Intensive Care Med (2000) 26: 1434–1440
DOI 10.1007/s001340000627

ORIGINAL

Daniel Lichtenstein
Gilbert Mezière
Philippe Biderman
Agnès Gepner

The "lung point": an ultrasound sign specific to pneumothorax

Received: 16 September 1999
Final revision received: 27 June 2000
Accepted: 3 July 2000
Published online: 16 September 2000

D. Lichtenstein (✉) · P. Biderman
Service de Réanimation Médicale,
Hôpital Ambroise-Paré,
9 avenue Charles-de-Gaulle,
92100 Boulogne (Paris), France
Phone: +33-1-49095601
Fax: +33-1-49095892

D. Lichtenstein · G. Mezière · A. Gepner
Service de Réanimation Polyvalente,
Centre Hospitalier Général,
Saint-Cloud (Paris), France

Abstract *Objective*: We studied an ultrasound sign, the fleeting appearance of a lung pattern (lung sliding or pathologic comet-tail artifacts) replacing a pneumothorax pattern (absent lung sliding plus exclusive horizontal lines) in a particular location of the chest wall. This sign was called the "lung point". *Design*: Prospective study. *Setting*: The medical ICU of a university-affiliated teaching hospital. *Patients*: The "lung point" was sought in 66 consecutive cases of proven pneumothorax analyzable using ultrasound – including 8 radio-occult cases diagnosed by means of CT – and in 233 consecutive hemithoraces studied by CT and free of pneumothorax – including 17 cases where pneumothorax was suspected. *Results*: The "lung point" was observed in 44 of 66 cases of pneumothorax (including 6 of 8 radio-occult cases) and in no case in the control group. The location of this sign roughly correlated with the radiological size of the pneumothorax. The "lung point" therefore had an overall sensitivity of 66 % (75 % in the case of radio-occult pneumothorax alone) and a specificity of 100 %. *Conclusion*: The presence of a "lung point" allows positive diagnosis of pneumothorax at the bedside using ultrasound.

Key words Pneumothorax · Intensive care unit · Ultrasound diagnosis · Lung, ultrasound diagnosis · Thorax, ultrasound diagnosis

Introduction

Pneumothorax is a basic problem in the intensive care unit (ICU) [1]. Bedside chest radiography is a familiar technique, but misdiagnosis may occur in 30 % of cases [2, 3]. Computed tomography (CT) is the gold standard, but necessitates transfer of critically ill patients and high irradiation. In some instances, any delay in the provision of radiological evidence is deleterious [4]. Hence, a quickly implemented technique at the bedside may be of interest. Lung ultrasound is not often performed: bone and air are traditionally considered natural obstacles.

However, clinical experience and literature data show that ultrasound has a part to play [5, 6, 7, 8]. Ultrasound allows pneumothorax to be confidently discounted when lung sliding is present [8] *or* when long comet-tail artifacts arising from the lung-wall interface – an ultrasound sign of interstitial syndrome [9] – are visible [10]. The pattern observed in pneumothorax, the disappearance of lung sliding [5, 6, 7, 8] plus exclusive horizontal artifacts arising from the lung-wall interface [10], was not specific in our previous observations. According to CT correlations, the specificity of absent lung sliding alone is 91 % [8] and that of horizontal lines arising from the pleural line alone 77 % [10]. We describe here a sign which may prove specific for pneumothorax and which has not yet been dealt with in the literature, to our knowledge: the fleeting appearance of lung pattern in a particular location of the chest wall.

