Lung

How can lung US help me?

Lung US is a comparatively recent addition to emergency US. Its systematic use was first described by Lichtenstein in his textbook *General ultrasound in the critically ill* (Springer, 2002). Since then, critical care doctors worldwide have taken it up for the following indications:

Diagnosis of

- pleural fluid
- pneumothorax (PTX),
- pulmonary oedema
- pneumonia
- abscess

Procedural guidance for

- thoracocentesis
- intercostal catheter placement

More generally, lung US is useful in:

- the approach to the breathless patient
- the approach to the shocked patient
- guiding ongoing fluid resuscitation

Why use ultrasound?

- Pneumothorax and massive haemothorax can be rapidly fatal if not detected and treated urgently
- Plain chest radiograph (CXR) can be unreliable
- Even with experience, differentiating between conditions such as pneumonia and pulmonary oedema can be challenging
- Lung US is easy to learn, non-invasive, rapid, repeatable and can be performed at the bedside.
- Lung US is more sensitive and reliable than mobile CXR in the detection of pleural fluid: it can detect as little as 100ml, with sensitivity >97%, and specificity 99-100%. In expert hands, lung US has been described as 98% sensitive and 99% specific for PTX, and 85.7% sensitive and 98% specific for pulmonary oedema.
- BUT lung US is very operator dependent! This means that it is less accurate in the hands of novice scanners.
- Lung US improves the safety of invasive procedures

Probe and scanner settings:

Probe: Paradoxically, the curved (abdominal) probe is best and the linear probe is worst. This is because the curved probe allows you to orient your view with respect to the diaphragm, heart and abdominal organs- otherwise you might think the liver is hepatized lung tissue!

Preset: Use the abdominal preset (not the 'lung' preset)

Fancy filters: You are **looking for artefacts**, so turn off all the fancy filters!
- Turn off compounding / multibeam
- Turn off tissue harmonics (THI)

Depth: this depends on what you're looking for.
- Lung sliding & A/B/C profiles (see below): 10cm will do.
- Base of lungs eg effusion: 15cm sometimes needed.

Where to scan?

Bottom line: Probe in sagittal axis, placed on:

- upper chest in midclavicular line: upper lobe lung
- lower chest, lateral to the midclavicular line on right (to avoid the heart on the left): middle lobe / lingula
- as posterior and inferior as possible (just above the diaphragm), allowing for patient position: lower lobe
- this should ensure that all lobes of the lung are imaged

Background

Ideally, scan as much of the lung as possible, to avoid missing localised conditions eg small areas of consolidation. However, sticking to the above points will suffice for a basic screen.

The principle is that air rises (pneumothorax) while fluid sinks (effusion), so that you should ensure you scan the **most & least dependent areas** of each lung, whatever the patient position.
- Scanning the least dependent (anterior) part of the chest will pick up a small pneumothorax: eg anterior chest in supine patient
- Scanning the most dependent part will pick up small pleural fluid collections: eg posterior/inferior chest in supine patient

Want to know more?

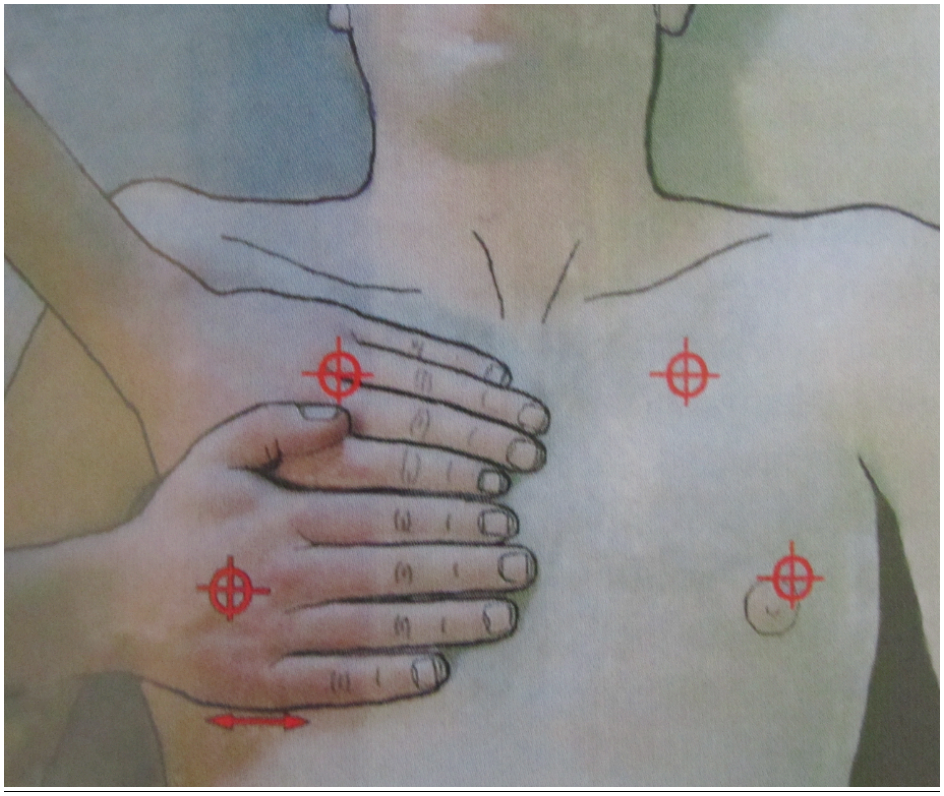
With the aim of standardising lung scanning, Lichtenstein defined three points to place one's probe:

1. The upper BLUE point: the root of the middle & ring fingers of a hand (of the same size as the patient's) placed just below the clavicle, fingertips on the midline of the sternum.

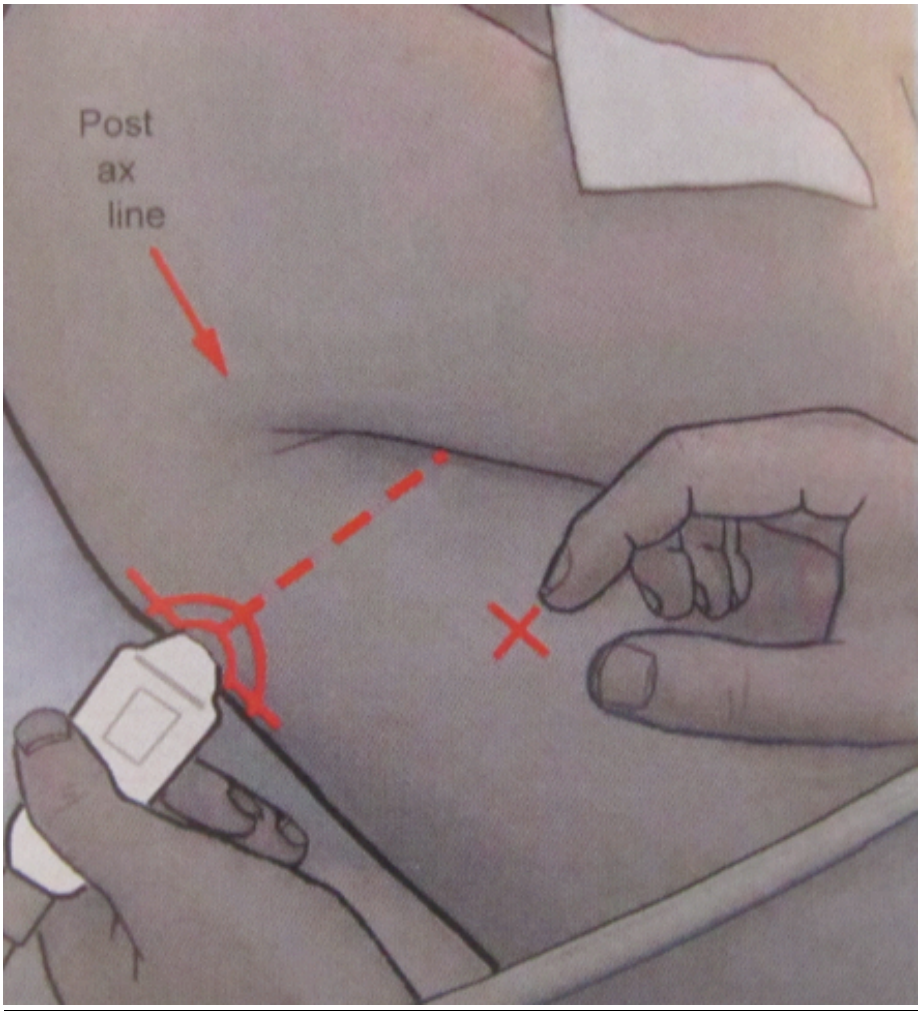
2. The lower BLUE point: the middle of the palm of a 2nd hand placed just below the first.

