the same air-fluid characteristics and split pleura sign are seen in CT. However, we could identify the difference with US. There are also some advantages to sonography which make US cooperate with CT in differentiating lung abscess from empyema. First, US is real-time. Second, US is portable and convenient, and the diagnostic and therapeutic procedures can be done at bed-side for critically ill patients.[18] Third, color Doppler US is the only imaging modality capable of assessing the vessel signals in peripheral lung abscess.

第二節 研究限制

However, there were some weak points in this clinical study. First, the retrospective reading of static images could not reach 100% correct. Second, we might misjudge “the vessels in passive atelectasis” as “the vessels in peri-cavitary consolidation” although the rate of identification of color Doppler US vessel signals is 14% (2/14) in passive atelectasis and only 6% (2/30) in empyema in our series. To avoid mistakes there are 3 key points in our experience: First, the passive atelectasis in empyema (Fig. 5c) is band-like shape with smooth margin and straight air-bronchograms (not like typical pulmonary consolidation (Fig. 2), characterized by irregular, serrated and somewhat blurred margin and a marked tree-shaped bronchoaerogram with ramifications[19]); second, the vessels in lung atelectasis, like air-bronchogram, are relatively straight (Fig. 5d);[14,15] third, the passive atelectasis does not surround the air-fluid lesion continuously (Fig. 5c). On the contrary, the lung abscess is surrounded by lung parenchyma with prominat consolidation (Fig. 2 and 6c); the vessels in pulmonary consolidation are abundant, branching and twisted (Fig. 2, and 6d).

第五章 結論

In conclusion, color Doppler US is powerful in differentiating the air-fluid abscess from empyema, with high specificity and without any risk. It is worthy of being widely used in chest medicine.

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Table 1. Sonographic Features for the Differential Diagnosis of Air-fluid Lung Abscess and Empyema

Sonographic Findings	Lung Abscess (N = 34) % (no.)	Empyema (N = 30) % (no.)	Inter-observer Variabilities % (no.)	P value
Wall characteristics				
Width uniformity	9 (2/22)	48 (14/29)	51 (26/51)	0.003*
Smooth luminal margin	9 (2/23)	52 (15/29)	40 (21/52)	0.001*
Smooth outer margin	9 (3/33)	50 (15/30)	32 (20/63)	0.0003*
Chest wall angle:				
Acute	28 (9/32)	45 (10/22)	22 (12/54)	0.19
Obtuse	31 (10/32)	14 (3/22)		0.14
Both	41 (13/32)	41 (9/22)		0.98
Split pleura sign	0 (0/34)	3 (1/30)	9 (6/64)	0.28
Internal echogenicity:				
Suspended microbubble sign	15 (5/34)	23 (7/30)	3 (2/64)	0.38
complex-septated effusions	0 (0/34)	40 (12/30)	2 (1/64)	0.00004*
Passive atelectsis	0 (0/34)	47 (14/30)	8 (5/64)	0.000007*
Identification of color Doppler US vessel signals in peri-cavitary consolidation	94 (32/34)	0 (0/30)	0 (0/64)	<0.000001*

Note.—Not all features could be assessed in every patient.

* Significant, analyzed by chi-square test.

