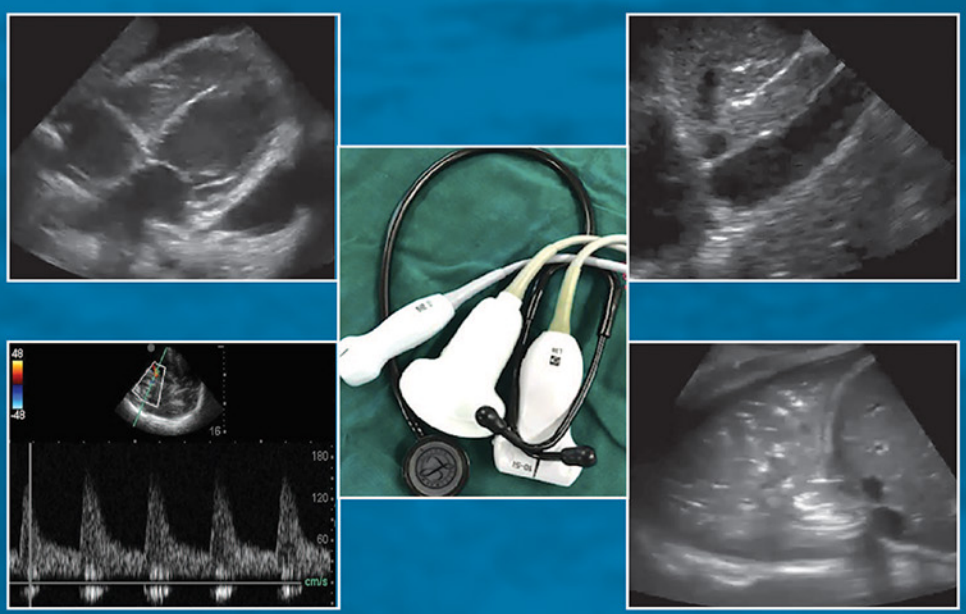
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CRITICAL CARE ULTRASOUND

for Emergency Situations and Clinical Applications



Editors
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Jayant Shelgaonkar

Foreword
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JAYPEE

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4 CHAPTER

Ultrasound of the Lung and Clinical Uses in Emergencies

Pradeep D'Costa

INTRODUCTION

Air was once considered the graveyard for the ultrasound machine as it was considered a very poor medium of propagation of the ultrasound waves.

The lungs were once considered the worst enemy of the ultrasound machine and old editions of famous medicine textbooks (Harrison's Principles of Internal Medicine) have also commented on the possible futility of lung ultrasound to help clinical decision making.

But over the last three decades or so, substantial progress has been made in the field of lung ultrasound and this has indeed changed the approach toward the same in a very substantial manner.

Various protocols have been described bedside lung ultrasound in emergency (BLUE), fluid administration limited by lung sonography (FALLS), which have made the approach to a previously considered complex topic a very simplified one!

The whole of interpretation of the lung ultrasound is based on production and identification of various lung artifacts and their interpretation in the clinical scenario.

Professor Daniel Lichteinstein, by his pioneering work in this field from the 80s, has forever changed the way people look at the lungs with the ultrasound probe!!

BASIC INFORMATION

The whole of the lung ultrasound is based on two important principles:

1. Lungs are composed of mainly air.
2. Pathologies of the lung mostly involve changing this milieu of air to one composed predominantly of fluid, air, etc.

It is the interaction of the ultrasound beam with this air-fluid interface, which produces the typical artifacts based on which reasonably accurate diagnosis can be made.

This interaction produces many true and false images (artifacts) which can then be used to make important clinical decisions.

What follows is a short description of various artifacts that have been described.

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Probe Positions (Fig. 4.1)

Various approaches have been described for performing lung ultrasound, but a basic layout has been described.

This involves examination of both lungs in various segments or intercostal spaces.

Each lung is commonly divided into around six various sections and each segment at least three intercostal spaces are scanned before ruling out or ruling in any pathology.

Commonly each lung is divided into six segments as shown in the diagram by anterior and posterior axillary lines (Figs. 4.1).

Probes Used

Commonly used probes (Fig. 4.2A and B) for lung ultrasound include:

- Linear probe—higher frequency—commonly to study the superficial layers like pleura and superficial lung surfaces
- Convex probe—medium-frequency probe—commonly used to study the deeper structures of the lung better.

Normal Appearances

A Normal Lung

Appearances of normal pleura:

- The normal pleura, composed of the parietal and visceral layers, is seen on the ultrasound image as a thick white, homogenous line.