3. The PLAPS point: the posterior continuation of the lower BLUE point (as far around as you can get the probe)

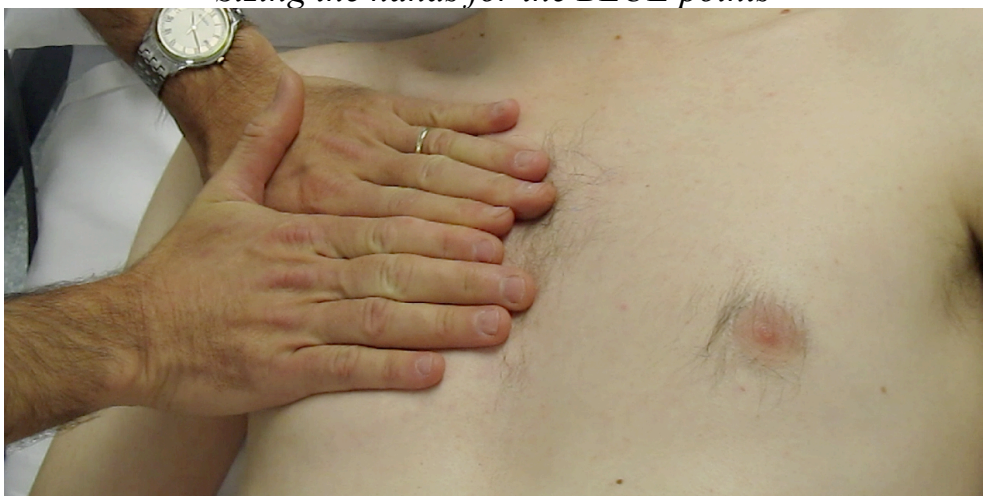
Lichtenstein's BLUE points
(from 'General Ultrasound In the Critically Ill'



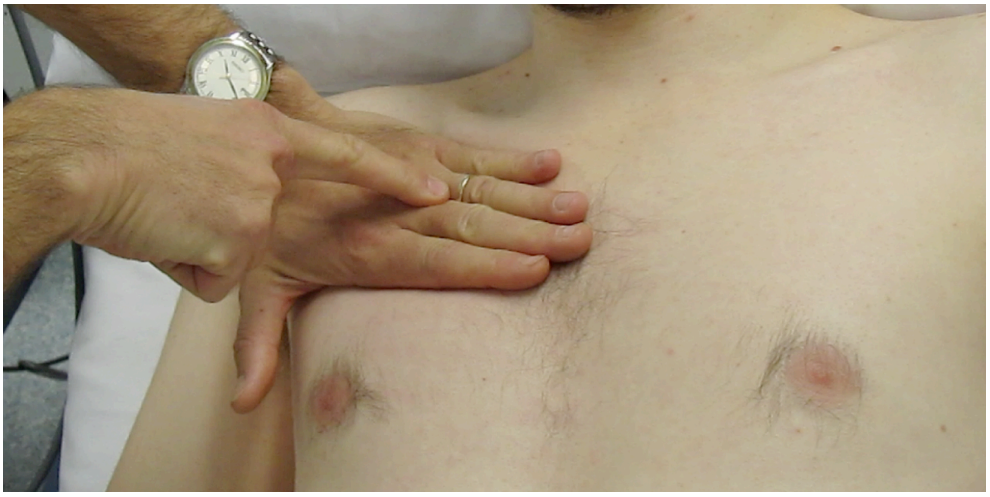
Lichtenstein's PLAPS point
(from 'General Ultrasound In the Critically Ill'



