# The Comet-tail Artifact

## An Ultrasound Sign of Alveolar-Interstitial Syndrome

DANIEL LICHTENSTEIN, GILBERT MÉZIÈRE, PHILIPPE BIDERMAN, AGNÈS GEPNER, and OLIVIER BARRÉ

Service de Réanimation Médicale and Service de Radiologie, Hôpital Ambroise-Paré, Boulogne (Paris), and Service de Réanimation Polyvalente, Centre Hospitalier Général, Saint-Cloud (Paris), France

**Can ultrasound be of any help in the diagnosis of alveolar-interstitial syndrome? In a prospective study, we examined 250 consecutive patients in a medical intensive care unit: 121 patients with radiologic alveolar-interstitial syndrome (disseminated to the whole lung, n = 92; localized, n = 29) and 129 patients without radiologic evidence of alveolar-interstitial syndrome. The antero-lateral chest wall was examined using ultrasound. The ultrasonic feature of multiple comet-tail artifacts fanning out from the lung surface was investigated. This pattern was present all over the lung surface in 86 of 92 patients with diffuse alveolar-interstitial syndrome (sensitivity of 93.4%). It was absent or confined to the last lateral intercostal space in 120 of 129 patients with normal chest X-ray (specificity of 93.0%). Tomodensitometric correlations showed that the thickened sub-pleural interlobular septa, as well as ground-glass areas, two lesions present in acute pulmonary edema, were associated with the presence of the comet-tail artifact. In conclusion, presence of the comet-tail artifact allowed diagnosis of alveolar-interstitial syndrome.** Lichtenstein D, Mézière G, Biderman P, Gepner A, Barré O. The comet-tail artifact: an ultrasound sign of alveolar-interstitial syndrome.

AM J RESPIR CRIT CARE MED 1997;156:1640–1646.

The diagnosis of alveolar-interstitial syndrome is based on chest X-ray. However, in critical care units, chest X-ray is performed at the bedside and technologic deficiencies may make this diagnosis difficult. Can ultrasound, a noninvasive, easily implemented technique, be of any use? Basically, the problem is that air stops the progression of the ultrasound beam, and only reverberation artifacts are visible under the lung surface. The lung is therefore usually considered poorly accessible to ultrasound. Yet clinical experience and review of the literature show that lung ultrasound has been previously proposed for diagnosing pneumothorax (1–4) or alveolar consolidation (5–8).

On the other hand, ultrasound patterns of the aerated lung are not well known, and airy artifacts arising from the lung surface have not been extensively studied. In fact, two opposed types of artifacts can clearly be differentiated arising from the lung surface. One type is a roughly horizontal repetition artifact. The other is a roughly vertical narrow-based artifact spreading up to the edge of the screen. According to a review of the literature, narrow repetition artifacts are known as "comet-tail" (9) or "ring-down" (10) artifacts. The comet-tail artifact was described in 1982 concerning an intra-hepatic shotgun pellet (9). It had also been noted at the lung surface in normal or pathologic conditions (9, 11), although no correlation had been made with a pathologic feature. As a consequence, no practical use had been made from this artifact at the lung level. Besides, in the first study (9), long and short varieties of comet-tail artifacts are presented without distinction. The artifact described in the present study corresponds to a long variety of comet-tail artifact, the one that extends to the edge of the screen.

To our knowledge, the normal or pathologic nature of the comet-tail artifact at the lung surface has not been established. Likewise, the horizontal artifact arising from the lung surface and its potentially normal significance have not been described. Clinical experience suggests that the comet-tail artifact arising from the lung-wall interface is very often seen in patients suffering from acute pulmonary edema. The aim of this study was to investigate whether this artifact was related to the presence of radiologic alveolar-interstitial syndrome in a series of critically ill patients. To our knowledge, the relation between the comet-tail artifact and alveolar-interstitial syndrome has not yet been dealt with in the literature, except in a preliminary report (12).

## METHODS

### Patients

During an 18-mo period, 282 consecutive patients (without pneumothorax) admitted to our intensive care unit were included in a prospective study. Thirty-two patients were excluded because of inconclusive radiography (noninterpretable, poorly defined X-ray, or patterns difficult to analyze; n = 29) or a noninterpretable ultrasound examination (n = 3). Therefore, 250 patients were included. Mean age was 58.3 yr (range, 17 to 89 yr). Fifty-three percent were on mechanical ventilation. Patients were divided into two groups. In 121 patients, a typical alveolar-interstitial syndrome was present on the bedside chest X-ray. Clinical features related to this alveolar-interstitial syndrome were adult respiratory distress syndrome (ARDS) (n = 31), pneumonia (n = 30), acute cardiogenic pulmonary edema (n = 37),

(*Received in original form July 23, 1996 and in revised form May 9, 1997*)