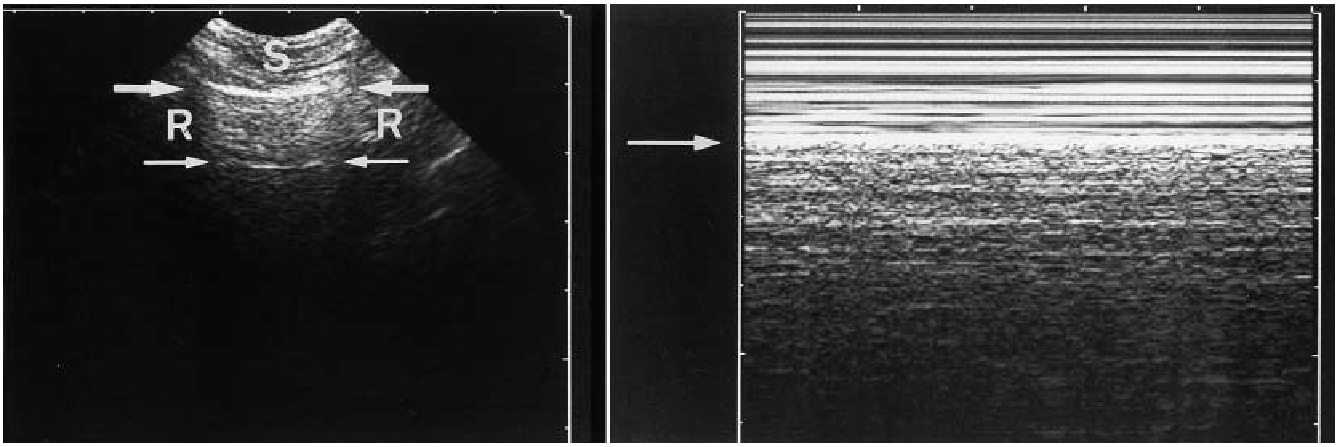

Fig. 1 Lung sliding (ultrasound, longitudinal scan, third intercostal space, normal subject). *Left*: real-time. Superficial layers *(S)*, shadow of ribs *(R)*, pleural line *(large arrows)*, roughly horizontal hyperechogenic line ("A line") *(fine arrows)*. Lung sliding cannot appear on this frozen view. *Right*: time-motion. This mode allows materialization of the lung sliding. The superficial layers yield a horizontal pattern, as they remain motionless. From and below the pleural line *(arrow)*, the pattern appears granulous, as the motion of the pleural line is reflected all over this area

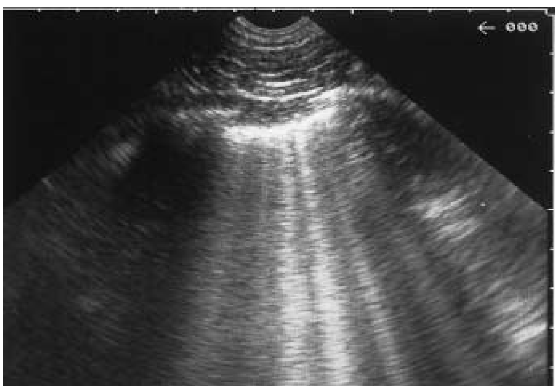

Fig. 2 Pathologic comet-tail artifacts (ultrasound, longitudinal scan, anterior chest wall, patient with interstitial syndrome). Note the roughly vertical orientation. "B lines" are defined by their origin (pleural line) and length (to the edge of the screen). Multiple "B lines" are defined by their number in one view. In this view, one can see 5 or 6several "B lines", a pattern reminiscent of a rocket at lift-off, hence the practical term of "lung rockets"

Patients and methods

Patients

A prospective study included 70 proven consecutive pneumothoraces in 64 ICU patients (mean age 43 years, range 17–90; 49 men, 15 women). Fifty cases occurred during spontaneous ventilation and 20 during mechanical ventilation. Pneumothorax was spontaneous in 32 cases, iatrogenic in 16, traumatic in 6, complicating acute or chronic lung disease in 9 and complicating mechanical ventilation in 7.

Of 70 pneumothoraces, 51 required a chest tube. Pneumothorax was proven on radiography in 60 cases. Ten radio-occult cases were proven only on CT, 8 were only apical, 6 only lateral, 14 apico-lateral and moderate, 2 were complex with parietal adherences and acute angle of contact, and complete retraction occurred in 30 cases.

