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Lung Ultrasound Will Soon Replace Chest Radiography in the Diagnosis of Acute Community-Acquired Pneumonia

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Abstract Acute community-acquired pneumonia should be diagnosed early to avoid most complications. The common diagnostic tools were represented by blood tests and chest X-ray with CT scan coming as a second-line exploration. The presence of air in the pulmonary parenchyma has long been thought of as not explorable by ultrasound. However, since the 1990s, several teams have described a semiology of ultrasonography of pulmonary diseases. Moreover, the safety of the technique and the development of mobile and ultra-portable devices have offered it as a first-line examination by a non-radiologist physician. The authors describe in this article ultrasonography as a way of learning the technique, and the main results observed in the literature. In conclusion, they propose it as the first-line examination instead of chest X-ray, and to reserve chest CT scan for complicated cases.

Keywords Community-acquired pneumonia (CAP) · Lung ultrasound · Chest radiography

Introduction

Community-acquired pneumonia (CAP) represents a frequent cause of hospitalization with high morbidity and mortality if treated late [1, 2]. Its recognition is therefore essential, but early diagnosis is often difficult because of the variability in its clinical presentation [3, 4]. Chest X-rays have long been a fundamental complementary diagnostic tool as indicated by the international recommendations [5, 6]. Yet, the conditions for achieving X-rays in emergency departments and ICUs are often poor in patients in a supine position or who cannot cooperate. This can explain the lack of sensitivity found in the most recent studies [7]. Moreover, the follow-up by serial X-rays can eventually inflict a significant cumulative ionizing radiation dose for patients [8, 9]. The chest CT scan is currently the gold standard in the field of lung imaging, with a sensitivity and specificity close to 100 % for the diagnosis of pulmonary diseases [10, 11]. However, its limited availability and again the exposure to ionizing radiation restrict its indications [12].

For a long time and because of the impermeability to the ultrasonic waves, the presence of air in the lung parenchyma suggested that the exploration of the thoracic cage was inaccessible by ultrasound (US). However, since the 1990s, several teams have been engaged in assessing the contribution of this technique in the diagnosis of respiratory diseases [13]. The description of ultrasonography, the safety of the technique, and the development of mobile and ultra-portable devices have lead to offer it as a first-line examination, at the patient bedside and by a non-radiologist physician [14].

Thoracic Ultrasound Overview

Thoracic Ultrasound Achievement

Portable and mobile devices allow performing the US exploration of the pulmonary parenchyma directly at the bedside, avoiding any time loss related to patient transfer, thus potentially improving patient comfort.

Most of the probes are suitable for this exploration. A convex abdominal (3.5 MHz) probe may be used subject to an optimal

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adjustment of gain and depth. Practitioners can also use a linear high-frequency probe (7–16 MHz), or even a cardiac probe.

Thoracic US is performed using a technique of grid lines (Fig. 1) carried out from top to bottom. Fields are located between the para sternal (PSL) and the anterior axillary line (AAL) for the anterior fields (I), between the anterior (AAL) and posterior axillary line (PAL) for the axillary fields (II) and between the PAL and para vertebral line (PVL) for the study of the posterior fields (III) (Fig. 1) [15].

Ideally, the examination is performed on a seated patient, allowing optimum exploration of posterior fields. If this is not possible, the US is performed on a supine patient tilted to the opposite side of interest.

The limits of the chest sonography are the barriers to US that the bony contours constitute, such as the scapula or ribs, which induce a cone of shadow of US absorption. To overcome these limits, we can slide the probe in the intercostal space.

In addition, lung area adjacent to the para vertebral space is not accessible to US, and the analysis of the mediastinum is not possible by US. A deep parenchymateous abnormality not connected to the chest wall is not visible by chest US because of the air barrier [16•].

Lung Ultrasound Learning

Chest US exploration is often integrated in a much larger exploration of the abdominal cavity, heart, and the proximal veins of the lower extremities. International scientific societies recommend a short training of 2 or 3 days, followed by an e-learning module taught by an expert in sonography. The training may include virtual courses by means of audio and video media. This allows the visualization of normal and pathological conditions. In one particular course, the learning practitioners can also send their images electronically and seek expert view, opinion, or advise [17].