Correspondence and requests for reprints should be addressed to Daniel Lichtenstein, Service de Réanimation Médicale, Hôpital Ambroise-Paré, 9, avenue du Général Charles-de-Gaulle, F-92100 Boulogne (Paris), France.

exacerbation of chronic interstitial lung disease (n = 6), and miscellaneous (n = 17). In 129 patients, bedside chest X-ray did not show alveolar-interstitial syndrome. Cause of admission to the intensive care unit was acute asthma (n = 10), pulmonary embolism (n = 6), exacerbation of chronic obstructive pulmonary disease (COPD) without pneumonia (n = 11), other respiratory insufficiencies (n = 5), sepsis without respiratory failure (n = 16), neurologic disorder (n = 21), attempted suicide (n = 21), gastrointestinal tract bleeding (n = 15), and miscellaneous (n = 24).

### Chest X-ray

A conventional antero-posterior chest X-ray was performed at the bedside, with a VMX portable unit (General Electric, CGR, Monza, Italy), and was read by an independent radiologist (O.B.) unaware of the ultrasound findings. In 121 patients, X-ray showed alveolar or interstitial syndrome, which was defined by the presence of alveolar opacities (ill-defined shadowing, confluent opacities with air bronchograms) and/or interstitial opacities (septal lines, linear, reticular, or nodular opacities); alveolar-interstitial syndrome extended to the whole lung in 92 patients and was localized in 29 patients. In 129 patients, chest X-ray was free of any alveolar-interstitial syndrome.

### Ultrasound

An ADR-4000 portable unit (Advanced Diagnostic Research, Tempe, AZ), equipped with a 3.0-MHz mechanical transducer for cardiac use, or a Hitachi Sumi 405 (Hitachi Medical Corporation, Tokyo, Japan) with a 3.5-MHz cardiac probe, was used by the same investigator (D.L.) unaware of the radiologic findings. Ultrasonographic examination and bedside chest X-ray were performed within 2 days after admission to the intensive care unit. Ultrasound was performed the same day as chest X-ray. Longitudinal scans of the anterior and lateral chest wall were taken in the supine position. The anterior chest wall was delineated from the clavicles to the diaphragm and from the sternum to the anterior axillary line. The lateral chest wall was delineated from the armpit to the diaphragm and from the anterior to the posterior axillary line. The area under focus was the hyperechogenic interface between the chest wall and the surface of the lung (or lung-wall interface). The comet-tail artifact arising from the lung-wall interface was the elementary pattern analyzed. It was defined as a hyperechogenic narrow-based reverberation type of artifact, spreading like a laser-ray up to the edge of the screen. The pattern considered pathologic was the presence of multiple comet-tail artifacts (at least three between two ribs in one longitudinal scan) fanning out from the lung-wall interface (Figure 1, *upper panel*). A distance $\leqslant 7 \pm 1$ mm was observable between two comet-tail artifacts. "Multiple comet-tail artifacts fanning out from the lung-wall interface" will henceforth be referred to as "the artifact." When lung consolidation (or pleural effusion) was directly visible using ultrasound, only the surrounding areas were investigated. After ultrasonographic examination, the 250 patients were classified into one of the following categories: (*1*) A positive test was defined as the presence of "the artifact" (n = 157). It was either disseminated or confined laterally to the last intercostal space. Disseminated "artifact" was diffuse (i.e., all over the anterior and lateral lung surface, wherever the probe was laid on the chest wall), lateral (i.e., visible over the lateral chest wall), anterior, or patchy (i.e., mingling of pathologic areas with areas free of "artifact," or fewer than three comet-tail artifacts per section). "The artifact" confined laterally to the last intercostal space above the diaphragm, a particular location previously noticed to be frequent in healthy subjects, was studied on its own. (*2*) A negative test was defined as complete absence of "the artifact" (n = 93). In these cases, the pattern comprised regularly spaced, roughly horizontal hyperechogenic lines, spreading from the lung-wall interface, with the same distance between each horizontal line (Figure 1, *lower panel*). Rare, isolated comet-tail artifacts were occasionally visible.