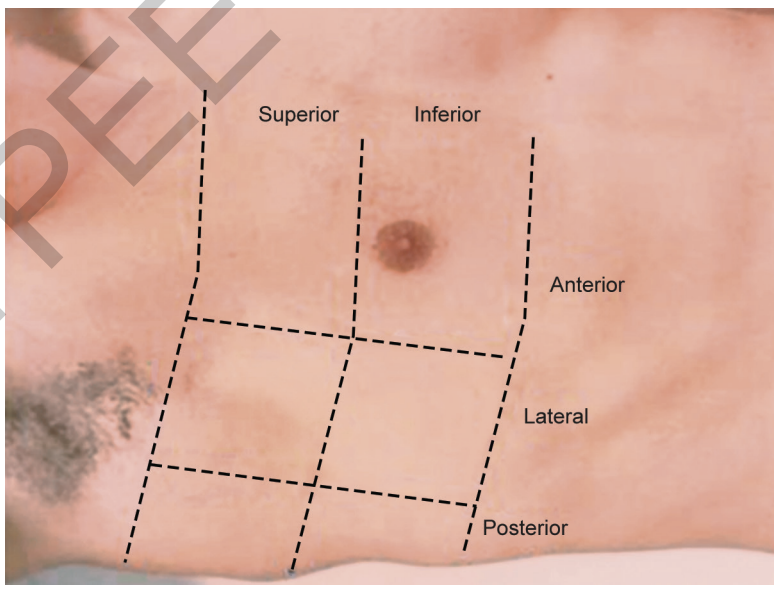


Fig. 4.1: Probe positions.

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Figs. 4.2A and B: Various probes used for lung ultrasound.

- Due to the dynamic nature of lung expansion with each breath, the pleura are seen to move in a horizontal manner with each respiration, this is called "the pleural sliding sign".
- It indicates a mobile lung.

Pathologies:

- Thickening of the pleura, immobility of the pleura, or reduced mobility of the pleura have been described.
- A pleural slide indicates a mobile lung under the pleura.

Normal lung profile

A normal lung segment is one in which you see:

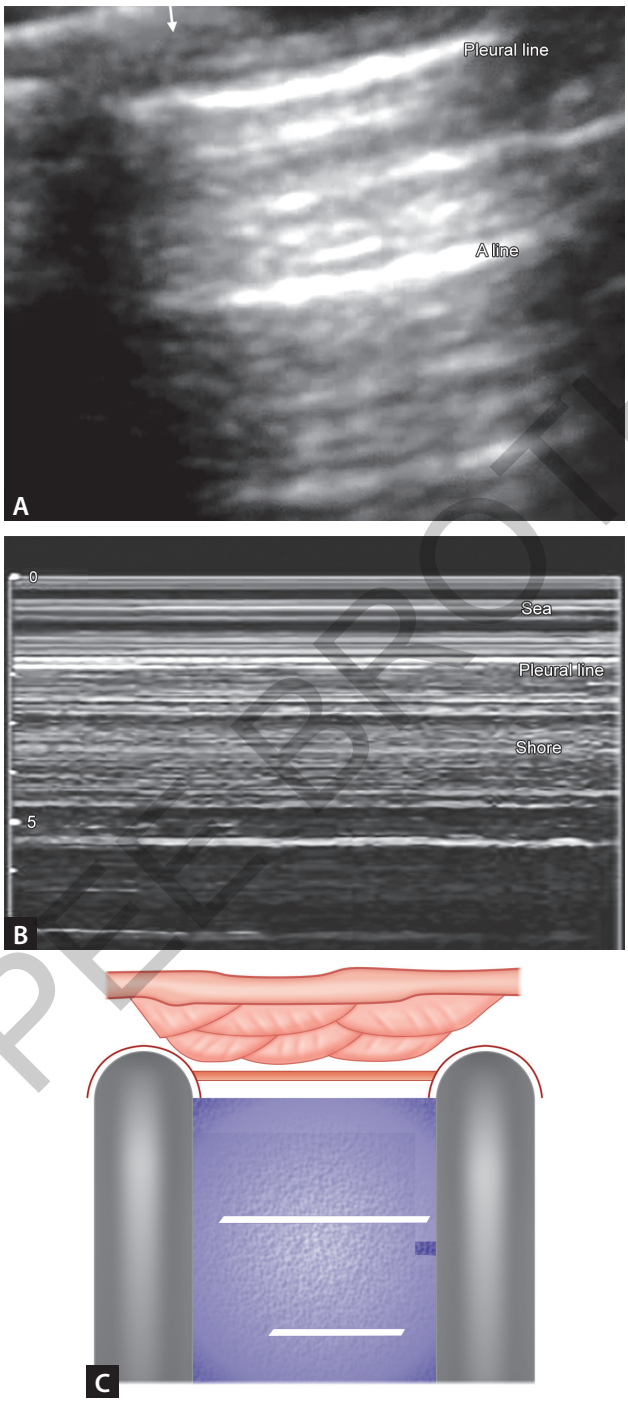
- Normal lung sliding or pleural sliding
- Horizontal reverberation artifacts—the *"A" lines.*