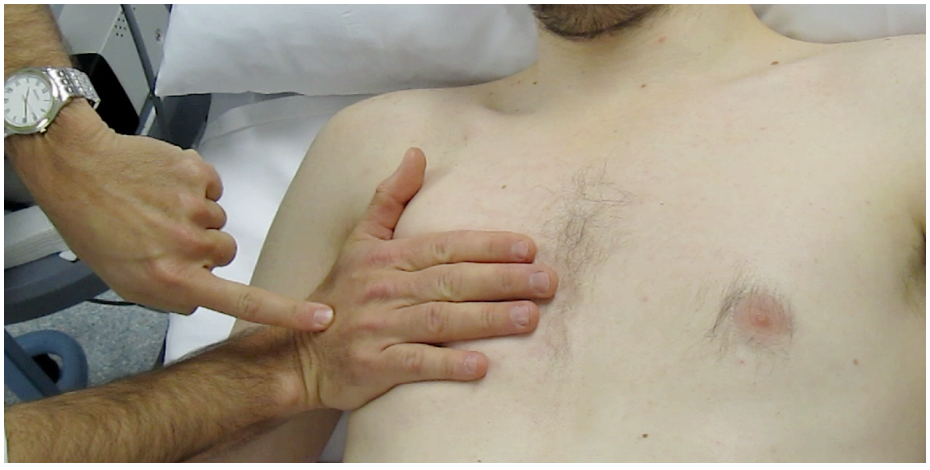
Sizing the hands for the BLUE points



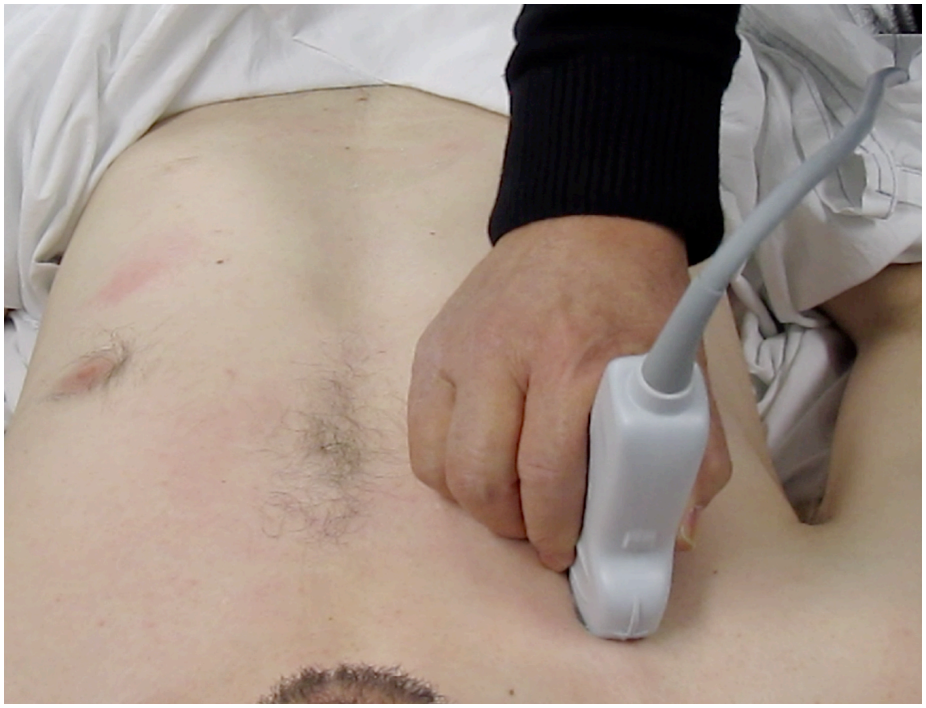
Upper BLUE point



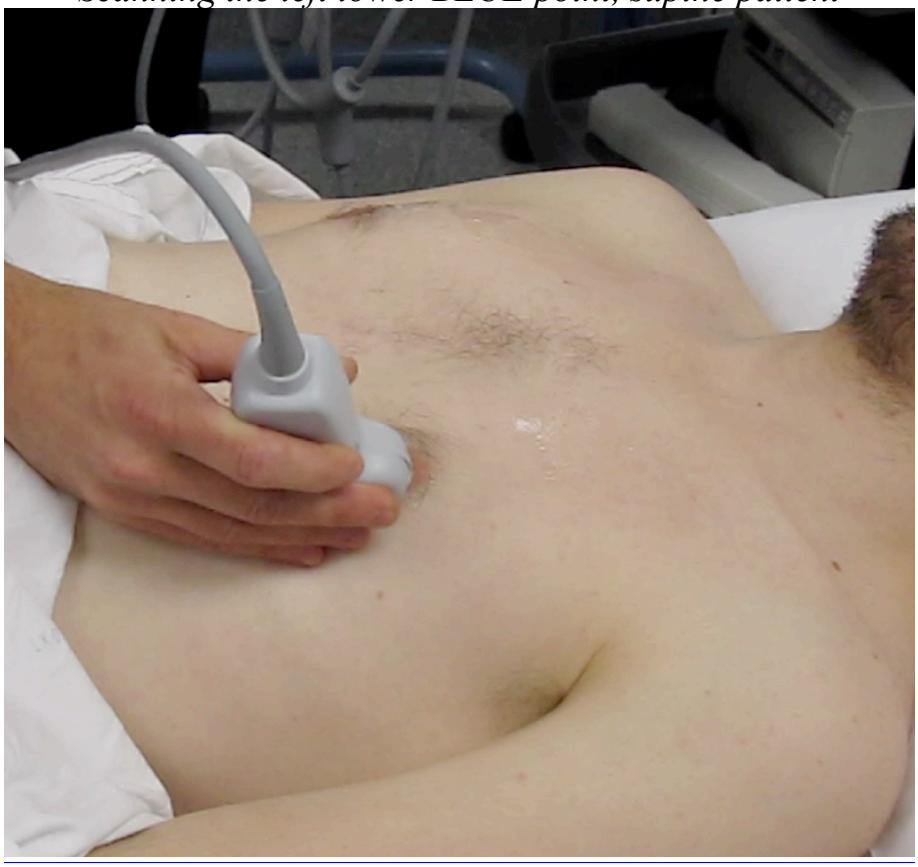
Lower BLUE point



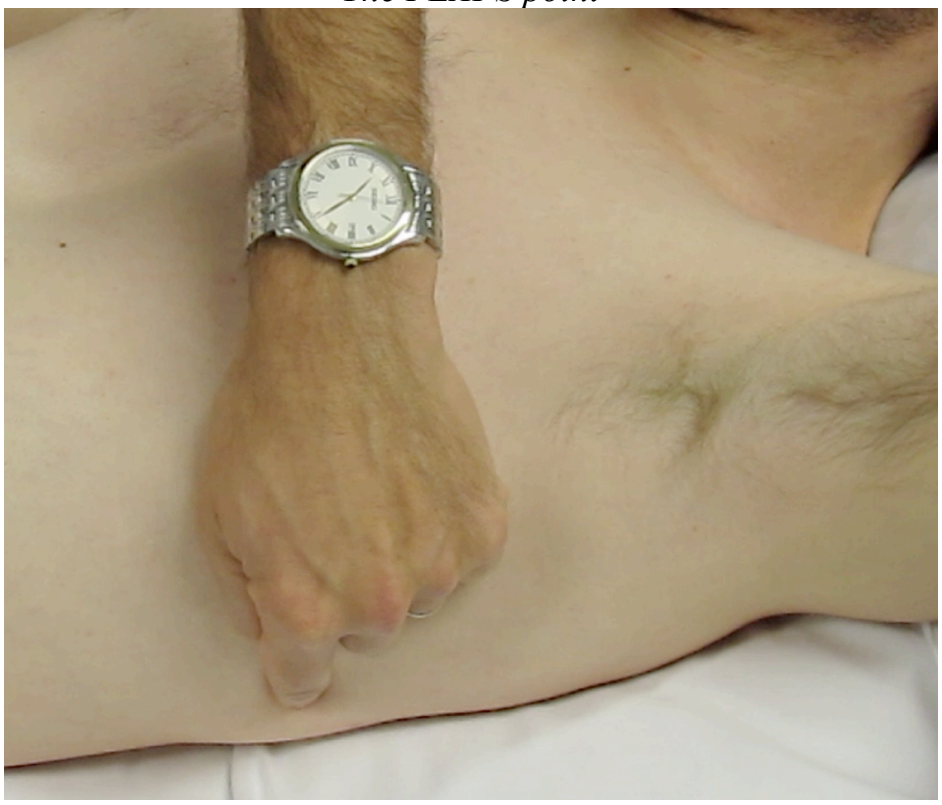
Scanning the right upper BLUE point, supine patient



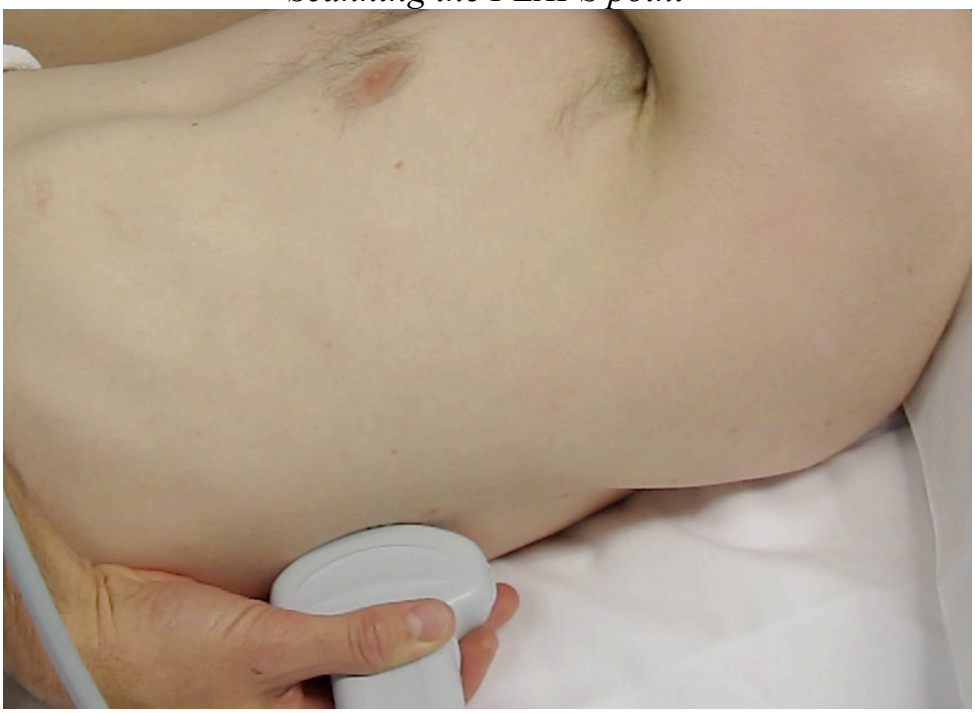
Scanning the left lower BLUE point, supine patient



The PLAPS point



Scanning the PLAPS point

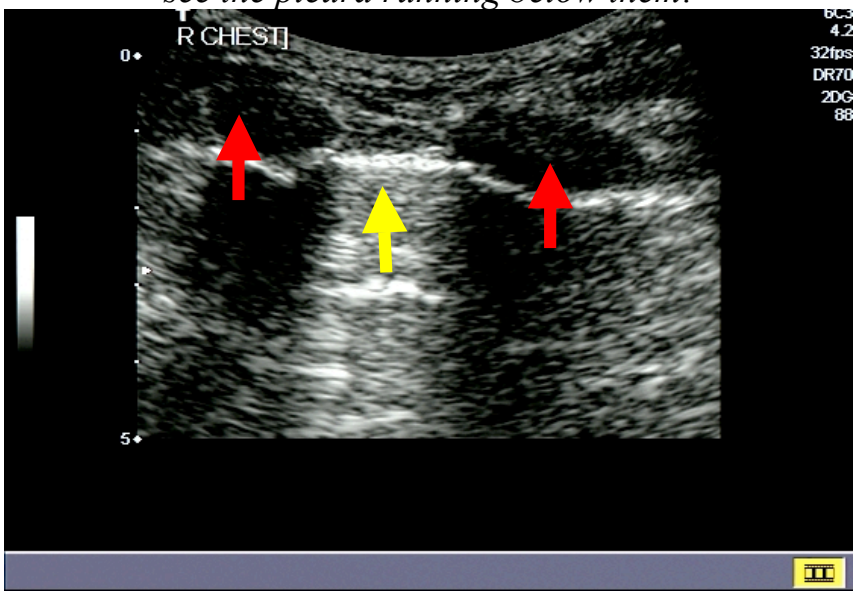


What am I looking for?

The landmarks: ribs & pleura

With the probe at right angles, identify the ribs by the shadows they cast. Then look between & below the ribs for the highly echogenic pleural line (fig below)

Fig: *curved probe perpendicular to costal cartilages (red arrows). Pleural line (yellow arrow) runs just below. NB you can tell these are costal cartilages not ribs, because you can see the pleura running below them!*



Pleural sliding

Normally the pleural line resembles a 'sparkling curtain' as the visceral pleura slides back & forth on the parietal pleura, with every breath. (The sparkle represents scatter from the air in the lung.) This is known as *pleural sliding* or *lung sliding*.

If present, it rules out pneumothorax (PTX) at that point. There could still be PTX elsewhere in the lung, so be sure to scan more than 1 lung window.

If absent, does this equal PTX?

Well, not always. Absent lung sliding is found in many conditions, e.g:

- Right main stem intubation (absence of sliding on the left side)
- Pleural tethering (eg due to lung cancer at the periphery)

- Pneumonia & ARDS (see below)

So how do I diagnose PTX?