The control group included 238 lungs in 119 consecutive ICU patients where absence of pneumothorax was proved by CT (82 men, 37 women, mean age 57 years, range 20–85; 80 ventilated patients). This control group comprised two sub-groups: 17 patients in whom pneumothorax was suspected but not proven on radiography, and 102 patients in whom pneumothorax was not suspected (although it may have been considered in a systematic search in critically ill, ventilated patients). CT was clinically requested in all 119 patients.

Methods

Radiography and computed tomography

Anteroposterior radiographies were performed at inspiration with a VMX portable unit (General Electric, Monza, Italy), and were all read by radiologists. Displacement of visceral pleura from parietal pleura by air within the pleural space was considered as specific for pneumothorax [2]. CT scans were performed from apex to diaphragm with a CT Twin Flash (Elscint Limited, Haifa, Israel) at a window width of 1,600 HU, level of –600 HU and sections of 10 or 1.5 mm.

Ultrasound

A Hitachi Sumi 405 (Hitachi Medical, Tokyo, Japan) with a 5 MHz microconvex probe (without Doppler) was used by an intensivist specifically trained in emergency echography and unaware of radiological or CT findings. The anterior chest wall was delineated from clavicles to diaphragm and from sternum to anterior axillary line (included). The lateral wall was delineated from armpit to diaphragm and from anterior to posterior axillary line (included). Longitudinal scans were performed in the supine position only, so that the upper half of the anterior wall was more dependent than the lower.