The "A" line:

- When the ultrasound probe is placed on the chest wall, the structures encountered by the beam include skin, subcutaneous tissue, intercostal muscles, nerves, and then the pleura.
- Once, the ultrasound beam reaches the pleura, it bounces back to the probe and reappears on the screen as a white horizontal line, which is equidistant as the pleural line.
- This white horizontal line is a "reverberation" artifact and is called the A line.
- Subsequent images on the screen produce multiple such horizontal lines, the further from the screen the more faint would be the line.
- This A profile along with the pleural sliding sign indicates a normally mobile lung.

Upon M-mode imaging through this lung segment we would get an image which would look like the seashore (i.e. immobile skin, subcut tissue, and muscles—these are the true images and give the appearance of "sea", and a dynamically moving lung beneath producing the granular appearance—shore, these are the false images), leading to this appearance being described as "the seashore sign" (Figs. 4.3A to C).

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Figs. 4.3A to C: (A) A profile; (B) Seashore sign; (C) Anatomy of normal lung.

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While a "wet" lung can be identified by the following characteristics.

B lines:

- These are vertical lines starting from the subpleural area
- Traverse the whole ultrasound screen
- They abolish the A lines
- They are thick and white lines
- They usually indicate fluid in the alveolar interstitial space
- Previous nomenclature called these lines included terms like "lung comets" or "lung rockets"
- The severity of the fluid-filled lungs was previously interpreted by measuring the amount or distance between two B lines
- Hence, the terms B3 or B7 lung rockets were introduced
- Hence, B3 rockets meant much more fluid-filled lungs than B 7 rockets (Figs. 4.4A to C).

The Z line:

- Many a times, vertical lines appear on the screen which may mimic B lines.
- The difference between the B lines and Z lines are that the Z lines do not traverse to the end of the screen, and they do not erase the A lines.
- These lines are a normal variant and do not signify anything abnormal.

The E lines:

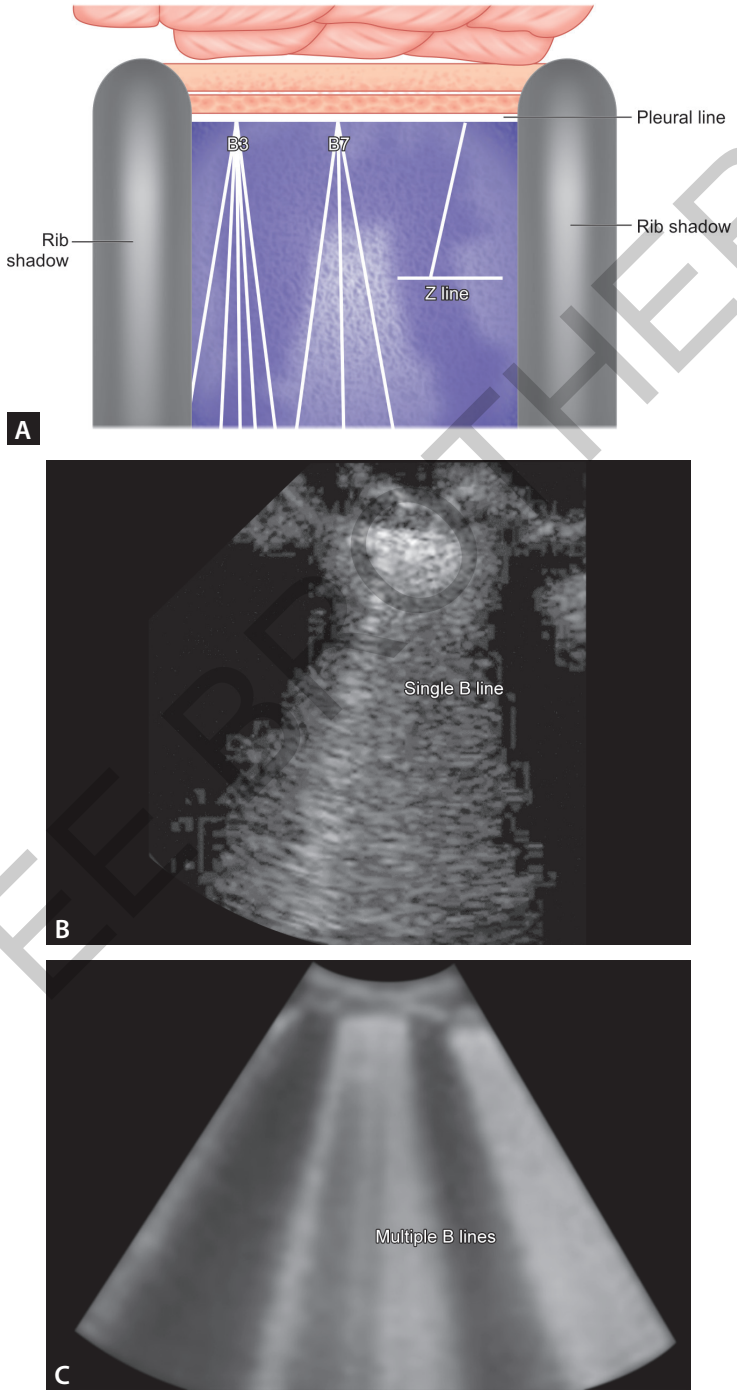
- These lines are also called "emphysema" lines.
- They are commonly seen when there is subcutaneous tissue air.
- What differentiates these lines from the "B" lines is the origin of the line, much higher than pleural line and the masking of all other architecture based on the fact that air is a very poor conductor of the ultrasound beam.
- These lines are commonly seen in patients of subcutaneous emphysema.