1. clinical picture
2. absent lung sliding
3. *A' profile* (see below; even 1 B line rules out PTX)
4. The lung point sign *(fig below):* This represents the site where normal lung gives way to PTX, so that on one side of the image sliding is present, while on the other side it is absent. Some say this is the only truly reliable sign of PTX. In other words, scan more of the lung & look for evidence that sliding is occurring in the lower chest, but not the upper chest.

NB if there is no lung point, there might still be a massive PTX which has collapsed the entire lung. Go back to the clinical picture & decide whether you need to go ahead & decompress the chest.

What about M-mode?

M-mode (Motion mode) is not essential but sometimes helps confirm the presence /absence of dynamic sliding. In M-mode, normal sliding is described as the seashore sign whereas the absence of normal sliding is described as the stratosphere sign.

Fig: M-mode image, seashore sign (normal lung)

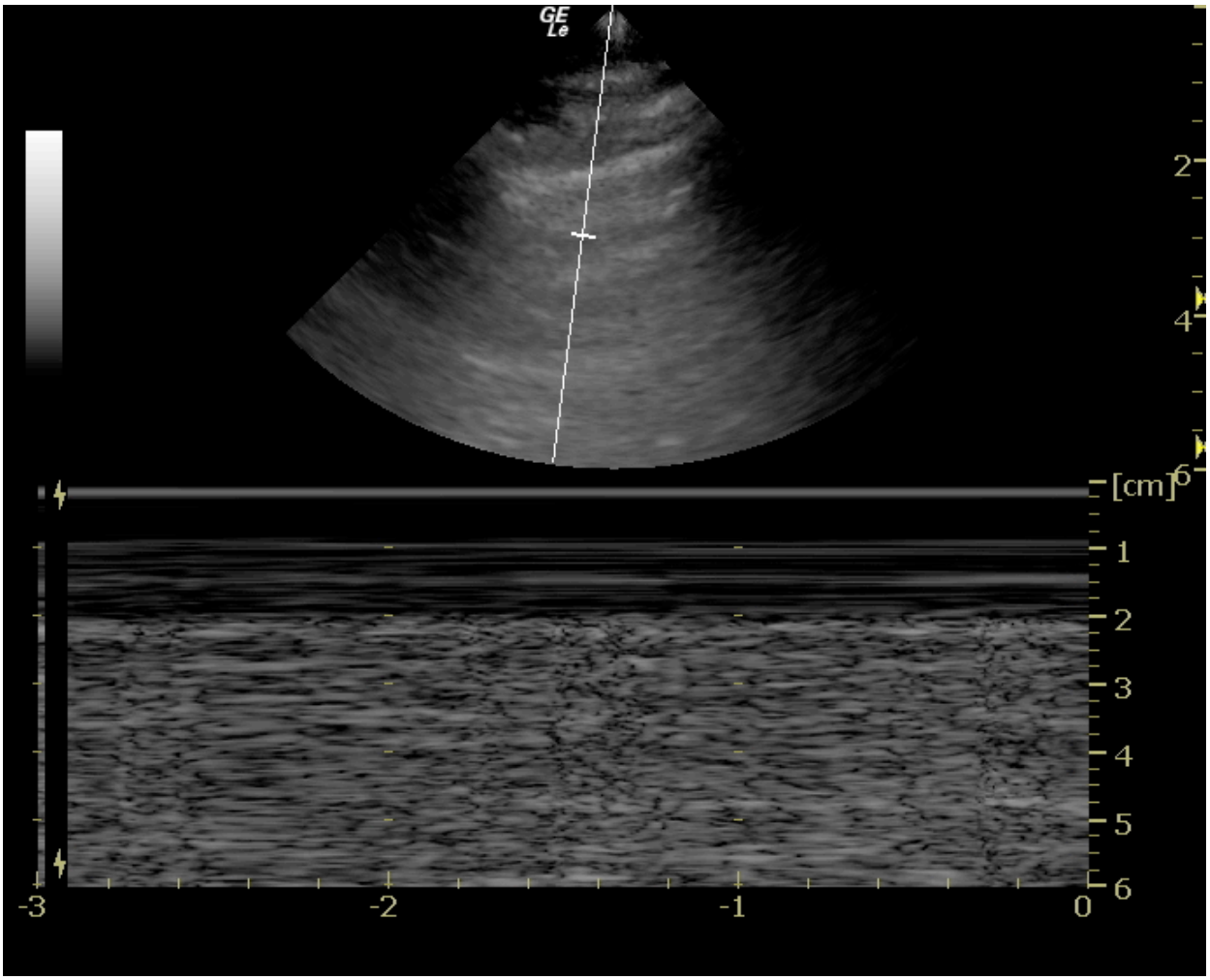


Fig: M-mode image, stratosphere sign (pneumothorax)

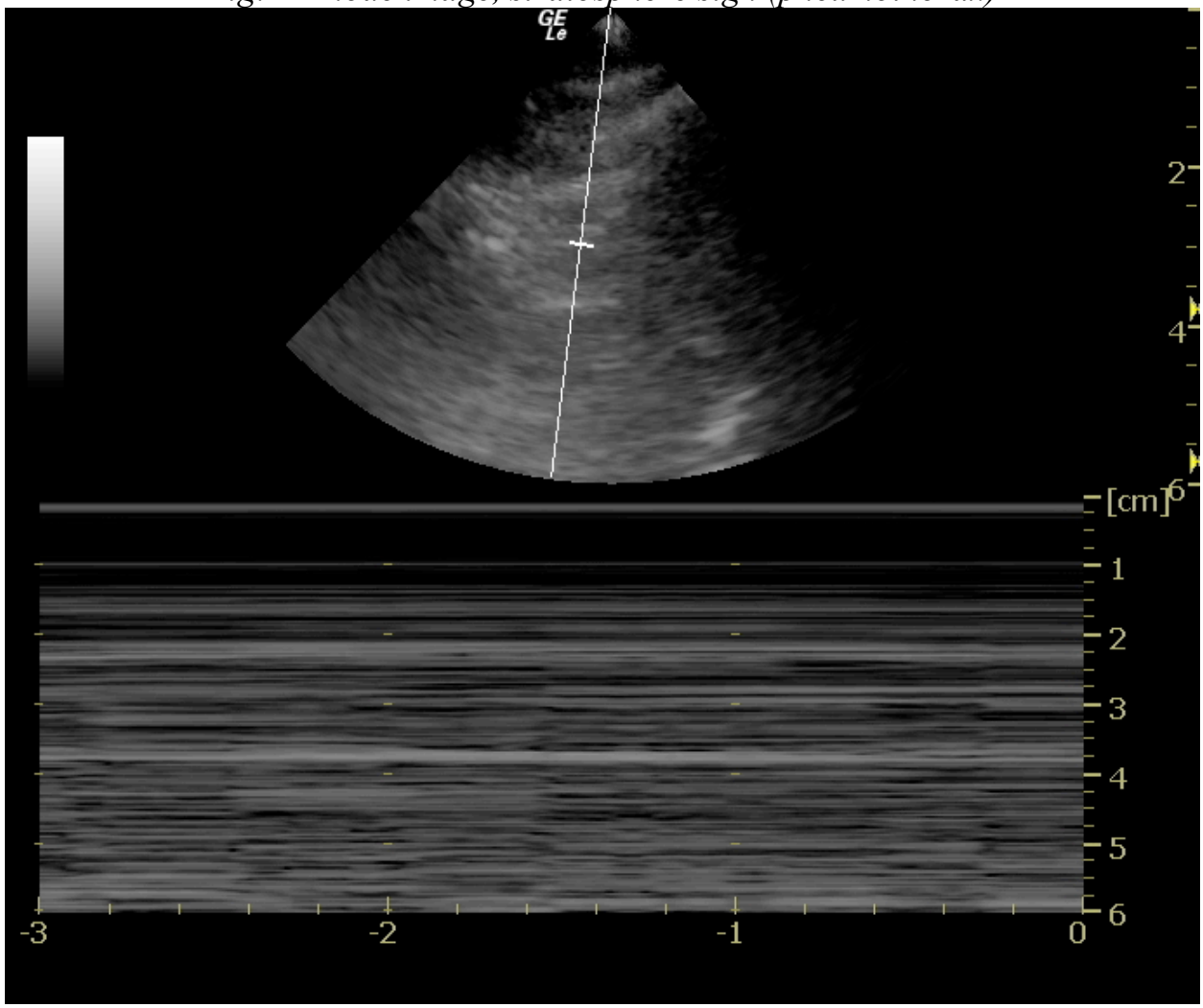
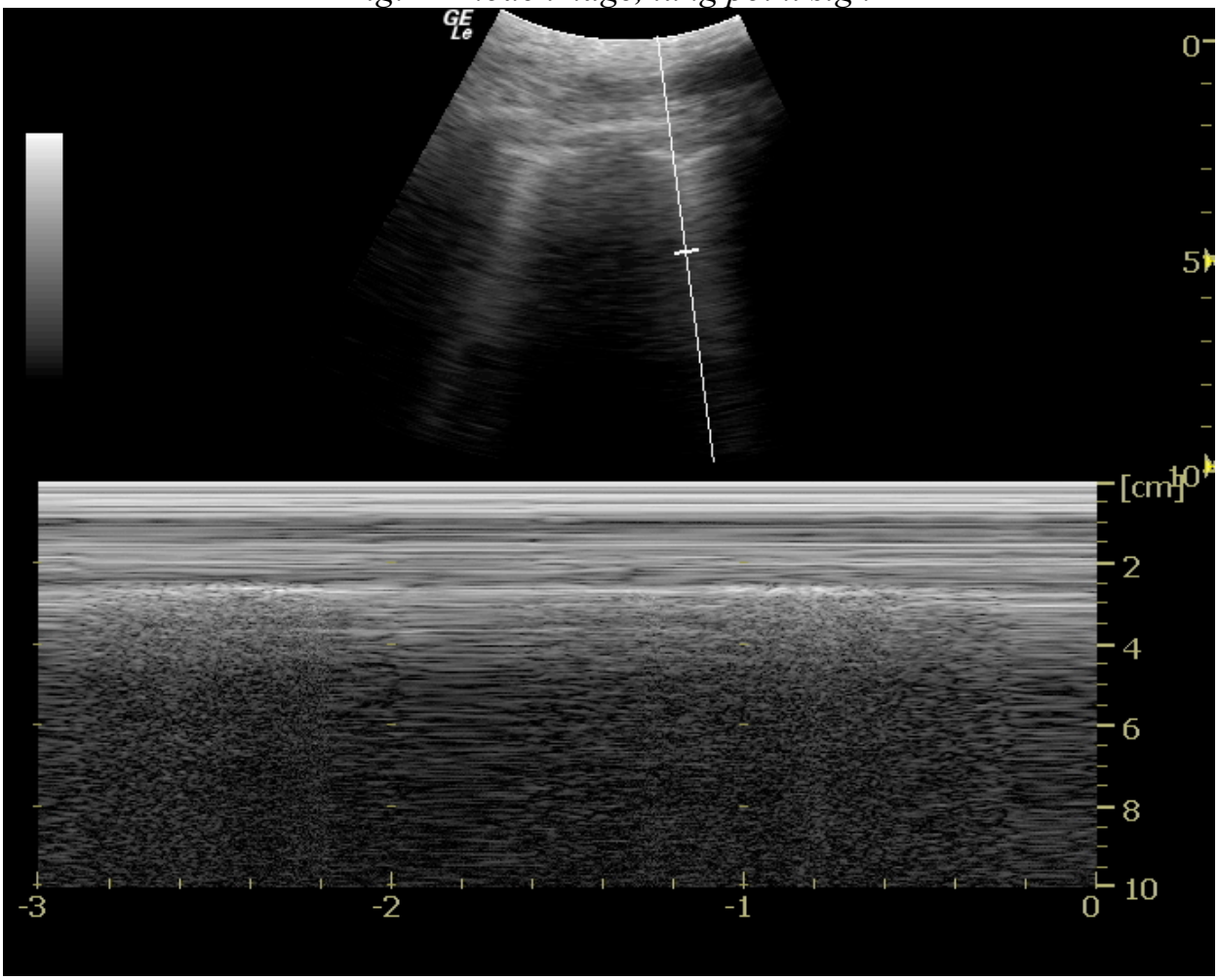