Figures

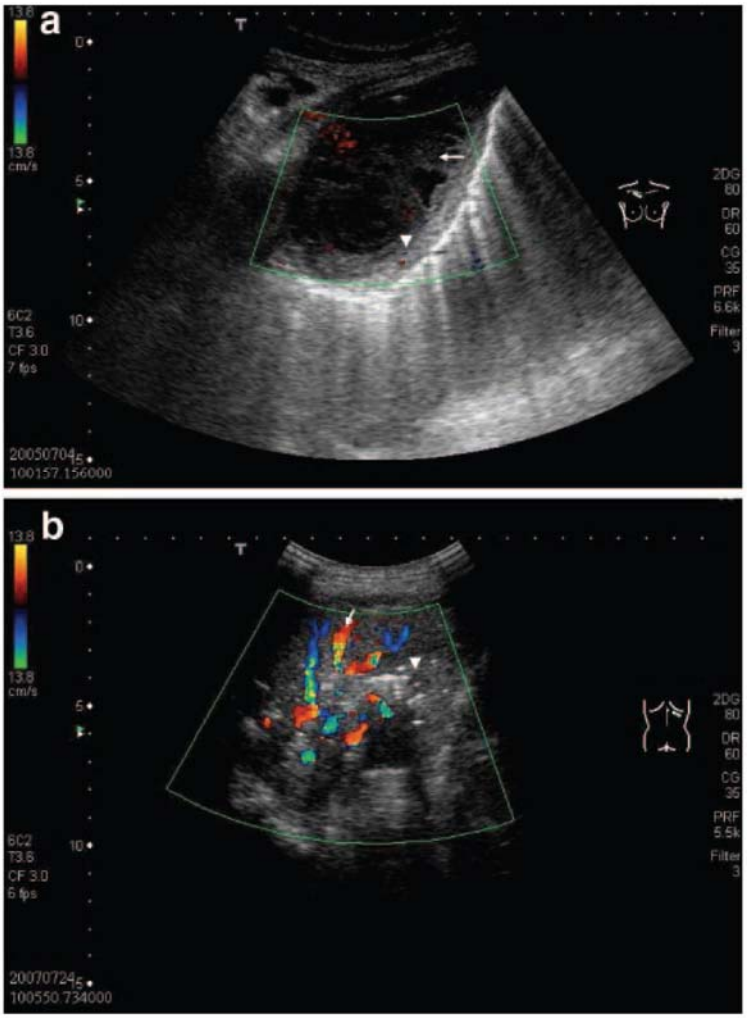

FIGURE 1. *Top*, *a*: empyema. A 32-year-old man had an empyema in the right upper lobe. Ultrasound examination of the chest revealed a hypoechoic lesion with complex-septated effusions (arrow), passive atelectasis (arrowhead), width uniformity, and smooth luminal and outer margins. Color Doppler ultrasound could not identify vessel signals in pericavitary atelectasis. *Bottom*, *b*: abscess. A 64-year-old man had an abscess in the right lower lobe. Ultrasound examination of the chest revealed a hypoechoic lesion with typical pulmonary consolidation (characterized by tree-shaped air bronchogram with ramifications) [arrowhead], irregular wall width, and irregular luminal and outer margins. Color Doppler ultrasound could identify vessel signals in pericavitary consolidation (arrow).