Now, the lung is studied in various segments both anteriorly and posteriorly, bilaterally to avoid missing any pathology.

Many typical profiles can give invaluable clues to the diagnosis of the underlying pathology and hence make treatment decisions easier.

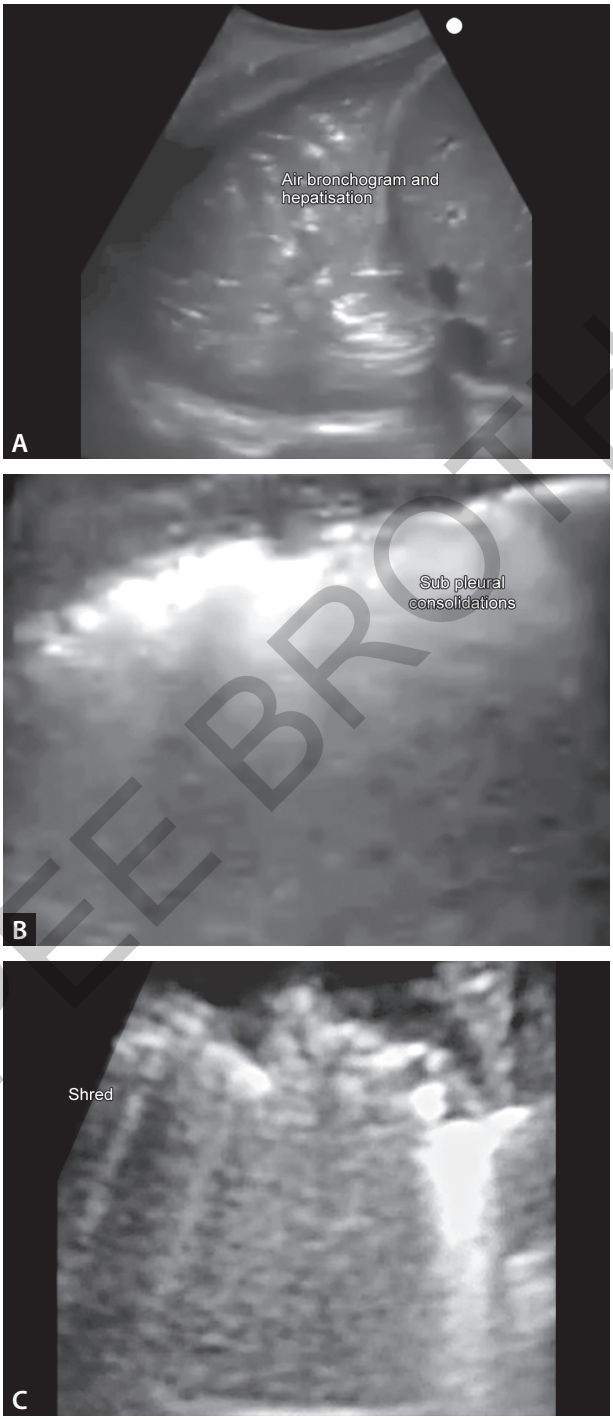
- Bilateral symmetrical B lines, many times more at bases than at the apices and many times associated with a 2D ECHO finding of a low systolic function or evidence of diastolic dysfunction make the possibility of cardiogenic pulmonary edema more likely.
- Bilateral lung fields showing a varied and different appearance, e.g. (A) profile in a segment, (B) in the adjoining segment, and (C) a profile (consolidation type) in certain segments point more in favor of a noncardiac cause of the problem like acute respiratory distress syndrome (ARDS), pneumonia, lung contusion, etc.
  - *The C profile or consolidation features:*
    - Typical identification of lung infective foci can also be accurately diagnosed by the use of bedside ultrasound.
    - The lung exhibits the following patterns of consolidation.
    - The initial stage development of small subpleural consolidations, this is the stage of microconsolidation.