Fig: M-mode image, lung point sign



Pleural fluid

Site: lung bases

Appearance:

- black / anechoic (fresh blood, transudate/ exudate) (fig 11)
- echogenic (eg clotted blood, exudate).
- complex (if multiloculated) (fig 12)

Sector probe RUQ, large pleural effusion (black) above diaphragm

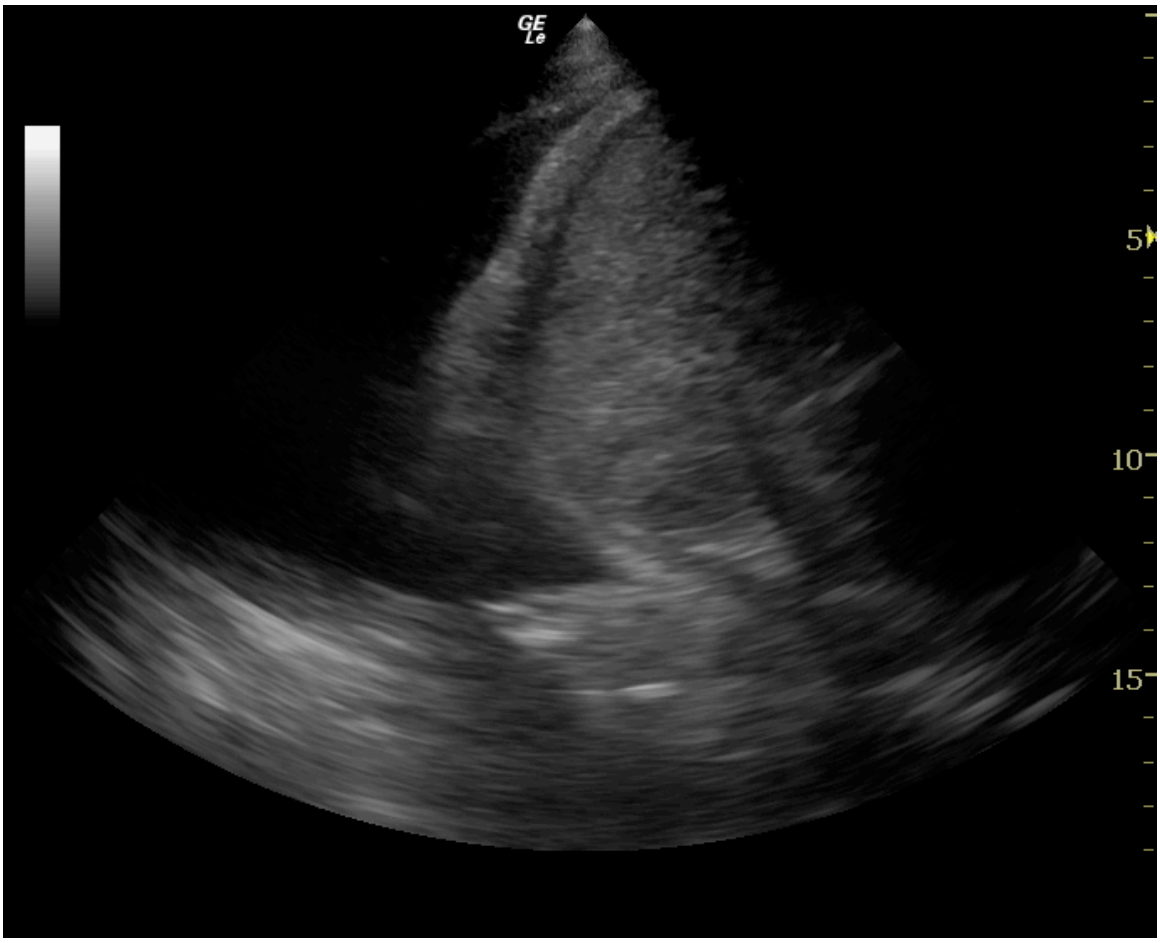
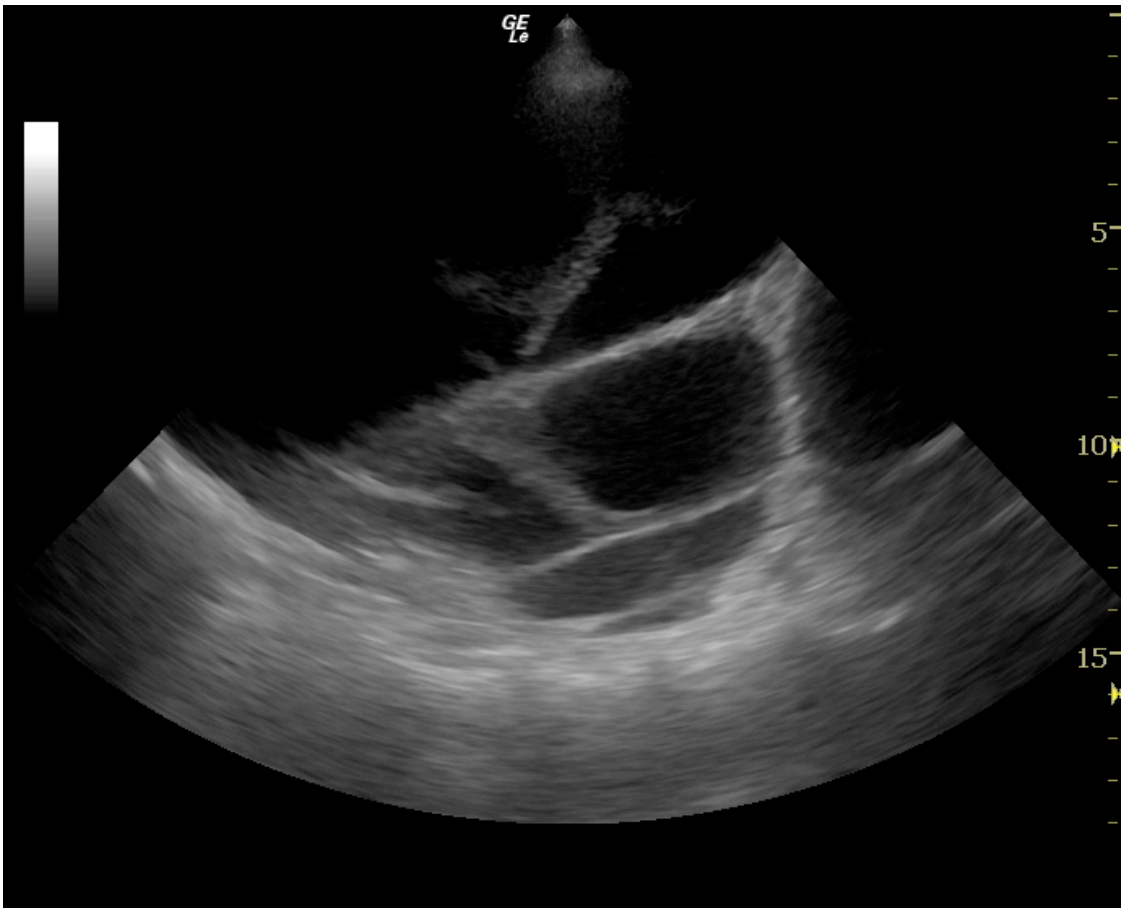