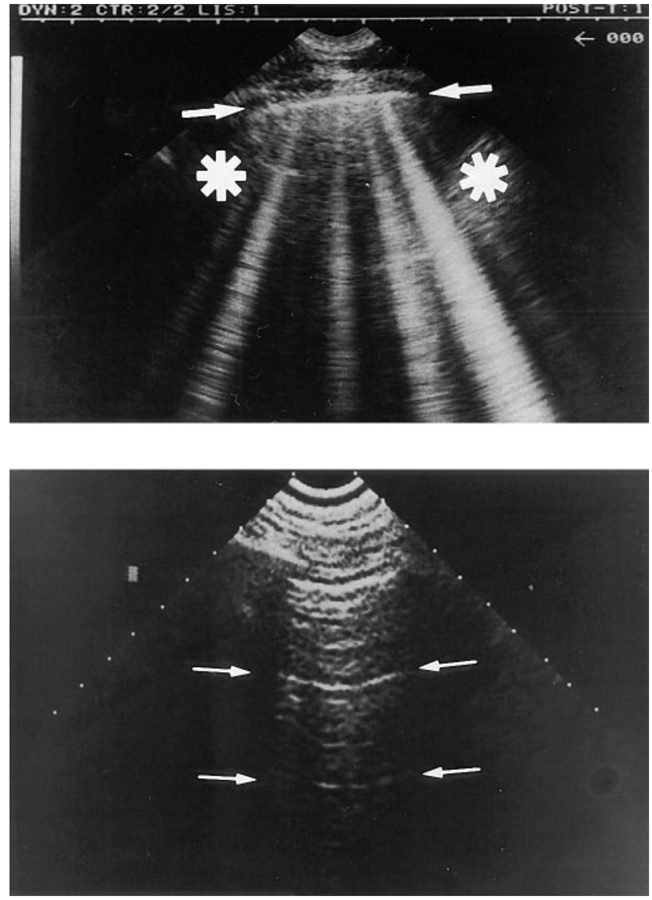


***Figure 1.*** Ultrasound. (*Upper panel*) Typical comet-tail artifacts obtained from a patient with acute pulmonary edema. Between two ribs (* = acoustic shadow of rib), a hyperechogenic line represents the interface between the lung and the chest wall (*arrows*). Several comet-tail artifacts are fanning out from the lung-wall interface, separated from each other by a distance of 8 mm. (*Lower panel*) Normal subject. The lung-wall interface reverberates at regular intervals, creating parallel, roughly horizontal hyperechogenic lines (*fine arrows*).

### Computerized Tomography (CT)

In 29 patients, a thoracic CT scan was recorded on the day of ultrasound examination (ARDS, n = 14; acute cardiogenic pulmonary edema, n = 3; interstitial lung diseases, n = 4; COPD, n = 1; asthma,

**TABLE 1**

**CORRELATION BETWEEN RADIOLOGIC AND SONOGRAPHIC PATTERNS**

| | Artifact Extending Beyond the Last Intercostal Space | Artifact Confined to the Last Intercostal Space | Absence of Artifact | Total |
|---|---|---|---|---|
| Diffuse alveolar-interstitial syndrome | 86 | 3 | 3 | 92 |
| Localized alveolar-interstitial syndrome | 19 | 4 | 6 | 29 |
| Absence of alveolar-interstitial syndrome | 9 | 36 | 84 | 129 |
| Total | 114 | 43 | 93 | 250 |

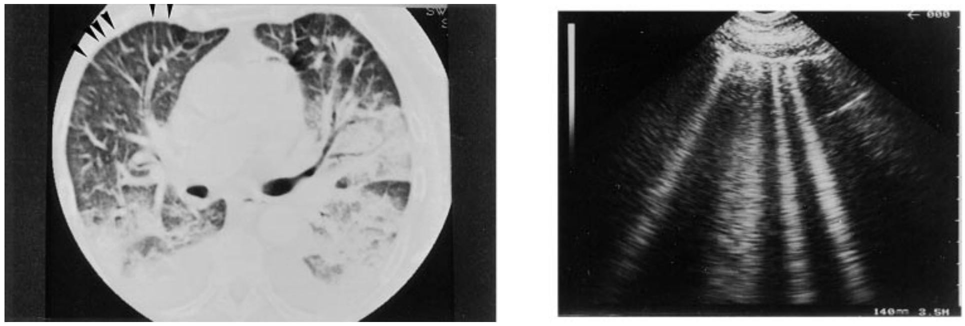

***Figure 2.*** Acute pulmonary edema. (*Left panel*) CT. Regularly spaced, thickened interlobular septa are clearly visible touching the anterior surface of the lung (*arrows*). Here, an average distance of 7 mm separates each septum. (*Right panel*) Ultrasound equivalent. "The artifact" was found all over the anterior lung surface.

n = 1; and normal X-ray, n = 6). CT scanning was performed from the apex to the diaphragm, using an Elscint CT Twin Flash (Elscint Limited, Haifa, Israel) at a window width of 1,600 HU and level of −600 HU. Thickness of the sections was 1.5 mm (n = 5) or 10 mm (n = 24). Attention was focused on superficial lung areas reaching the anterior lung surface.