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Figs. 4.4A to C: (A) Wet lung profiles, B-lines or B3 or B7-lines; (B) Single B-line; (C) Multiple B-lines.

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Figs. 4.5A to C: (A) Air bronchogram (note white dots); (B) Subpleural consolidations; (C) SHRED sign—note multiple irregular "B" lines from multiple levels with surrounding pleural effusion.

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- As more lung areas start getting involved, macroconsolidation like changes set in and involve larger lung areas.
- These areas exhibit some "wet" lung profiles, but in addition may exhibit the "shred" sign—appearance of an irregular distorted pleural line, with appearance of B lines arising from various levels.
- The tissue like sign—the lung parenchyma on the ultrasound looks exactly like a solid organ, commonly compared to the liver and spleen. This has been described in pathology textbooks as the stage of "hepatization" of lung parenchyma.
- The air bronchogram—the appearance of air moving in and out of the terminal airways can be well picked up by the ultrasound, and gives the appearance of white dots moving dynamically with respiration—this has been described as a "true consolidation pattern" or a dynamic air bronchogram (Figs. 4.5A to C).
- A static air bronchogram, on the other hand, could imply areas of the lung, which have developed air trapping and atelectasis.
- The *"lung pulse"* on the other hand, many a times is confused with "lung point", but is a totally independent sign, is a typical finding of the cardiac pulsations being transmitted to a nonaerated lungs, and giving the appearance of a pulsating lung.
- The causes of the lung pulse could be of a significant nature (e.g. lung collapse due to a unilateral lung intubation or mucus plug block of a bronchus).

– *Diagnosis of a pneumothorax by ultrasound:*

We will look at the lungs, inferior vena cava (IVC) for making a diagnosis.

LUNG FINDINGS IN PNEUMOTHORAX (FIGS. 4.6A TO C)

The following diagnostic criteria are usually present in a case of a pneumothorax:

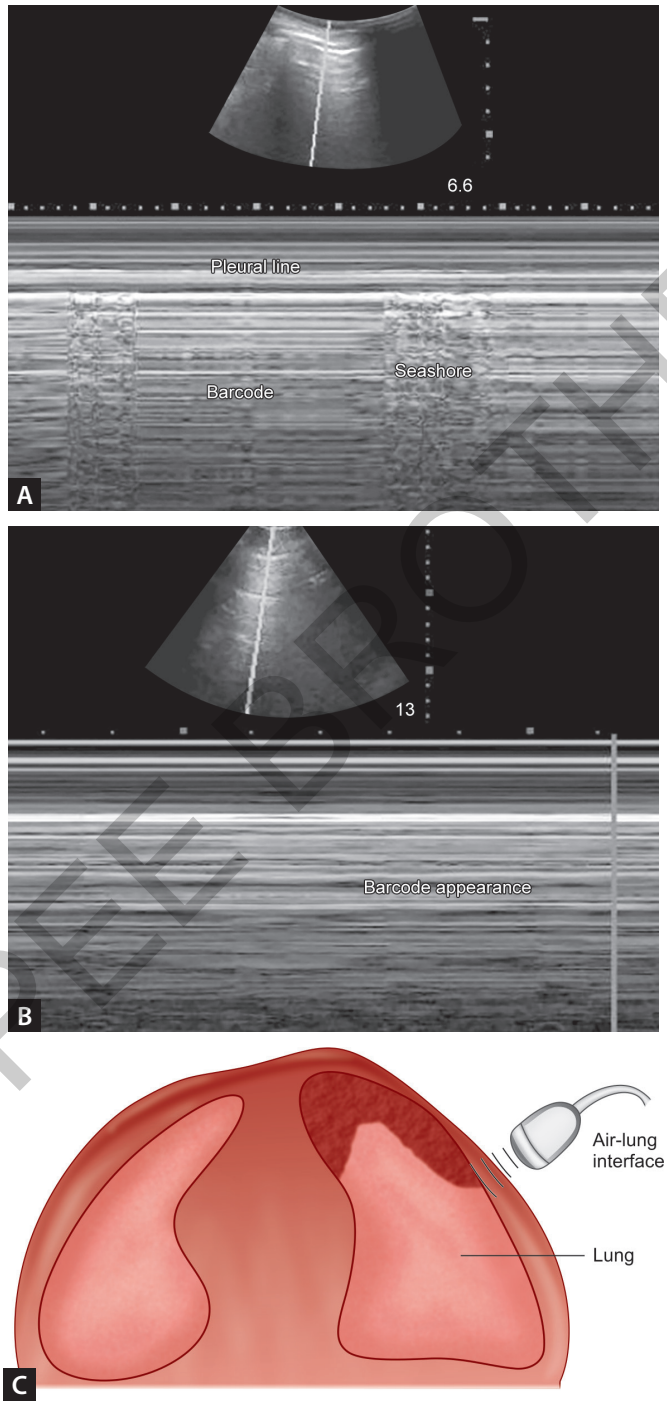
- Absence of lung sliding
- A profile
- Presence of B profile, C profile, lung sliding, and lung pulse effectively rules out a pneumothorax in the lung segment studied
- Presence of stratosphere or barcode sign—this is the appearance of the lung on M mode, which is immobile and may be present in a patient who has a pneumothorax
- Presence of the "lung point"—this is the point on the chest wall where during inspiration, the lung expands and creates a typical seashore sign on M mode, and on expiration there is only air present beneath the probe giving the typical "barcode" or "stratosphere" sign.