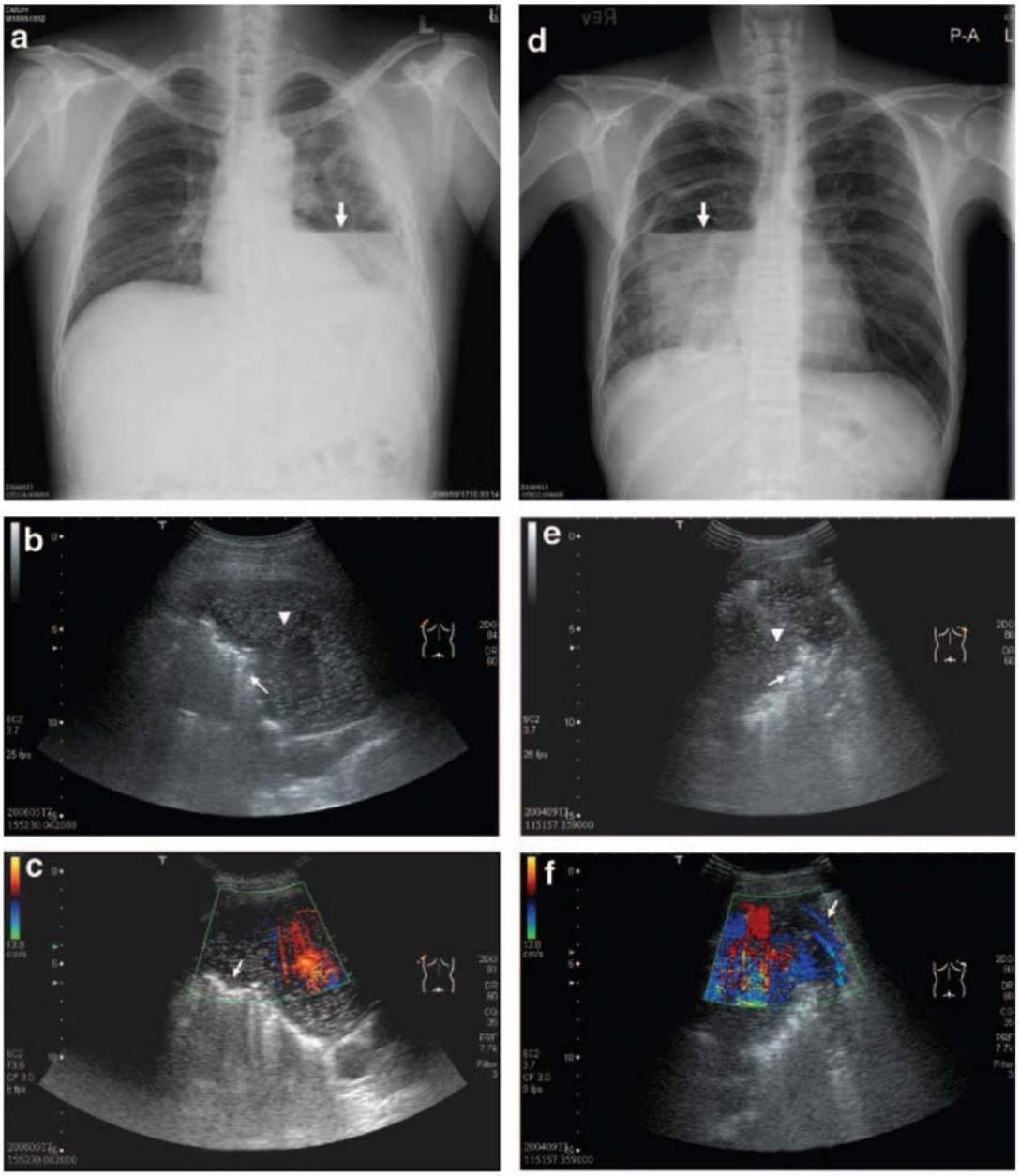

FIGURE 2. *Top left*, *a*, to *bottom left*, *c*: empyema. *Top left*, *a*: radiograph of the chest of a 43-year-old man shows an air-fluid level (arrow) in the left lower lobe. *Middle left*, *b*: grayscale ultrasound examination reveals a hypoechoic lesion with suspended microbubble sign (arrowhead), irregular wall width, and irregular luminal and outer margins (arrow). The sonographic characteristics favored lung abscess. *Bottom left*, *c*: color Doppler ultrasound, however, could not identify vessel signals in pericavitary lesion (arrow), which is the typical finding of empyema. *Top right*, *d*, to *bottom right*, *f*: abscess. *Top right*, *d*: radiograph of the chest of a 37-year-old man shows an air-fluid level (arrow) in the right lower lobe. *Middle right*, *e*: grayscale ultrasound examination reveals a hypoechoic lesion with suspended microbubble signs (arrowhead), irregular wall width, and irregular luminal and outer margins (arrow). The sonographic characteristics favored lung abscess. *Bottom right*, *f*: color Doppler ultrasound also could identify vessel signals in pericavitary consolidation (arrow).