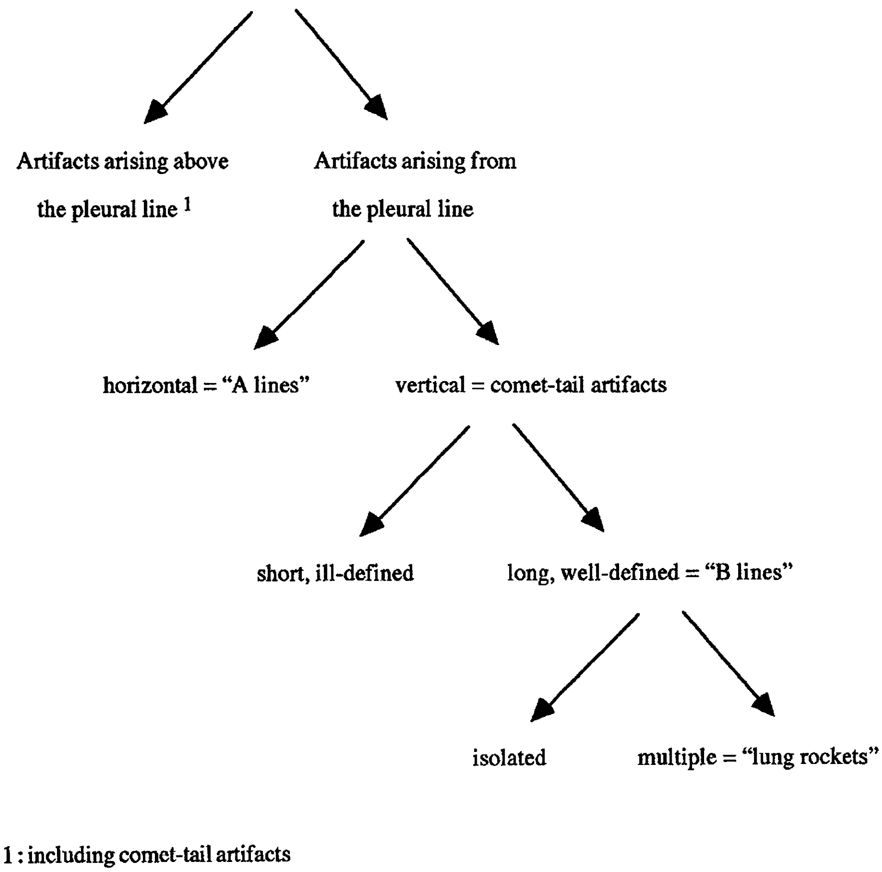

Fig. 3 Labeling of air artifacts encountered at the chest wall

Basic lung semiology

The pleural line is a hyperechogenic line visible between two ribs and ± 0.5 cm lower. It shows the lung-wall interface, or interface between chest wall and lung surface. Lung sliding is a kind of twinkling synchronized with respiration, normally visible at the pleural line (Fig. 1). Only air artifacts arise from the pleural line. Two contrasting types of artifacts can, however, be described. One is horizontal, the other vertical (comet-tail artifact). In the interest of brevity, using alphabetic notation, horizontal regularly spaced hyperechogenic lines representing reverberations of the pleural line (Fig. 1) were called "ultrasound A lines", and narrow-based comet-tail artifacts arising from the pleural line and spreading up to the edge of the screen (Fig. 2) "ultrasound B lines" [11]. Note that short, large, ill-defined comet-tail artifacts arising from the pleural line, often observed in normal subjects as well as in cases of pneumothorax, are not "B lines". Likewise, comet-tail artifacts may arise *above* the pleural line in cases of parietal emphysema or parietal shotgun pellets [10]. When several "B lines" are simultaneously visible, a suggestive term is "lung rockets" (Fig. 2). Fig. 3 classifies the static patterns.

Absent lung sliding plus exclusive "A lines" was suggestive of pneumothorax (Fig. 4). Absence of pneumothorax was defined as: (a) anterior "A lines" if associated with lung sliding, or (b) anterior "B lines" associated, or not, with lung sliding.

The sign under study has the following features: (a) pattern suggestive of pneumothorax, (b) sudden change in this pattern to either lung sliding, "B lines" or alteration of "A lines", (c) appear-

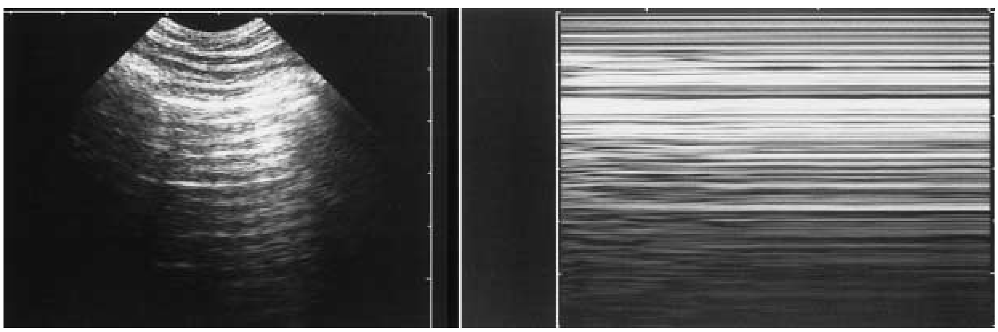

Fig. 4 Pneumothorax (ultrasound, longitudinal scan of the culminant area of the anterior chest wall). *Left*: real-time. There is absence of lung sliding associated to "A lines". The absence of lung sliding cannot be deduced from this view, hence quasi-similar to Fig. 1 A (normal subject). *Right*: time-motion. The complete absence of lung motion is clearly objectified in this mode by the exclusively horizontal pattern on each side of the pleural line