  This lung point when found is the most accurate sign of the presence of a pneumothorax.

Inferior Vena Cava

- The IVC—many times a dilated and turgid IVC is encountered in these patients.
- Heart—unless a coexisting cardiac pathology, the systolic cardiac function is normal.

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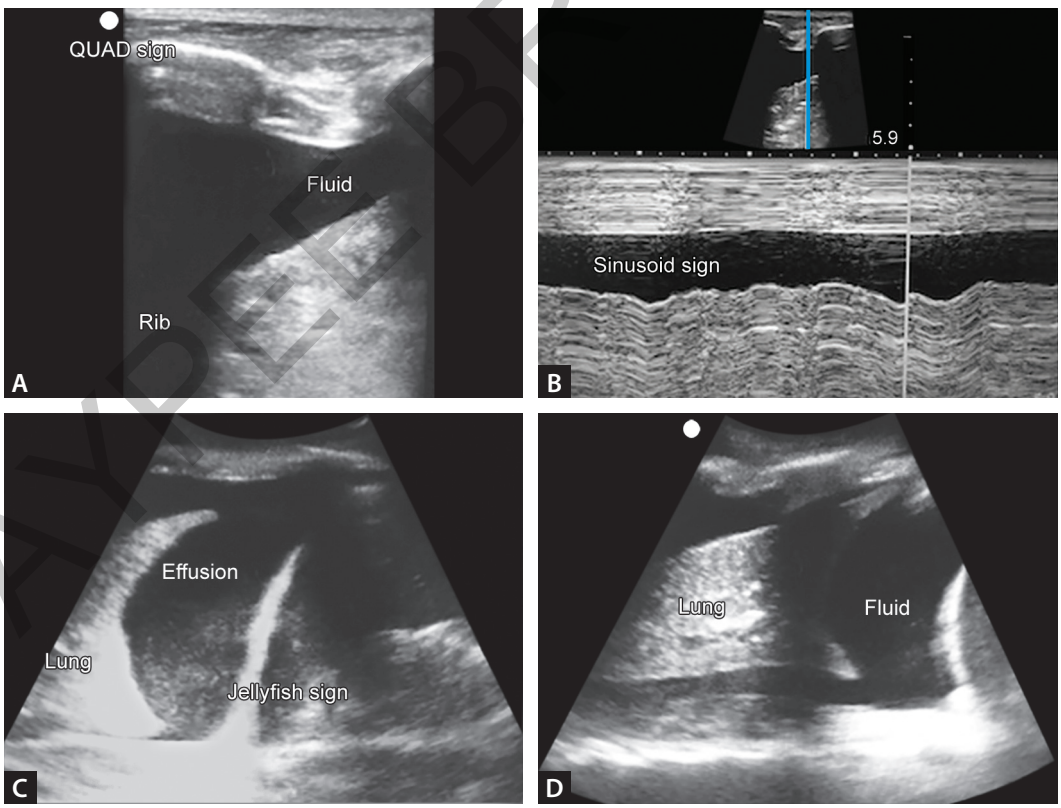


Figs. 4.6A to C: (A) The lung point; (B) Barcode or stratosphere sign, and lung point (note barcode alternating with seashore sign); (C) Pneumothorax—location of lung point.