Proficiency in performing and interpreting US scans is achieved after 15 examinations, and the variability between operators has been low [18]. Training such as this incites non-radiologist clinicians to perform US of the chest. US become an integrated part of the clinical approach, leading some to consider it as the stethoscope of the third millennium [19].

What Kind of Images Is Found by Ultrasound?

Normal Lung Because air completely reflects the ultrasonic waves, normal lung parenchyma theoretically cannot be detected by US. Only the visceral pleura is visible in the form of a white hyperechoic dynamic line moving synchronously with respiratory movement (sliding sign).

Lines that are perpendicular to the chest surface and arise from the pleural line and go deep down are called B lines, or ring down artifacts, whose presence is associated with the sliding sign, which allows a diagnosis of pneumothorax to be excluded [20]. In addition, there are parallel lines to the pleural surface repeating in depth, which are reverberations of the pleural line named A lines (Fig. 2a).

Segmental or Lobar Pneumonia When the pleural line is no longer distinguishable but appears broken and replaced by an authentic echo-texture of parenchyma analogous to hepatic tissue, it is consistent with segmental or lobar pneumonia. This image contains air bronchograms (hyperechoic) or fluid bronchograms (anechoic), which are mobile with the respiratory movements [21] (Fig. 2b).

Atelectasis This is the same images but the images of air bronchograms are absent [22] (Fig. 2c).