## RESULTS

### Evaluation of the Comet-tail Artifact for Diagnosing Alveolar-Interstitial Syndrome

All but three patients were successfully analyzed using ultrasound. The feasibility of the ultrasound study was thus 99%. The relation between the presence of "the artifact" and radiologic alveolar-interstitial syndrome is shown in Table 1. When considering all patients with diffuse or localized interstitial-alveolar syndrome, "the artifact" had a sensitivity of 92.5% and a specificity of 65.1% for diagnosing radiologic alveolar-interstitial syndrome. When considering "the artifact" confined laterally to the last intercostal space above the diaphragm as potentially present in normal patients and therefore not abnormal—this location having been observed in 28% of patients with normal X-rays, including healthy subjects—sensitivity decreased to 86.7% and specificity increased to 93.0%. When considering patients with *diffuse* alveolar-interstitial syndrome (n = 92) versus those with normal X-rays (n = 129), i.e., two diametrically opposed populations, and when considering the lower lateral space location as normal, "the artifact" extending beyond this basal location had a sensitivity of 93.4% and a specificity of 93.0%. When considering patients with localized alveolar-interstitial syndromes, "the artifact" had a sensitivity of 79.3% if the last intercostal location was considered pathologic and a sensitivity of 65.5% if this location was considered normal.

Fifteen discordant cases were noted. Six cases with diffuse alveolar-interstitial syndrome were considered false-negatives, because the antero-lateral "artifact" was absent (three cases) or confined to the last intercostal space (three cases): three patients with ARDS after aspiration pneumonitis, two with bacterial ARDS, and one with pneumonia caused by *Pneumocystis carinii*. Nine of 129 patients with normal X-rays were considered false-positives: "the artifact" was diffuse in three cases (one patient with air embolism, one with probable fat embolism following total hip replacement, and one with acute renal failure), lateral in one case (patient with chest pain), anterior in two drug poisonings, and patchy in three cases (one patient with pulmonary embolism, one with acute asthma, and one with exacerbation of chronic respiratory insufficiency).

### CT and Ultrasonographic Correlations

Seventeen patients had alveolar-interstitial syndrome on CT, 15 of them exhibiting diffuse anterolateral "artifacts." All of these 15 patients showed dense structures reaching the anterolateral lung surface. In 11 of these 15 patients, it was possible to observe sub-pleural thickened interlobular septa touching the visceral pleura all over the anterior and lateral surface of the lung. The average distance between two sub-pleural septa was about 7 ± 1 mm (Figure 2). In four of these 15 patients, anterior sub-pleural ground-glass areas were visible, appear-

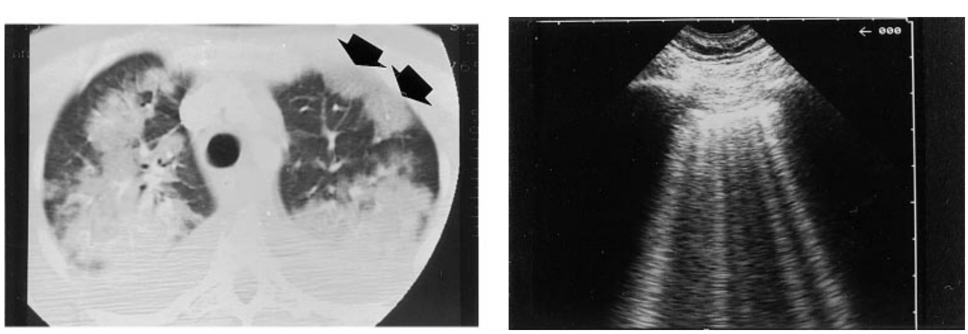

***Figure 3.*** Acute pulmonary edema. (*Left panel*) CT. At this level, ground-glass areas can be observed in the left lung (*arrows*). Note posterior consolidations. (*Right panel*) Ultrasound equivalent. Closely spaced comet-tail artifacts are visible.

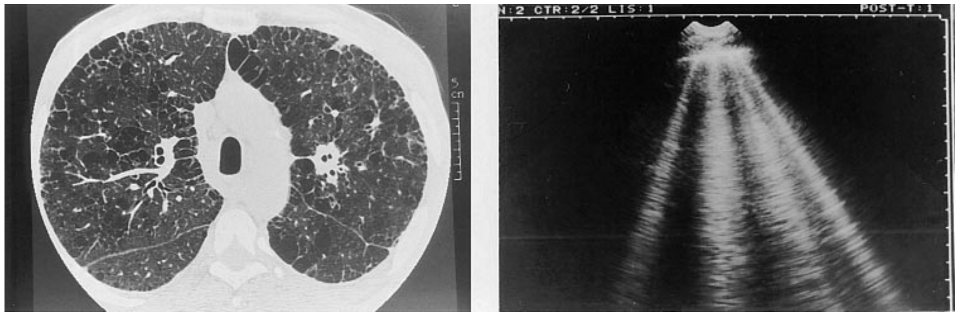

***Figure 4.*** Diffuse interstitial fibrosis. (*Left panel*) CT. Thickened interlobular septa can be observed reaching the whole surface of the lung. The average distance between two septa was calculated to be 6.5 mm by dividing the projected perimeter of the entire visceral pleura at this level (94.5 cm) by the total number of visible sub-pleural septa (n = 144). (*Right panel*) Ultrasound equivalent. These four comet-tail artifacts are separated from each other by a distance of 7 mm.

ing as nondependent areas of density between −500 and −100 HU (Figure 3). In two ARDS patients with absence of anterior "artifact," CT analysis showed an anterior area free of sub-pleural thickened interlobular septa and of ground-glass areas. There were massive alveolar consolidations of the dependent areas. In four patients with interstitial syndrome, CT revealed the presence of sub-pleural thickened interlobular septa regularly spaced all over the lung surface (Figure 4). All exhibited massive antero-lateral "artifacts."