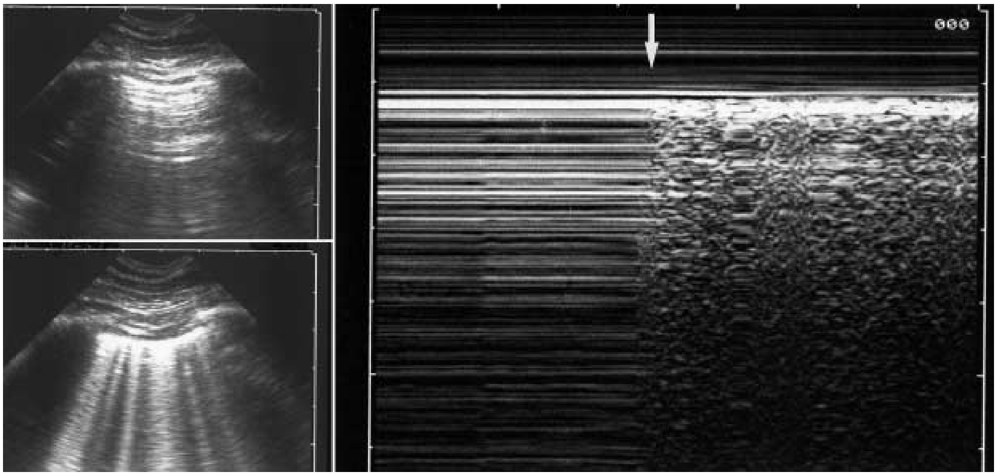

Fig. 5 The "lung point" (ultrasound, longitudinal scan of the third intercostal space along the anterior axillary line, supine patient with pneumothorax). *Left, top*: expiration. Absence of lung sliding plus "A lines". *Left, bottom*: inspiration. Fleeting appearance of lung sliding with "lung rockets". *Right*: time-motion mode clearly shows the sudden *(arrow)* inspiratory appearance of a granulous pattern beneath the pleural line

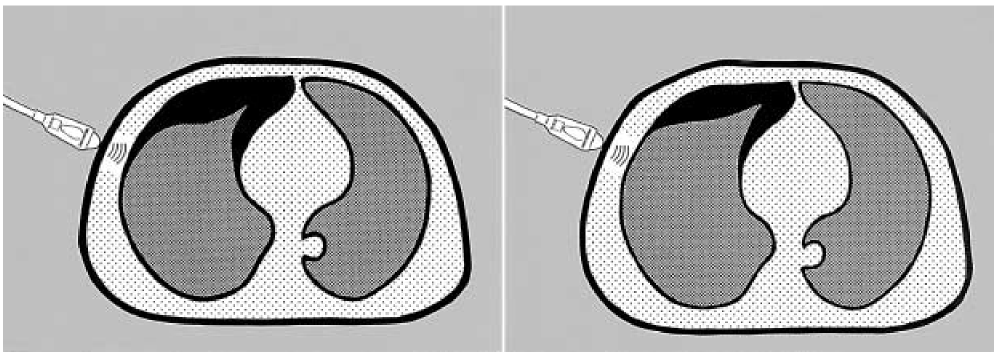

Fig. 6 A theoretical explanation of the "lung point". *Left*: at expiration, the pneumothorax has a defined volume on CT. A probe placed at a point slightly superior to the lung level will display a pneumothorax pattern. *Right*: at inspiration, the lung volume should slightly increase, therefore increasing the surface of the lung in contact with the wall. The probe remaining at the same location will thus display a fleeting pattern of lung, i.e. lung sliding and/or "B lines"

ance of this sign on inspiration, return to pneumothorax pattern on expiration (Fig. 5). This sign should be sought with the probe absolutely motionless on a particular location (see Fig. 6). In the last intercostal space of normal subjects, movements of liver or spleen may simulate the described sign at first sight. Theorizing that this change might correspond to the fleeting visualization of the lung touching the wall on inspiration, we called it the "lung point" (Fig. 6). It was sought along the intercostal spaces of the anterior and lateral chest wall, then posteriorly by lifting one side of the patient's back in order to slide the probe between bed and back. The short length of the probe (9 cm) made this maneuver easy. The probe was placed on six equidistant points of each intercostal space. Care was taken to observe a whole respiratory cycle at each point (this lasted no more than 5 min).

Study design

The relation between the presence of the "lung point" and pneumothorax was investigated. The same relation was examined in patients who had only undergone CT (i.e. radio-occult cases versus control group). We also investigated whether or not the "lung point" was visible in spontaneous or mechanical ventilation.