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PLEURAL EFFUSION (FIGS. 4.7A TO D)

- A pleural effusion is usually diagnosed as an echo-free area seen between the visceral and parietal pleura.
- Contours of the effusion vary with different phases of respiration and also with the posture of the patient.
- Pleural effusions are also identified by the sinusoid or quad sign.
- When an M-mode image is taken through the area of interest, the effusion gives a typical appearance of a "sinusoid" or a "quad".
- The pleural effusion is delineated by the following borders—(1) the pleural line, (2 and 3) the shadow of the ribs, and (4) the lung line (visceral pleura), this has been described as the *quad sign*.
  - It is a static sign.
- On application of M-mode, real-time images show the lung line moving toward the pleural line on inspiration. This has been described as *sinusoid sign.*
  - It is a dynamic sign



Figs. 4.7A to D: The sonographic appearance of pleural effusion.

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- The jellyfish sign
  - The sight of a freely moving lung within free fluid gives the appearance of a jellyfish moving in water and hence has been described as some as the jellyfish sign.

The sonographic appearance of pleural effusion depends on the cause, nature, and duration of the collection.

Different appearances that may be observed include:

- Anechoic—usually clear and featureless
- Transudates are mostly anechoic
- Complex but nonseptated
- Complex and septated
- Echogenic
- Complex, septated, and echogenic fluid is usually exudative in nature
- Inflammatory effusions commonly produce strands.
- The clinical relevance to knowing the type of effusion is that thoracocentesis is usually possible in effusions that are anechoic, complex, or complex with movable septae
- Sometimes confusion may exist in between a pleural thickening and an effusion.

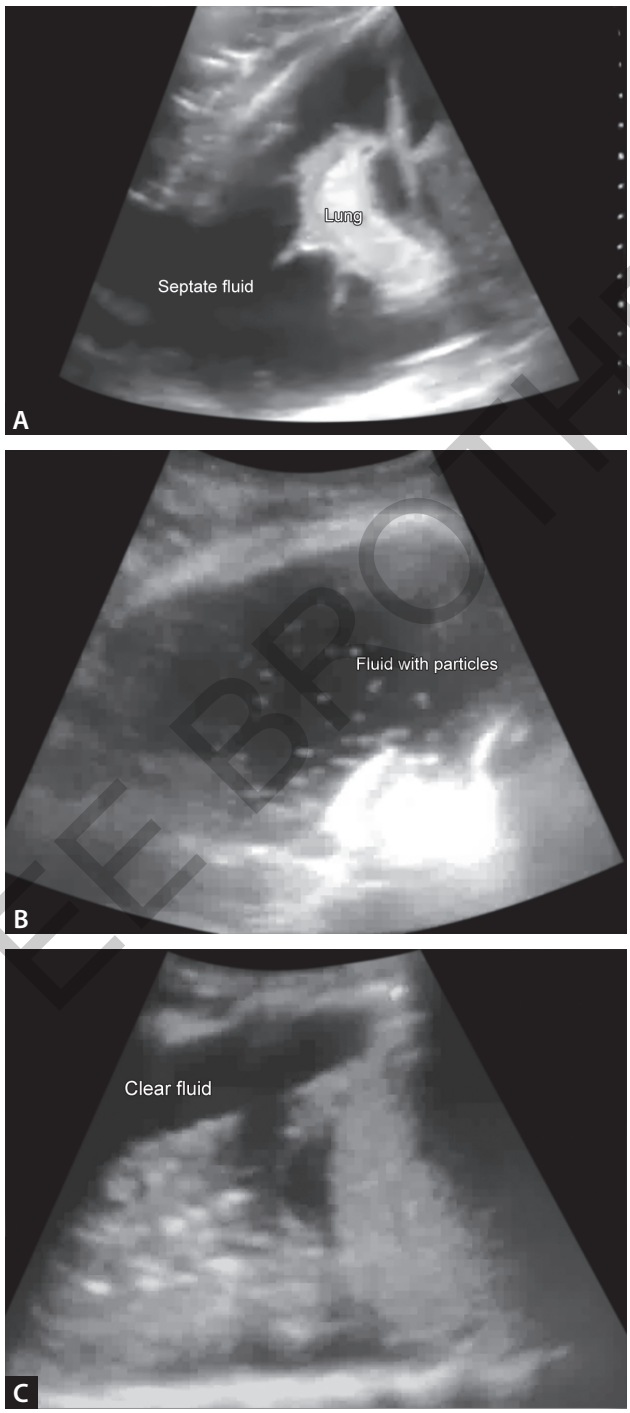
Types of Effusions (Figs. 4.8A to C)

- Septate effusion
- The *"fluid color sign"*
- Transmitted respiratory and/or cardiac pulsations may exhibit a signal in a case of effusion and are absent in pleural thickening
- This fact may be useful when the effusion is of a very small quantity (sensitivity 89.2, specificity 100%)
- Thoracocentesis
- *Safe puncture:* More than three intercostal spaces with in-plane (IP) distance more than 1.5 cm; absence of interposition of lung, heart, liver, and spleen; interpleural distance variation; and mark best puncture point and fixed patient position. (0% complications).