In six patients with normal X-ray and in two patients with COPD or asthma (all of them free of "artifact"), no anterior dense structure was visible (Figure 5). One patient with febrile chest pain and normal X-ray but with lateral "artifact" showed alveolar consolidation of the left lower lobe with a lateral interstitial pattern. In one healthy subject with "the artifact" confined to the last intercostal space, sub-pleural thickened interlobular septa were visible on the last sections, in the area where the inferior lung strip is jammed between the liver (or spleen) and the chest wall (Figure 6).

## DISCUSSION

### Significance of the Comet-tail Artifact

The comet-tail artifact appears when there is a marked difference in acoustic impedance between an object and its surroundings (9). The reflection of the beam creates a phenomenon of resonance. The time lag between successive reverberations is interpreted as a distance, resulting in a center that behaves like a persistent source, generating a series of very closely spaced pseudo-interfaces (13). The beam seems to be "trapped" in a closed system, resulting in endless to-and-fro echoing (Figure 7). These interfaces yield, on the screen, a narrow-based laser-like ray extending to the edge of the screen (up to at least 20 cm in our experience). On the figures displayed here, the width of the comet-tail artifact regularly increases with the depth, to a value of about 1 cm.

At the surface of the lung, the prominent element is air. Its acoustic impedance is $0.0004 \times 10^5$ gp/cm$^2$ · s (14), which is very different from that of bone ($7 \times 10^5$ gp/cm$^2$ · s), parenchyma ($1.65 \times 10^5$ gp/cm$^2$ · s), and water ($1.48 \times 10^5$ gp/cm$^2$ · s). Bony tissues are not expected to be found at the surface of the lung. Knowing that a normal lung contains much air and little water, the comet-tail artifact described in the present study has the following characteristics: it is related to a small water-rich structure, below the resolution of the ultrasound beam (which is about 1 mm), surrounded by air (resulting in a high impedance gradient). It is absent under normal conditions and present in alveolar-interstitial syndromes. This element has to be present at and all over the surface of the lung, and each element is separated from each other by an average distance of 7 mm. In addition, it is frequently found in the last intercostal space in normal subjects.

Sub-pleural interlobular septa thickened by edema perfectly combine all of these properties. This hypothesis was confirmed by CT correlations. When focusing only on the lung surface, no dense structure was visible in normal subjects. Vessels ceased to be visible before reaching the surface, and interlobular septa were not visible. Normal interstitial tissue is not

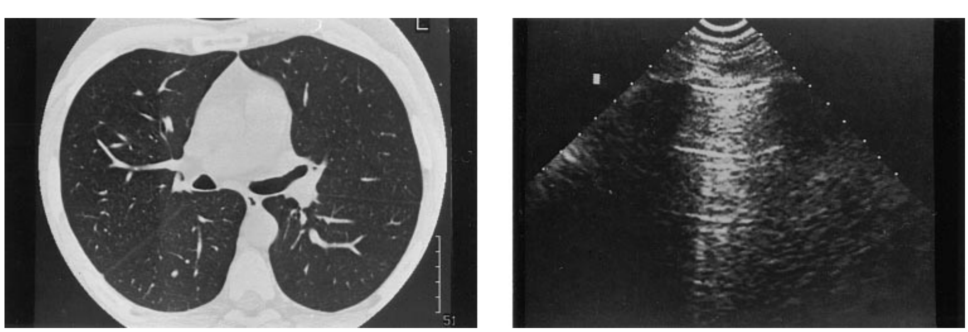

***Figure 5.*** Normal lung. (*Left panel*) CT. No dense structure is visible against the surface. (*Right panel*) Ultrasound equivalent. Two or three regular horizontal reverberations of the lung-wall interface are visible.

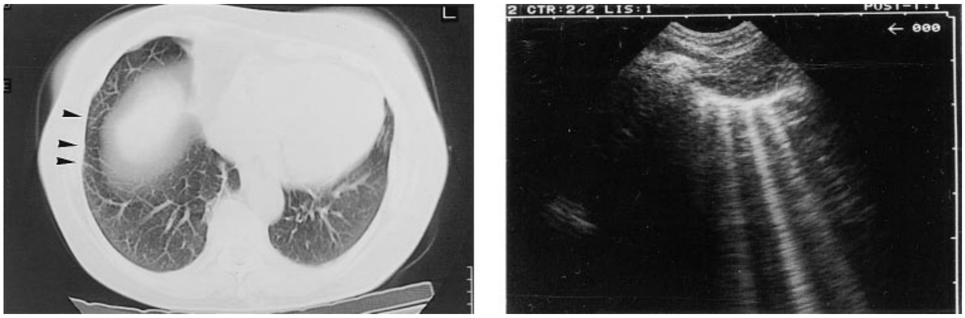

***Figure 6.*** Normal lung. (*Left panel*) CT section at the level of the hepatic dome. Note visible sub-pleural interlobular septa in this area (*arrows*). (*Right panel*) Ultrasound equivalent. Three comet-tail artifacts are visible arising from the lung surface.