Fig 12: sector probe RUQ, large loculated pleural effusion



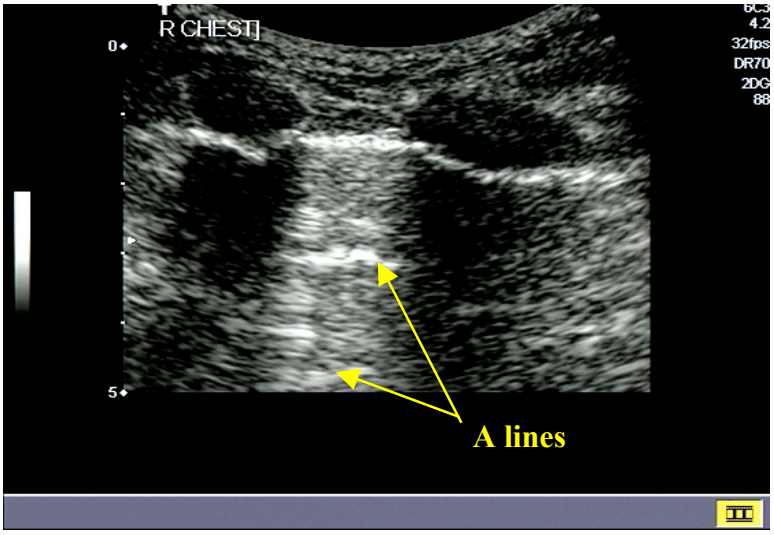
A lines, B lines & other lines

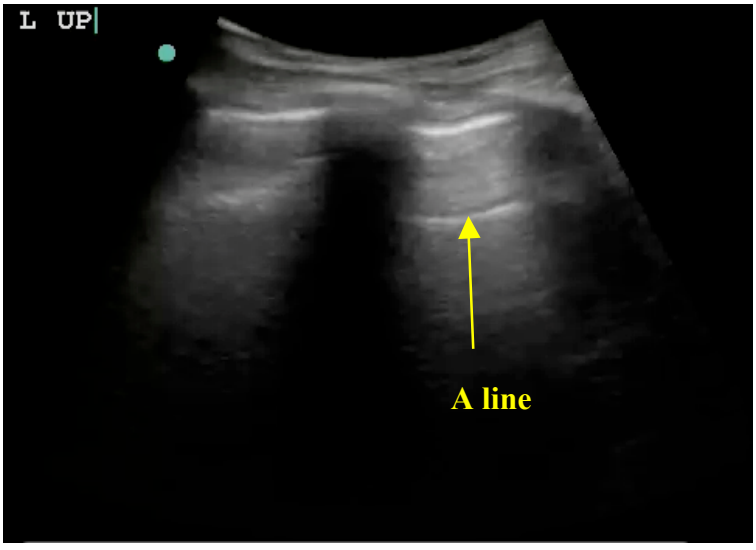
Broadly speaking, *A lines* are associated with air in a PTX or with dry lungs. By contrast, *B lines* arise from air and fluid intermingling in the lung interstitium, but may also be seen in pulmonary fibrosis. As noted above, even a single B line appears to rule out PTX.

A lines

These are reverberation artefacts which arise from the pleural line. They are horizontal and static and represent normal reverberation artefact from the pleura. *(fig below)* Note that they imply dry air:

- Static dry air in a PTX = A lines without sliding
- Dynamic dry air in normal lung = A lines with sliding



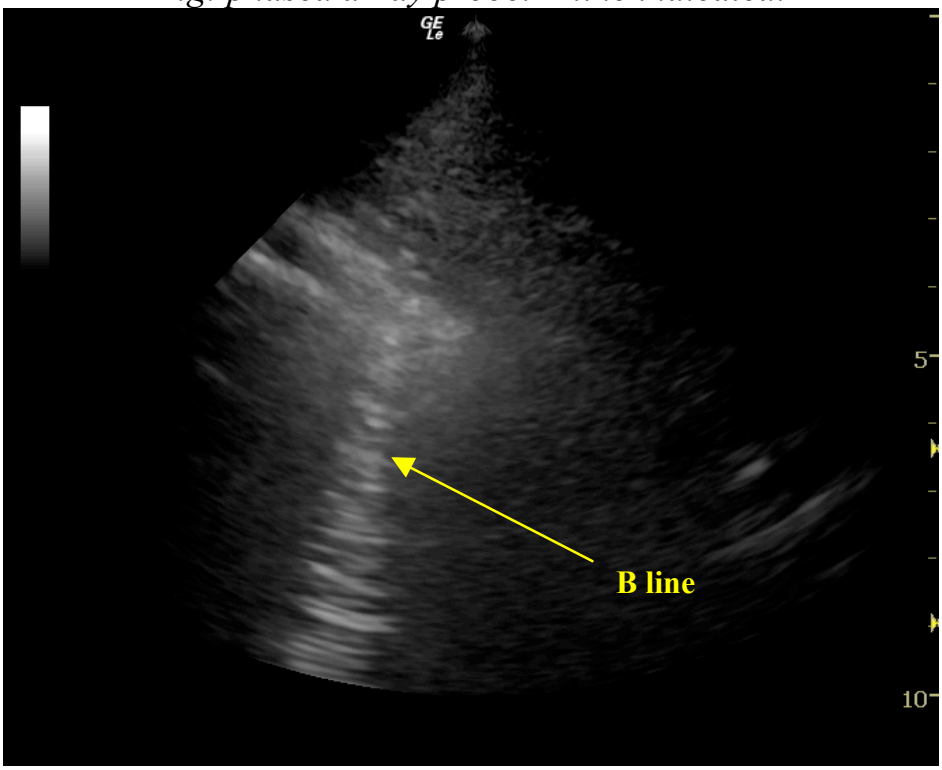


B lines

These are hyperechoic reverberation effects from air/water interfaces in interlobular septa.

- ultrasonic equivalent of Kerley B lines
- vertical & move with respiration
- Obliterate A lines
- Bright
- Reach to the edge of screen
- Sometimes called ‘comet tails’, but this is a misnomer

Fig: phased array probe. B line indicated.