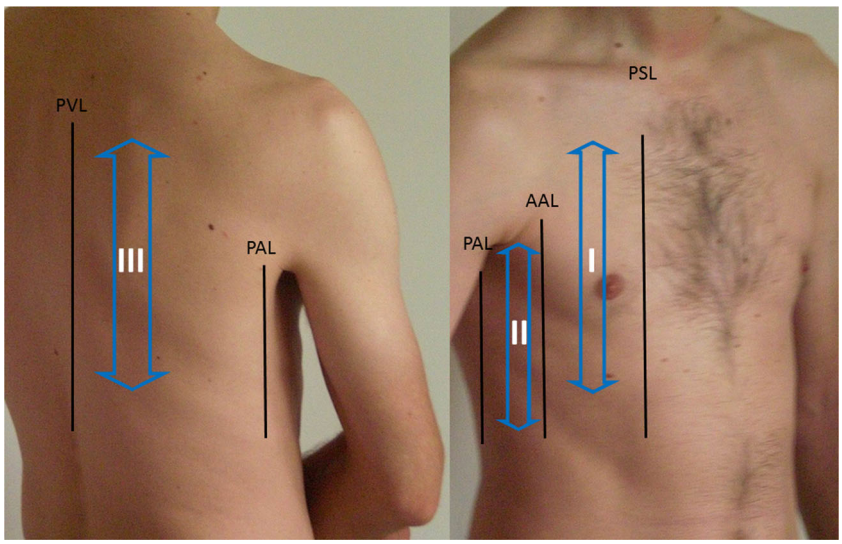

Fig. 1 Chest ultrasound scan achievement

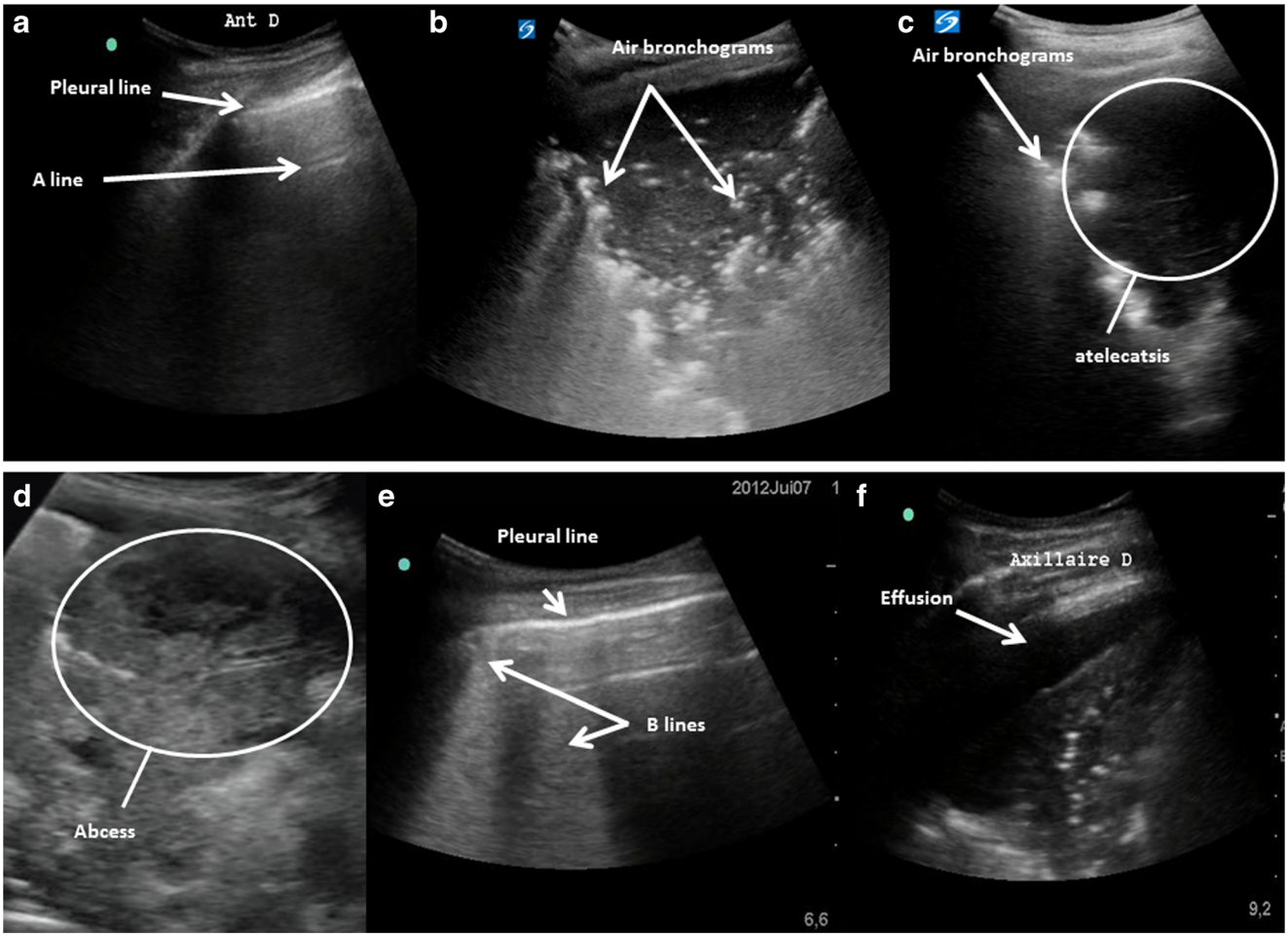

Fig. 2 Normal and pathological lung aspects of ultrasounds images

Lung Abscess A lung abscess is consistent with a consolidation within which is found an image of cystic appearance whose contours are echoic and the fluid content is normally anechoic. Nevertheless, in the case of an abscess, the liquid viewed may be more echogenic due to a thick purulent content. A guided thoracentesis with aspiration may be performed using US [23] (Fig. 2d).

Interstitial Pneumonia With interstitial pneumonia, the pleural line is always visible, but presents a shredded aspect with many B lines originating from the pleural line and spreading down to the edge of the screen. They are bottomless because they are visible regardless of the depth. They are dynamic and synchronous with the respiratory movements. This aspect corresponds to the X-ray or CT scan micro-nodule opacities. Visualizing more than three B lines per field in a longitudinal plane between two ribs is considered pathological. These can be seen in cases of fibrosis, cardiogenic pulmonary edema, pulmonary contusion, acute respiratory distress syndrome (ARDS), atelectasis as well as in association with a consolidation and/or alveolar syndrome. They are therefore not specific to an infectious etiology [24–26] (Fig. 2e).