visible using CT, even at high resolution (15). In alveolar-interstitial syndromes, sub-pleural thickened interlobular septa were found most of the time in patients exhibiting "the artifact." The distance between two septa at the lung surface (about 7 mm) perfectly correlated with the average distance found between two comet-tail artifacts. Another type of lesion was associated with "the artifact": ground-glass areas, which were often visible, associated or not with visible sub-pleural thickened interlobular septa. In ground-glass areas, the comet-tail artifacts seemed to be more numerous (Figure 3, *right panel*), although we have not yet prospectively investigated this particular feature. In chronic interstitial diseases, thickened interlobular septa were clearly visible touching the whole lung surface (Figure 4). Lastly, CT correlations showed that sub-pleural thickened septa can be visible in the diaphragmatic sections in healthy subjects. In 27.9% of patients with normal radiographs, "the artifact" was confined to the last intercostal space. Fine transverse lines can be observed on X-rays just above the diaphragm in 18% of healthy subjects (16). The relative similarity of these percentages is noteworthy (the difference may simply reflect a slight superiority of ultrasound in detecting these lines).

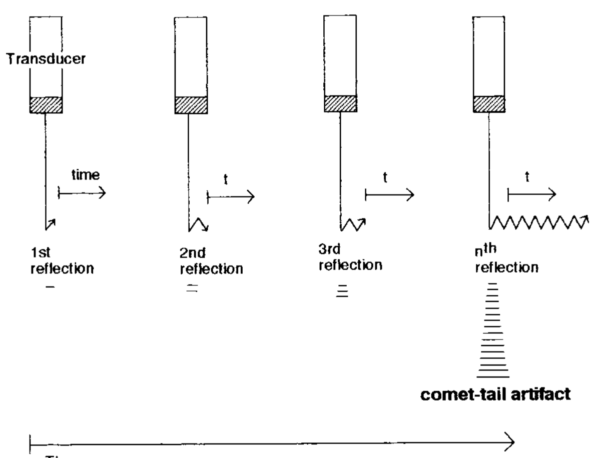


***Figure 7.*** Schematic explanation of the formation of the comet-tail artifact. The path of the sound beam is shown as a function of time in order to avoid superimpositions. When the beam meets the sub-pleural end of the thickened septum, it reflects indefinitely at a speed of 1,450 m/s, resulting in an artifact composed of all the micro-reflections. Each reflection of the beam is displayed on the screen behind the previous reflection. A distance of about 1 mm separates each reflection.

Thickened septa visible on the chest radiograph in pulmonary edema are known as "Kerley lines" (17). They are rarely visible on a bedside chest X-ray in emergency situations. In the present study, "the artifact" appeared as a sonographic equivalent of Kerley lines. It should be outlined that alveolar consolidation can be visualized using ultrasound (5) inasmuch as there is contact with the surface of the lung. The image is distinct from "the artifact": it is a real image and not an artifact (Figure 8).

How can ultrasound detect a pathologic feature without really "visualizing" it? The sub-pleural end of a thickened septum is too thin to be visualized by the ultrasound beam (spatial resolution of about 1 mm), but it should be thick enough to "disturb" the beam and create a difference in acoustic impedance with the surrounding air. As for the ground-glass areas, one possible hypothesis is that a close mingling of sub-millimetric air-filled and liquid-filled areas may create the impedance gradient.

### Review of Discordant Cases

In some patients, bedside chest X-ray displayed features that ultrasound did not detect and vice versa. Six of 92 patients with diffuse alveolar-interstitial syndrome (6.5%) exhibited absence or paucity of "artifact." Two of these six patients underwent CT, which revealed the coexistence of dependent injured areas with nondependent aerated areas. This distribution has been observed in patients with ARDS (18, 19). As the