Results

Relation between "lung point" and pneumothorax

In the study group, parietal emphysema prevented ultrasound analysis in four cases (including two radio-occult cases). All 66 analyzable pneumothoraces had absent lung sliding plus exclusive "A lines" on at least the lower half, or more, of the anterior chest wall. The "lung point" was present (anterior, lateral or posterior) in 44 of 66 cases. Less than 1 min was necessary. It was never found in the remaining 22 cases. Rough correlation was found with the radiological volume of the pneumothorax (Table 1).

In the control group, 2 of 238 hemithoraces were unanalyzable (huge dressing, calcified pleura). In three cases, the anterior pattern was not airy but showed alveolar consolidation or pleural effusion. In the 233 remaining cases with airy pattern, a "lung point" was never observed. Anterior lung sliding was present in 182 cases (thus discounting pneumothorax) and absent in 51 (complete in 32 cases, partial in 19). "B lines" were present in 40 of these 51 cases (thus discounting pneumothorax), and "A lines" were the exclusive pattern in

Table 1 Detection and location of the "lung point" (70 cases of pneumothorax and 238 controls)

Radiography[1] (1) or CT[2] (2)	Ultrasound patterns at the chest wall in supine patients					
	"Lung point" present ($n = 44$)			"Lung point" absent	Other patterns[a]	Non-feasible study
	Anterior	Lateral	Posterior			
Pneumothorax						
Radio-occult[2]	5	1	0	2	0	2
Partial[1]	9	1	1	3	0	0
Complete and moderate[1]	3	7	2	2	0	0
Complete retraction[1]	0	8	7	13	0	2
Parietal adherences[1]	0	0	0	2	0	0
Control group[2]	0	0	0	233	3	2

[a] anterior alveolar syndrome or pleural effusion

Table 2 Ultrasound patterns of the anterior chest wall (66 analyzable cases of pneumothorax and 233 analyzable controls with only airy pattern)

Radiography or CT	Anterior ultrasound pattern allowing pneumothorax to be discounted			Anterior ultrasound pattern suggestive of pneumothorax, i.e. lung sliding absent plus "A lines"	
	Lung sliding plus "A lines"	Lung sliding plus "B lines"	Lung sliding absent plus "B lines"	"Lung point" absent	"Lung point" detected
Pneumothorax	0	0	0	22	44
Control group	76	106	40	11	0

Table 3 "Lung point" of 66 analyzable cases of pneumothorax and 233 analyzable controls with air pattern

Radiography[1] (1) or CT[2] (2)	Ultrasound	
	"Lung point" detected	"Lung point" not detected
Pneumothorax patent on radiography[1]	38	20
Radio-occult pneumothorax[2]	6	2
Control group[2]	0	233

11 (Table 2). These 11 cases therefore had a pattern suggestive of pneumothorax. The "lung point" was carefully sought all over the lung surface, but was detected in none of these cases. If one considers only the sub-group of 17 clinically suspected pneumothoraces, all ultrasound examinations were feasible, all had anterior airy patterns, lung sliding was present in 11 cases, "B lines" with absent lung sliding in 3 cases, and "A lines" with absent lung sliding (i.e. pattern suggestive of pneumothorax) in 3 cases. On the other hand, no "lung point" was identified, as in other control patients. The "lung point" was present in 32 of 48 spontaneously breathing cases versus 12 of 18 mechanically ventilated cases, i.e. 66 % in both situations.

All in all, the feasibility of ultrasound was 98 %. The "lung point" had a sensitivity of 66 % and a specificity of 100 % for the diagnosis of pneumothorax (Table 3).

Relation between "lung point" and radio-occult pneumothorax

When considering CT as the sole gold standard, the "lung point" was found in 6 of 8 radio-occult cases and in none of the 233 controls, i.e. a sensitivity of 75 %, and an unchanged specificity of 100 % (Table 3).