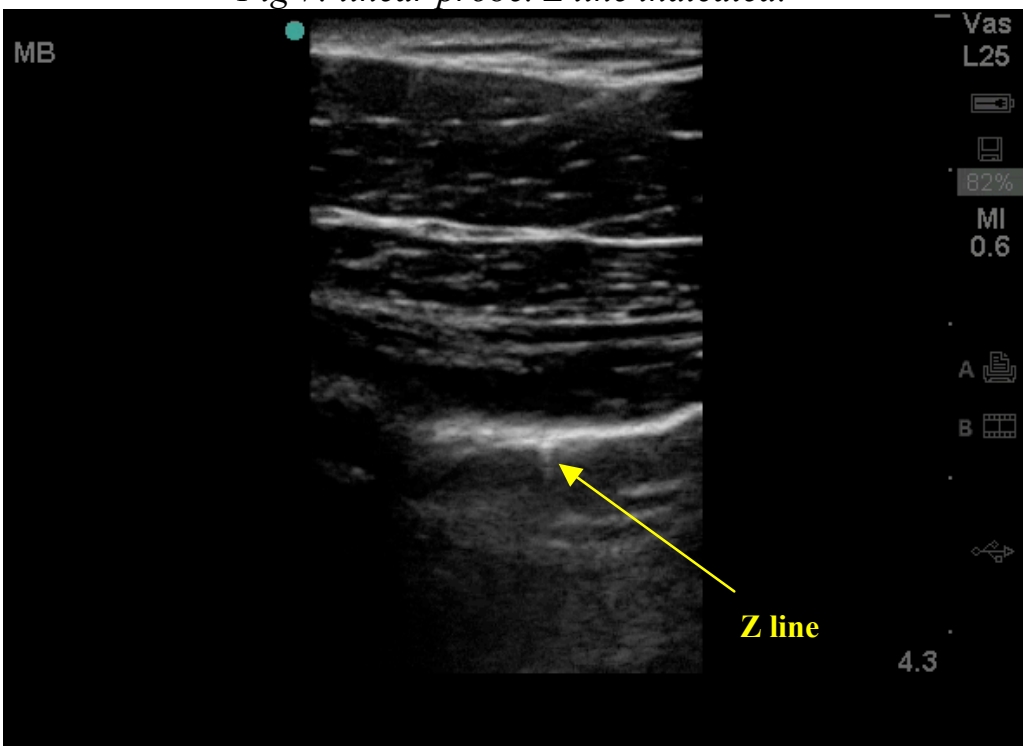


Up to 1/3 of normal subjects have B lines in dependent regions, but if they are widespread they are termed lung rockets and considered pathological (see below).

Other lines

There are other lines which are also vertical, but they fade quickly, don't obliterate A lines and have no apparent significance. (fig 7)

Fig 7: linear probe. Z line indicated.



What if I see no lines at all?

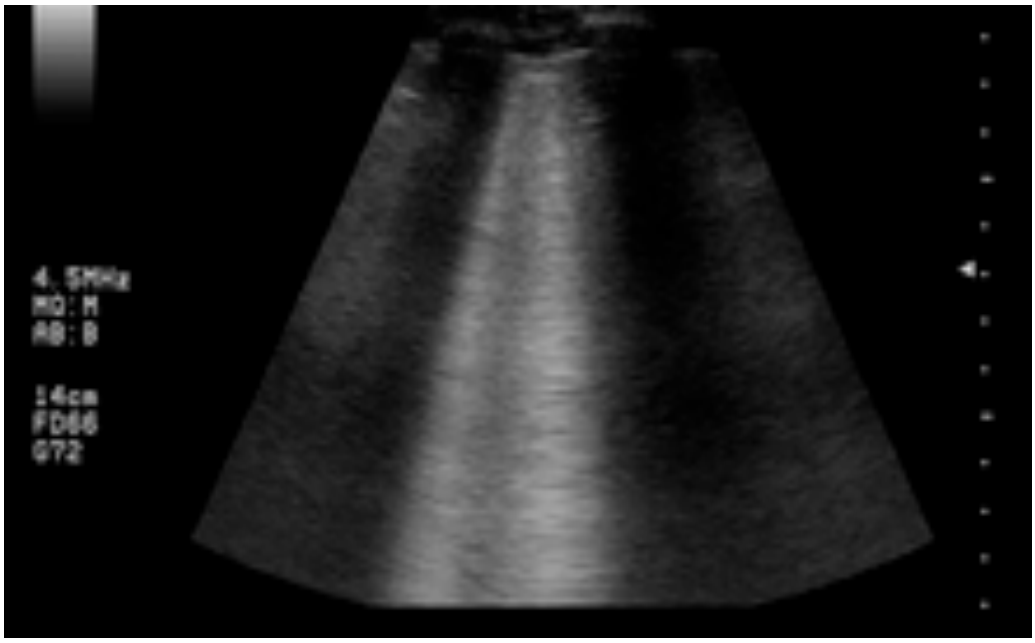
No lines at all (neither A nor B) = the same significance as A lines.

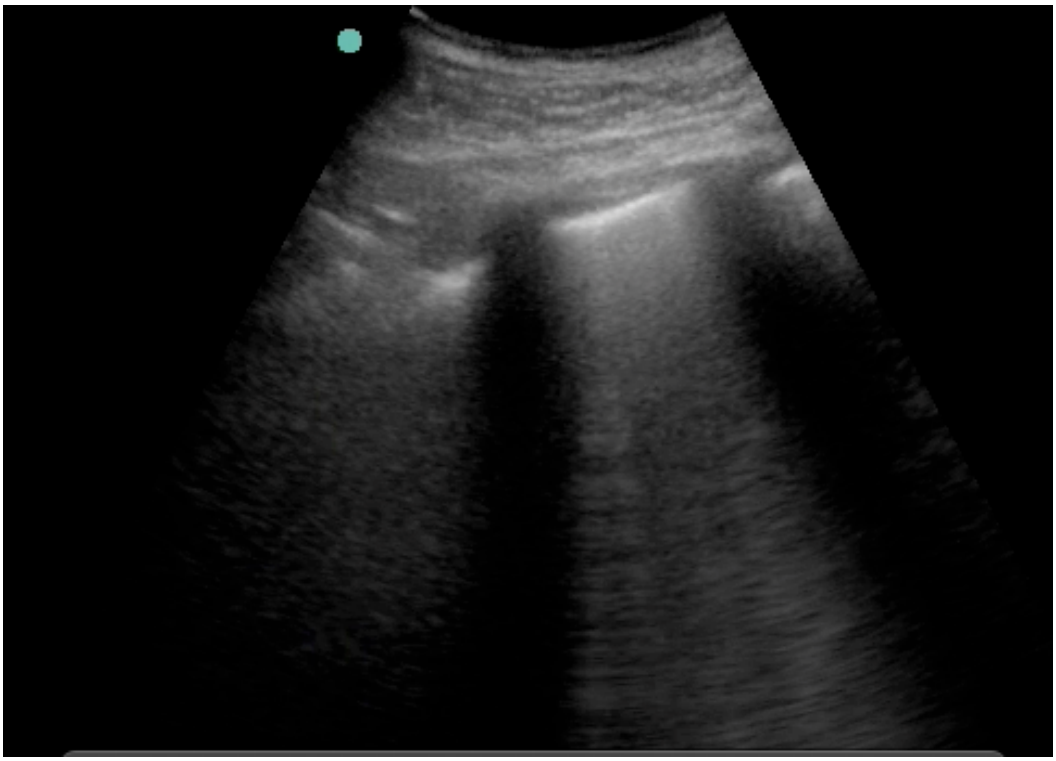
Lung rockets & consolidation too

'When several B lines are visible in a single scan, the pattern evokes a rocket at lift-off, and we have adopted the term lung rockets' (Lichtenstein p106).

If you see ≥ 3 B lines in one resp cycle in one US window, you have seen 'lung rockets'.

Figs: lung rockets





They can be found in the following conditions:

- Normal lung bases (25% of normal individuals)
- Oedema (wet lungs)
    - Acute cardiogenic pulmonary oedema (APO)
    - Pneumonia
    - ARDS
- Fibrosis

So how do we use US to differ between these conditions?

The following lung US findings are used to diagnose and differentiate APO, ARDS and pneumonia.

1. Multiple B lines (‘Lung rockets’) are found in diseased lung:

The occasional B line is a normal finding, as are multiple B lines in the most dependent portions of the lung in approximately 25% of normal individuals. However, if three or more B lines are seen in a single view, they are termed ‘lung rockets’ and the lung is deemed abnormal at that point. Lung rockets are sometimes termed lung comets, but an international consensus conference in 2009 dropped the latter term to standardise terminology.

Lung rockets may be found in any condition associated with pulmonary oedema, whether widespread and symmetrical (APO), patchy (ARDS and disseminated pneumonia) or localised (localised inflammation such as lobar pneumonia).

Pioneers of lung US such as Lichtenstein and Volpicelli coined the term ‘alveolar-interstitial syndrome’ to explain this finding, later refining the term to ‘interstitial syndrome’ to avoid confusion with alveolar consolidation (see below).