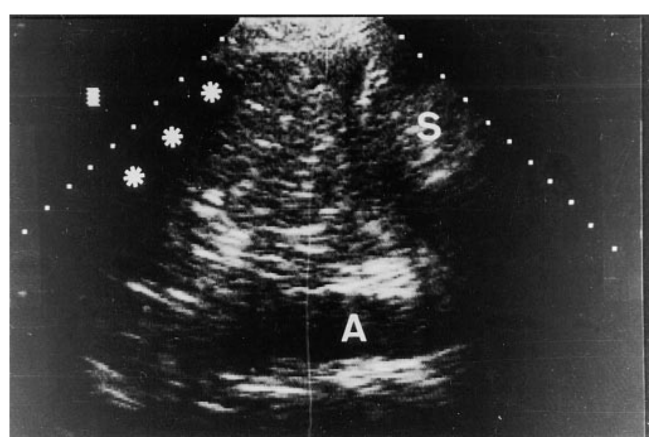


***Figure 8.*** Alveolar consolidation (ultrasound) in a patient with ARDS. Tissular echostructure with punctiform hyperechogenic elements corresponding to the air bronchograms (A = thoracic aorta; S = spleen; * = acoustic shadow of rib).

presence of pneumothorax would obviously hinder analysis of the lung, care was taken to check the sonographic presence of "lung sliding" in each of these patients, thus ruling out infra-radiologic pneumothorax (4). Nine of 129 patients without radiologic alveolar-interstitial syndrome (6.9%) gave "the artifact." In this group, a number of infra-radiologic interstitial syndromes may have been included. The radiologic detection of interstitial syndrome is often questionable and subjective, particularly when using a bedside chest film (20). In one patient with probable fat embolism, a radiologic alveolar-interstitial syndrome appeared on the third day. These data may only suggest that in this patient, sonographic signs preceded radiologic signs.

### Technical Aspects and Clinical Relevance of Lung Ultrasound

Unlike other regions (heart, intra-abdominal organs), the surface of the lung can be easily visualized using ultrasound. "The artifact" was quickly detected. Small surface probes of 3.0 and 3.5 MHz were quite suitable for this application, but 2.5-, 5-, and 7.5-MHz probes were equally effective. A simple portable unit (without Doppler) was sufficient. Last but not least, the skill needed to recognize "the artifact" was easily learned. Our findings can be simply summarized: the normal lung pattern is characterized by roughly horizontal, parallel lines. Alveolar-interstitial syndrome yields roughly vertical, parallel lines. The disposition of the airy artifacts is thus diametrically opposed in these two conditions. In our daily practice, when describing "multiple comet-tail artifacts fanning out from the lung-wall interface in a frozen image," we use a practical and eloquent term: "lung rockets."

In the present study, acute pulmonary edema as well as chronic interstitial diseases led to "the artifact." Both mild and severe pulmonary edema resulted in diffuse "artifacts." This may turn into an advantage if further data could prove that "the artifact" is detectable at a very early stage of pulmonary edema. Alveolar edema is always preceded by interstitial edema, a constant feature of pulmonary edema (21) whose radiologic diagnosis is difficult at the bedside. Ground-glass areas may correspond to the interstitial edema described in the early stage of ARDS (22). If the presence of "the artifact" confined laterally to the last intercostal space is considered normal, a localized alveolar-interstitial syndrome may be overlooked. In these cases, posterior investigation should reveal the associated alveolar syndrome. Acoustic barriers such as pneumothorax, parietal emphysema, parietal shotgun pellets, pleural calcifications, chest tubes, or thoracic dressings are obvious obstacles to lung ultrasound study.

Has sonographic recognition of alveolar-interstitial syndrome any clinical relevance? Probably not when the clinical diagnosis is evident or when a high-quality chest X-ray is quickly obtained. Likewise, sonographic recognition of interstitial disease will be of limited interest for the radiologist, who has good quality chest X-rays and an easy assess to CT. By contrast, the intensivist must make daily therapeutic decisions on the basis of a bedside chest X-ray, the only reasonable tool in routine practice, which is known to be often technically deficient (23). As detection of an alveolar-interstitial syndrome is a crucial step in the diagnostic procedure in a dyspneic patient, this new application of ultrasound will afford basic information, at least equivalent to bedside X-ray. Other applications will be considered in further reports. About all, "the artifact" may provide vital information when a pneumothorax is suspected. It may be valuable for differentiating cardiogenic pulmonary edema from decompensated COPD. Finally, it may also prove useful when a radiograph is not available (pre-hospital emergencies), not readily available (extreme emergencies in the intensive care unit), or undesirable (pregnancy). The use of ultrasound in dyspneic patients is one of several techniques that may lead to ultrasound being considered as a "visual stethoscope" (24).

## Conclusions

The lung is often considered poorly accessible to ultrasound. In the present study, analysis of the comet-tail artifact allowed us to detect alveolar-interstitial syndromes, at the bedside. CT data showed that ultrasound was able to detect two patterns present at the lung surface: the thickening of the sub-pleural interlobular septa and the ground-glass areas. The simplicity and high feasibility of ultrasound make it an attractive and easy-to-use diagnostic tool at the bedside for the intensivist.

***Acknowledgment*:** The writers are grateful to Prof. Jean-Jacques Rouby for his precious advice. They thank David Marsh for the translation of this work, and Didier Joseph for the photographic work. The chest radiographs and CTs were taken in the department of Prof. P. Lacombe, to whom the writers are grateful. Lastly, the writers wish to thank Prof. François Jardin, who made this work possible.