The Pleural Effusion With a pleural effusion, the pleural line is replaced by an echo-free space between the visceral and the parietal pleura. The echo structure may be again variable as in the case of a loculated pleural effusion. If it is associated with an alveolar consolidation, it is called a pleuropneumonia [27] (Fig. 2f).

Diagnostic Performance of Lung Ultrasounds in Acquired Pneumonia

From the first studies evaluating the ability of US to detect alveolar consolidation, the sensitivity of the test was about 90 %. In these studies, US was carried out after radiographic confirmation of a lung image, which introduced a bias for US examination. However, in 10 % of cases, micro-abscesses and minimal effusions not visualized on X-rays were found [28•, 29, 30].

Lichtenstein et al. conducted several studies on chest US performed in critically ill patients during the years 2000 to 2006, highlighting the contribution of the US compared to the lung auscultation and X-rays [31]. Indeed, performance comparison of lung auscultation, X-rays, and chest US with CT scan in 32 patients with ARDS showed a diagnostic

accuracy of 95 % for the chest US versus 55 % for the clinical examination and 75 % for X-rays in cases of alveolar-interstitial syndrome. Thus, in this study, the performance of chest US was equivalent to CT [32].

These studies in critically ill patients have led to the edification of the bedside lung ultrasound in emergency (BLUE) protocol, which classifies most lung diseases in intensive care by following an algorithm coupling chest US and analysis of proximal venous trunks [16•].

Others have sought to demonstrate the value of using cardiopulmonary US to distinguish between cardiac and pulmonary origin of dyspnea. Elevated filling pressures and a bilateral interstitial syndrome (represented by B lines), with or without bilateral pleural effusion, led to a cardiac rather than a pulmonary etiology [33–35].

Since the year 2000, numerous publications from emergency department data have confirmed the interest of chest US in the diagnosis of CAP. The US examination was feasible at the patient bedside in 100 % of cases, with a mean completion time of 5 to 13 min and a strong diagnostic performance: sensitivity ranged from 85 to 95 % and specificity was 92 %, versus 70 and 85 % for X-rays, respectively [36–39]. This difference in sensitivity was wider when US was compared to clinical signs evolving for less than 24 h [40•]. The US also detected a precocious pneumonia, where 24 to 48 h were needed for the chest radiograph [40•, 41]. Furthermore, the correlation between the chest US and the CT scan was 90 % [26, 42–44].

However, these studies included a number of limitations. Most of the studies were conducted at a single-study center, without randomization, and included a small number of patients.

The affirmation of the final diagnosis in most studies was based on paraclinical elements including an X-ray and/or chest US rather than a CT scan, which is considered the gold standard examination.

Despite these limitations, two meta-analyses confirmed the true contribution of the chest US in the diagnosis of acute pulmonary disease with a sensitivity and specificity of 93 %, higher than that observed with the chest X-ray in all studies.

These results were typical of the real world in that the studies had been conducted in intensive care, in an emergency department, or on medicine wards. The authors of these studies have therefore suggested substituting the X-ray of the chest by the US, reserving the use of the CT scan to cases of doubt about the diagnosis [45, 46].

A prospective multicenter study also reported a higher sensitivity and specificity when using chest US compared to a chest X-rays in the monitoring of CAP [47••]. Thus, several authors propose chest US for diagnosis and follow-up purposes [48–50].

Conclusion

Currently, chest ultrasounds can be proposed as the first-line examination for diagnosis in acute pneumonia because of its higher sensitivity and specificity when compared to chest X-rays.

US may be an integrated part of the clinical approach, which aims at early diagnosis and treatment. The recourse to chest CT scan should be limited to doubtful diagnostic cases.

CAP, Community-acquired pneumonia; US, Ultrasound

Compliance with Ethical Standards

Conflict of Interest Drs Bourcier, Braga, and Garnier have no conflicts of interests to declare.

Human and Animal Rights and Informed Consent The authors of this article state that lung studies have been done and used for reference in this paper.

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