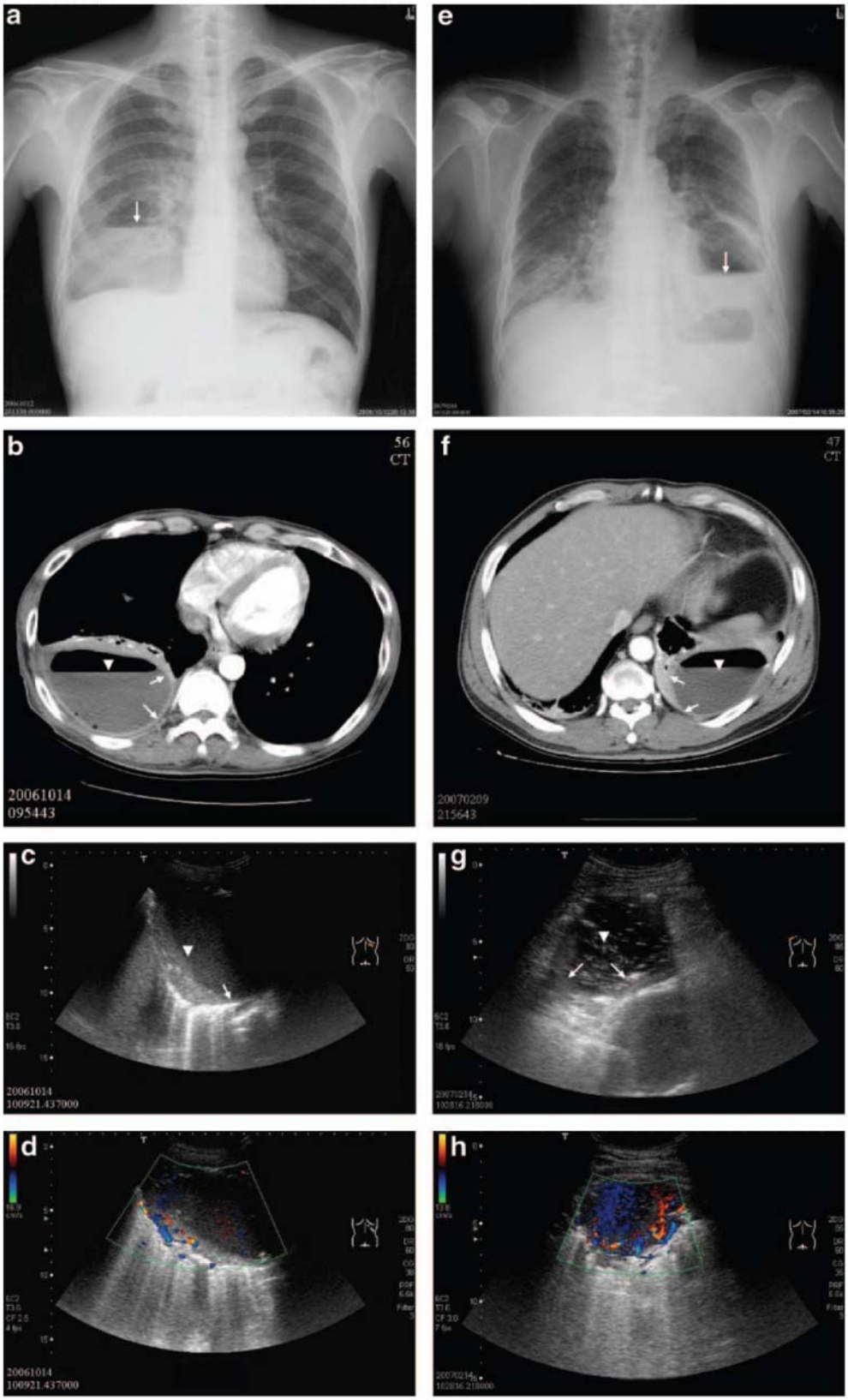

FIGURE 3. *Top left*, *a*, to *bottom left*, *d*: empyema. *Top left*, *a*: chest radiograph of a 39-year-old man shows an air-fluid level (arrow) in the right lower lobe. *Top center left*, *b*: CT scan image shows a cavitary lesion with an air-fluid level (arrowhead) and split pleura sign (arrow). *Bottom center left*, *c*: grayscale ultrasound examination reveals a band-like shape with smooth margin and straight air-bronchograms (arrowhead) [not like typical pulmonary consolidation characterized by irregular, serrated, and somewhat blurred margin and a marked tree-shaped air bronchogram with ramifications]. The band-like shape does not surround the air-fluid lesion continuously (arrow), which is a typical

FIGURE 3. (continued) presentation of passive atelectasis. *Bottom left*, *d*: the vessels in passive atelectasis, like the air bronchogram, are relatively straight. *Top right*, *e*, to *bottom right*, *h*: abscess. *Top right*, *e*: radiograph of the chest of a 47-year-old man shows an air-fluid level (arrow) in the left lower lobe. *Top center right*, *f*: CT scan image shows a cavitary lesion with an air-fluid level (arrowhead), mimicking split pleura sign (arrow). *Bottom center right*, *g*: grayscale ultrasound examination of the chest reveals a hypoechoic lesion with suspended microbubble sign (arrowhead), which is surrounded by whole-lung parenchyma (arrow). *Bottom right*, *h*: color Doppler ultrasound can identify vessel signals in pericavitary consolidation in a lung abscess. The vessels in pulmonary consolidation are abundant, branching, and twisted.