Discussion

By visualizing lung sliding or "B lines", ultrasound could already discount pneumothorax. With the "lung point", it can now be confirmed. The "lung point" may be explained by a slight increase in pulmonary volume during inspiration (Fig. 6). This is an "all or nothing" pattern, whether the lung is in contact or not with the wall. Only a real-time technique like ultrasound can detect such a fleeting sign.

Fine correlations with pneumothorax volume will be dealt with in future reports. Note that an anterior "lung point" roughly correlated with a small pneumothorax. Table 1 shows that ultrasound was more sensitive than radiography for detecting small pneumothoraces. Incipient pneumothorax should therefore be detected using

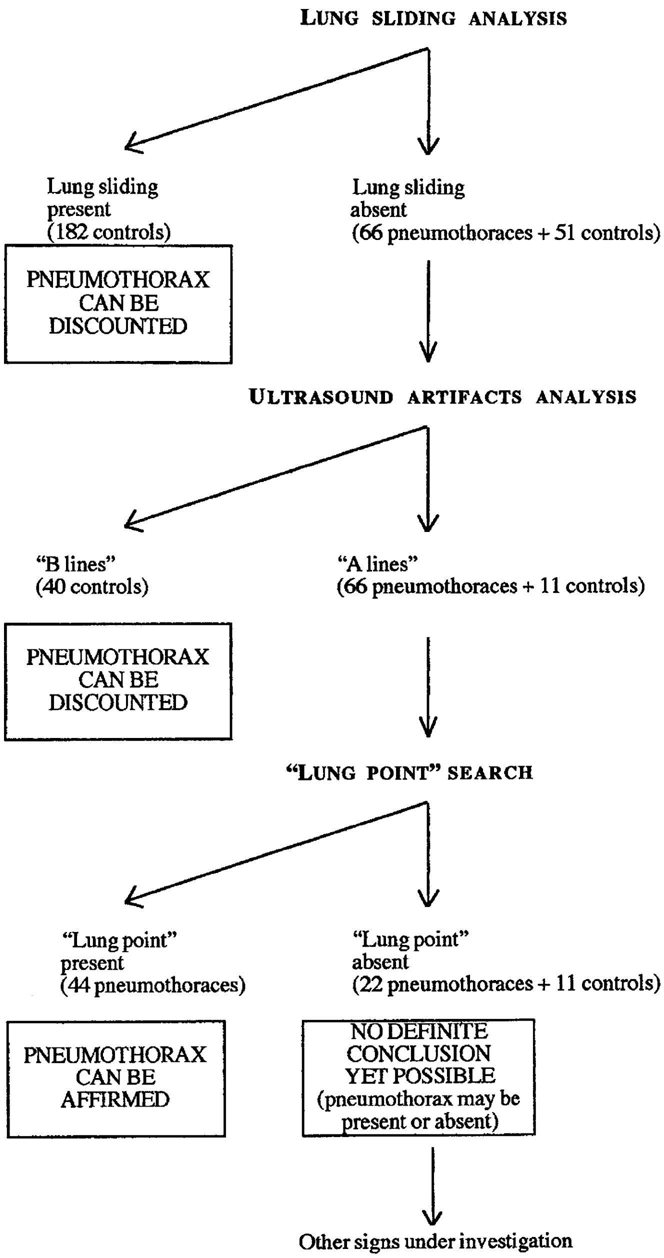

Fig. 7 Flow chart. Analysis of 299 lungs after exclusion of unanalyzable cases ($n = 6$) and cases with non-aerated pattern ($n = 3$)

ultrasound. Major pneumothoraces logically result in a posterior or absent "lung point" (see Table 1) since complete retraction has a low probability of touching the chest wall even on inspiration.