## References

1. Rantanen, N. W. 1986. Diseases of the thorax. *Vet. Clin. North Am.* 2:49–66.
2. Wernecke, K., M. Galanski, P. E. Peters, and J. Hansen. 1987. Pneumothorax: evaluation by ultrasound, preliminary results. *J. Thorac. Imag.* 2:76–78.
3. Targhetta, R., J. M. Bourgeois, and P. Balmes. 1992. Ultrasonographic approach to diagnosing hydropneumothorax. *Chest* 101:931–934.
4. Lichtenstein, D., and Y. Menu. 1995. A bedside ultrasound sign ruling out pneumothorax in the critically ill: lung sliding. *Chest* 108:1345–1348.
5. Dorne, H. L. 1986. Differentiation of pulmonary parenchymal consolidation from pleural disease using the sonographic fluid bronchogram. *Radiology* 158:41–42.
6. Weinbert, B., E. E. Diakoumakis, E. G. Kass, B. Seife, and Z. B. Zvi. 1986. The air bronchogram: sonographic demonstration. *Am. J. Roentgenol.* 147:593.
7. Yang, P. C., K. T. Luh, D. B. Chang, C. J. Yu, S. H. Kuo, and H. D. Wu. 1992. Ultrasonographic evaluation of pulmonary consolidation. *Am. Rev. Respir. Dis.* 146:757–762.
8. Targhetta, R., R. Chavagneaux, J. M. Bourgeois, M. Dauzat, P. Balmes, and L. Pourcelot. 1992. Sonographic approach to diagnosing pulmonary consolidation. *J. Ultrasound Med.* 11:667–672.
9. Ziskin, M. C., D. I. Thickman, N. J. Goldenberg, M. S. Lapayowker, and J. M. Becker. 1982. The comet tail artifact. *J. Ultrasound Med.* 1:1–7.
10. Avruch, L., and P. L. Cooperberg. 1985. The ring-down artifact. *J. Ultrasound Med.* 4:21–28.
11. Targhetta, R., R. Chavagneux, P. Balmes, C. Lemerre, J. M. Mauboussin, J. M. Bourgeois, and L. Pourcelot. 1994. Sonographic lung surface evaluation in pulmonary sarcoidosis: preliminary results. *J. Ultrasound Med.* 13:381–388.
12. Lichtenstein, D. 1994. Diagnostic échographique de l'oedème pulmonaire (letter to the editor). *Rev. Imag. Med.* 6:561–562.
13. Bourgeois, J. M., M. Boynard, and P. Espinasse. 1995. L'image par L'échographie, 1st ed. Sauramps Médical, Paris. 242.
14. Taboury, J. 1982. Guide Pratique D'échographie Abdominale, 2nd ed. Masson, Paris. 2–4.
15. Rémy, J. 1987. Tomodensitométrie du Thorax, 1st ed. Vigot, Paris. 224.
16. Felson, B. 1973. Chest Roentgenology, 1st ed. W. B. Saunders, Philadelphia. 244–245.
17. Kerley, P. 1933. Radiology in heart disease. *B.M.J.* 2:594.
18. Gattinoni, L., A. Pesenti, A. Torresin, S. Vesconi, G. P. Rossi, R. Fumagalli, R. Marcolin, D. Mascheroni, M. Langer, G. Iapichino, F. Rossi, and S. Baglioni. 1988. CT in acute respiratory failure. *In* W. Kox, J. Boultbee, and R. Donaldson, editors. Imaging and Labelling Techniques in the Critically Ill, 1st ed. Springer-Verlag, New York. 67–75.
19. Puybasset, L., P. Cluzel, L. Gallart, G. S. Umamaheswara Rao, J. D. Law-Koune, Q. Lu, A. Slutsky, P. Coriat, and J. J. Rouby. 1996. CT scan assessment of the segmental distribution of ARDS induced lung consolidations. *Br. J. Anaesth.* 76(Suppl. 2):A142.
20. Rigler, L. G. 1950. Roentgen examination of the chest: its limitations in the diagnosis of disease. *J.A.M.A.* 142:773.

21. Staub, N. C. 1974. Pulmonary edema. *Physiol. Rev*. 54:678–811.
22. Keske, U., D. Pappert, E. Paust, K. Neumann, K. J. Falke, and R. Felix. 1995. Acute respiratory distress syndrome: CT-morphology. *Eur. Radiol*. 5:S138.
23. Wiener, M. D., S. M. Garay, B. S. Leitman, D. N. Wiener, and C. E. Ravin. 1991. Imaging of the intensive care unit patient. *Clin. Chest Med*. 12:169–198.
24. Lichtenstein, D. 1992. General Ultrasound in the Critically Ill (L'échographie Générale en Réanimation), 1st ed. Springer-Verlag, New York. 139–141.