DIAPHRAGM (FIGS. 4.9A AND B)

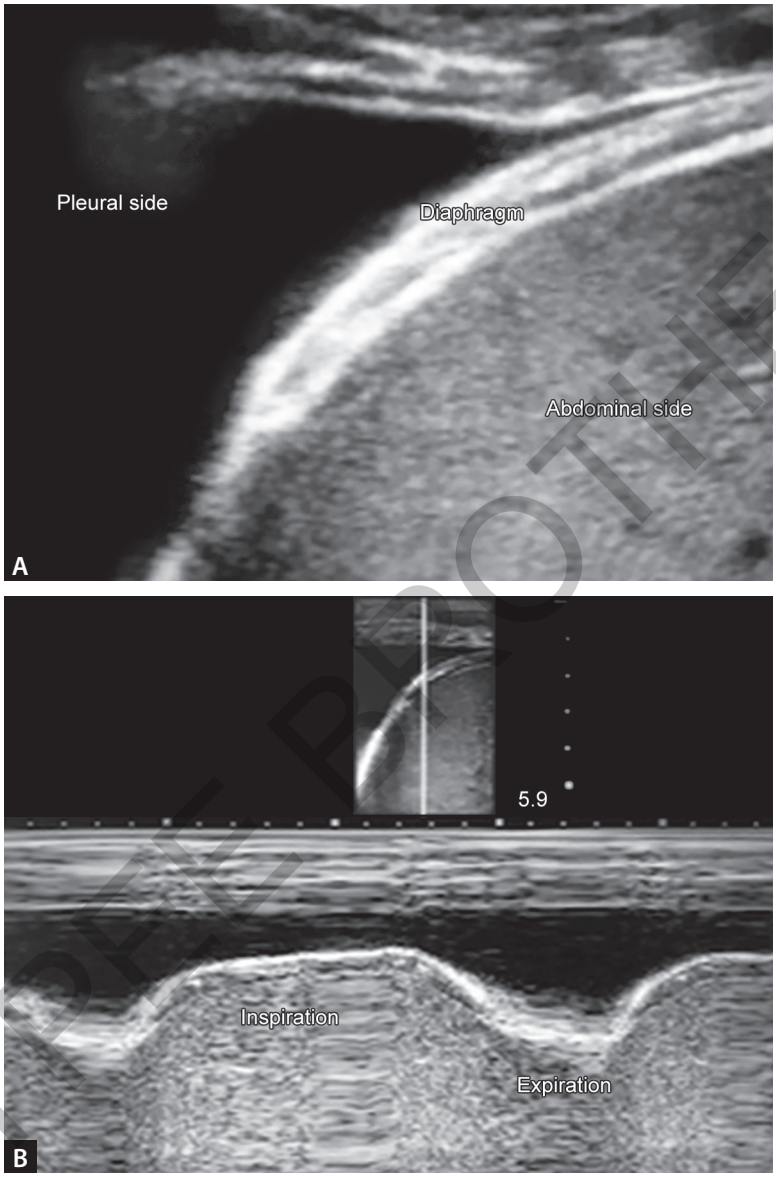
- The utility of ultrasound in diaphragm movements has been taken advantage of in various studies.
- Movements of the diaphragm have been studied during weaning trials and have found a good correlation with weaning.
- Identified by its deep location, curved geometry, and muscular echotexture.
- Longitudinally, muscles have a mixed echogenic appearance, consisting of hypoechoic (dark) muscle fibers separated by hyperechoic (bright) fibroadipose septae (perimysium).
- Transversely, the mixed echogenicity pattern of muscle produces a "starry night" appearance.
- The diaphragm can be seen as 2 echogenic layers of peritoneum and pleura sandwiching a more hypoechoic line of the muscle itself (Fig. 4.10).

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Figs. 4.8A to C: **(A) Exudative effusion with fibrin strands; (B) Pleural fluid with particulate matter; (C) Transudative effusion-clear.**

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Figs. 4.9A and B: (A) Normal diaphragm anatomy; (B) Diaphragm movements.

- It thickens during inspiration, unless it is severely atrophic.
- An atrophic diaphragm will appear as a very thin strip deep to the intercostal muscles, and it may not move with inspiration
- Thickness and echogenicity of the diaphragm can be assessed using B mode ultrasound

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