In this study we confronted the problem of defining a pertinent gold standard. Performing a CT in pneumothoraces which are patent in radiography should have led to a rigorous methodology based on a single gold standard, but at the expense of substantial and pointless irradiation of young patients. However, this methodological weakness did not affect the percentages or the conclusions. In practice, the gold standard was the radiography when it showed obvious pneumothoraces, and CT whenever it proved necessary. If one considers only patients who underwent CT, the sensitivity of the "lung point" increases. In fact, the need for CT presupposes a small pneumothorax, a condition favorable to detection of a "lung point". Major pneumothoraces rarely need CT for confirmation.

This study again shows that the absence of lung sliding is frequent in ICU patients without pneumothorax (1/4 of cases). ICU patients referred for lung CT constitute a particular population, supposed to have severe lung disease. In such patients, lung sliding is often absent and "B lines", when present, provide precious help. When lung sliding, "B lines" but also "lung point" are absent, no conclusion should be drawn, and it appears prudent – time permitting – to use radiography or CT to confirm pneumothorax. Ultrasound should not immediately replace radiography, but the use of CT may be reduced. On the other hand, ultrasound may have a major impact on the pre-hospital diagnosis of pneumothorax [12]. Other significant points will be a sensitivity superior to that of radiography, simplicity, high feasibility and a short learning curve [13], since the "lung point" appears in a highly characteristic fashion. A flow chart describes our routine approach (Fig. 7). *Note that bulky units and probe frequencies below 3 MHz will not be adequate.*

This application may justify the presence of a portable ultrasound unit in the ICU, although a number of other applications are possible if it is used routinely like a stethoscope [14]. In conclusion, detection of a "lung point" allowed pneumothorax to be affirmed.

Acknowledgments We wish to thank Professor François Jardin for his trust, David Marsh for the translation of this work and Professor Pascal Lacombe, in whose department CTs were taken.

References

1. Kollef MH (1991) Risk factors for the misdiagnosis of pneumothorax in the intensive care unit. Crit Care Med 19: 906–910
2. Chiles C, Ravin CE (1986) Radiographic recognition of pneumothorax in the intensive care unit. Crit Care Med 14: 677–680
3. Tocino IM, Miller MH, Fairfax WR (1985) Distribution of pneumothorax in the supine and semi-recumbent critically ill adult. Am J Roentgenol 144: 901–905
4. Steier M, Ching N, Roberts EB, et al. (1974) Pneumothorax complicating ventilatory support. J Thorac Cardiovasc Surg 67: 17–23
5. Rantanen NW (1986) Diseases of the thorax. Vet Clin North Am 2: 49–66
6. Wernecke K, Galanski M, Peters PE, Hansen J (1987) Pneumothorax: evaluation by ultrasound, preliminary results. J Thorac Imaging 2: 76–78
7. Targhetta R, Bourgeois JM, Balmes P (1992) Ultrasonographic approach to diagnosing hydropneumothorax. Chest 101: 931–934
8. Lichtenstein D, Menu Y (1995) A bedside ultrasound sign ruling out pneumothorax in the critically ill: lung sliding. Chest 108: 1345–1348
9. Lichtenstein D, Mezière G, Biderman P, Gepner A, Barré O (1997) The comet-tail artifact: an ultrasound sign of alveolar-interstitial syndrome. Am J Respir Crit Care Med 156: 1640–1646
10. Lichtenstein D, Mezière G, Biderman P, Gepner A (1999) The comet-tail artifact, an ultrasound sign ruling out pneumothorax. Intensive Care Med 25: 383–388
11. Lichtenstein D (1997) “L’échographie pulmonaire: une méthode d’avenir en médecine d’urgence et de réanimation?” (editorial). Rev Pneumol Clin 53: 63–68
12. Lichtenstein D, Courret JP (1998) Feasibility of ultrasound in the helicopter. Intensive Care Med 24: 1119
13. Lichtenstein D, Mezière G (1998) Apprentissage de l’échographie générale d’urgence par le réanimateur. Réan Urg 7 (suppl 1):108 s
14. Lichtenstein D (1992) General ultrasound in the critically ill (L’échographie générale en réanimation) 1st edn. Springer, Paris Berlin New York, pp 11–12