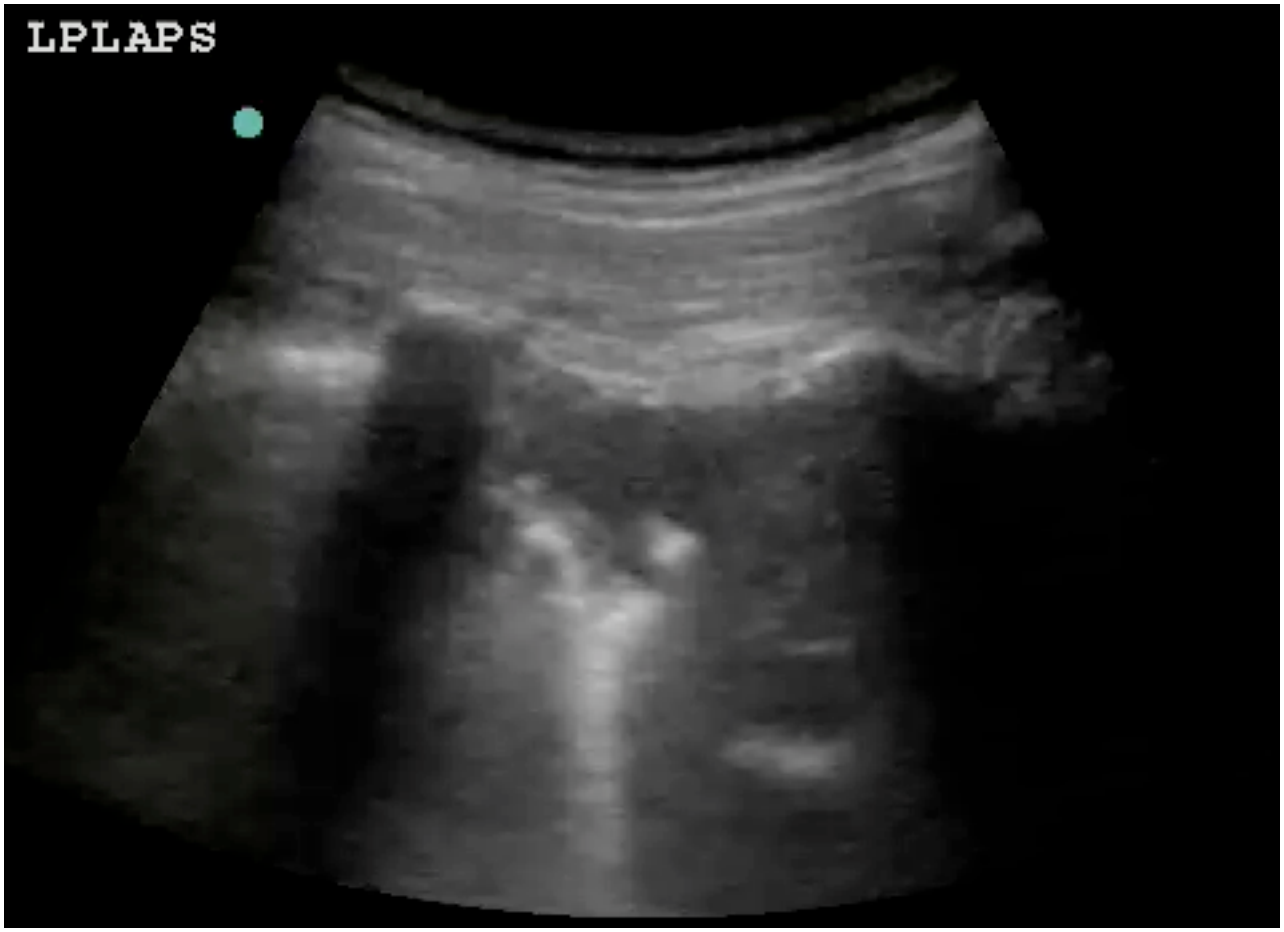
2. Distribution of lung rockets differs with disease process: Any condition which causes interstitial oedema or fibrosis will generate lung rockets. However, their distribution gives an important clue to the cause:

- In APO, rockets are widespread, bilateral and observed throughout the lungs.
- In ARDS and disseminated pneumonia they are patchy and alternate with areas of normal lung.
- In fibrosis, they may be restricted to either upper or lower lobes, or may be widespread.
- In localised inflammation such as lobar pneumonia, they are localised.

3. Interstitial oedema is associated with pleural effusions, which affect lung sliding: In APO, the effusions are transudative and facilitate lung sliding. In inflammatory oedema (pneumonia and ARDS), the effusion is exudative, proteinaceous and ‘sticky’. This tends to ‘glue’ the lung to the chest wall and thus lung sliding is reduced or even absent.

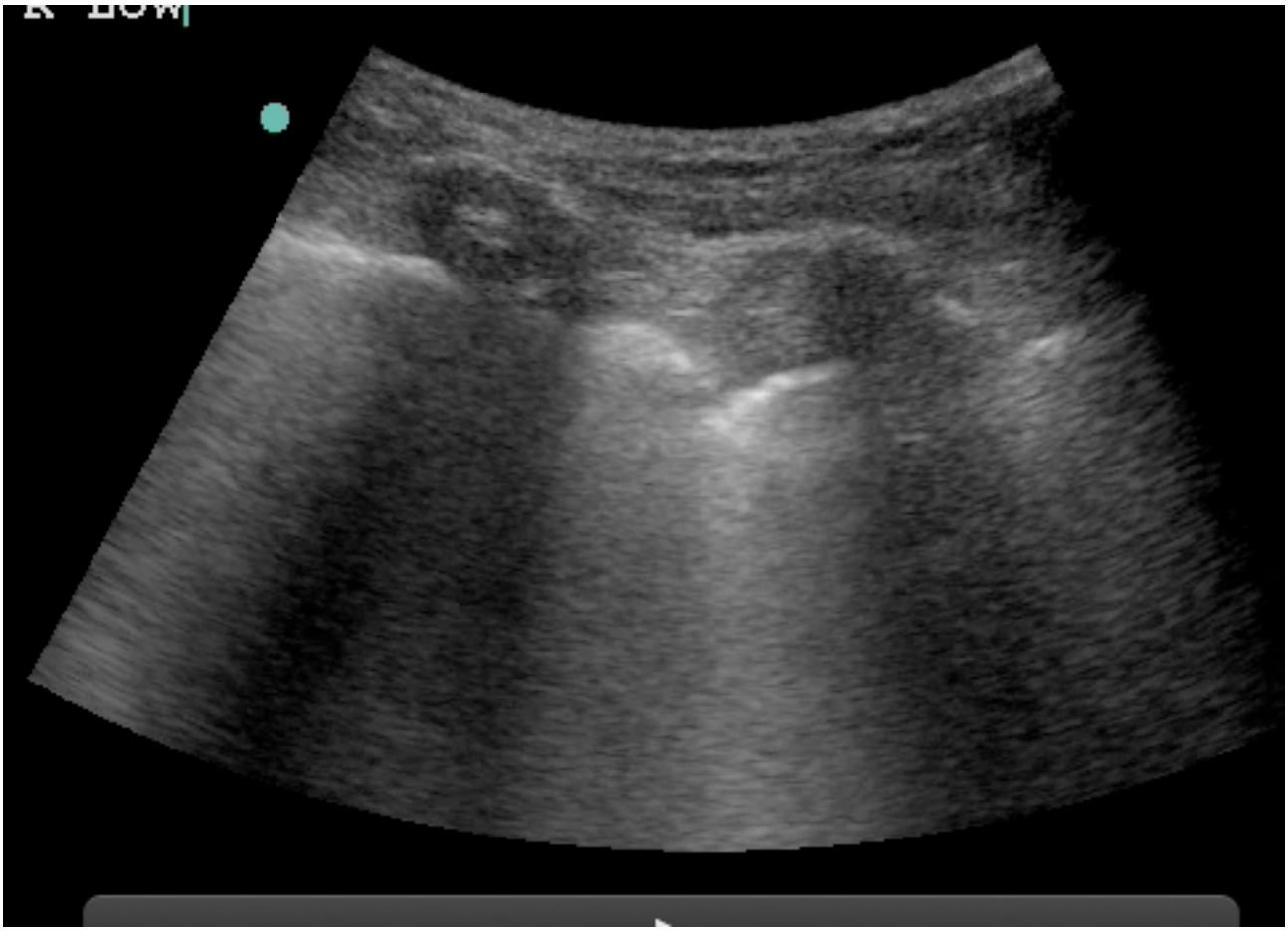
4. Fluid-filled lung tissue has a specific US appearance: when alveoli fill with fluid (whether oedema from atelectasis, blood from pulmonary contusion, pus from pneumonia, areas of malignancy or even infarcted lung from pulmonary embolus) they begin to transmit sound waves (whereas normal air-filled alveoli scatter sound waves). If areas of fluid-filled alveolar tissue abut the pleura, they appear dark, irregular and with a ‘liver-like’ consistency (hepatisation) on US.

Alveolar consolidation (irregular dark patch deep to pleura)
at left PLAPS point: pneumonia

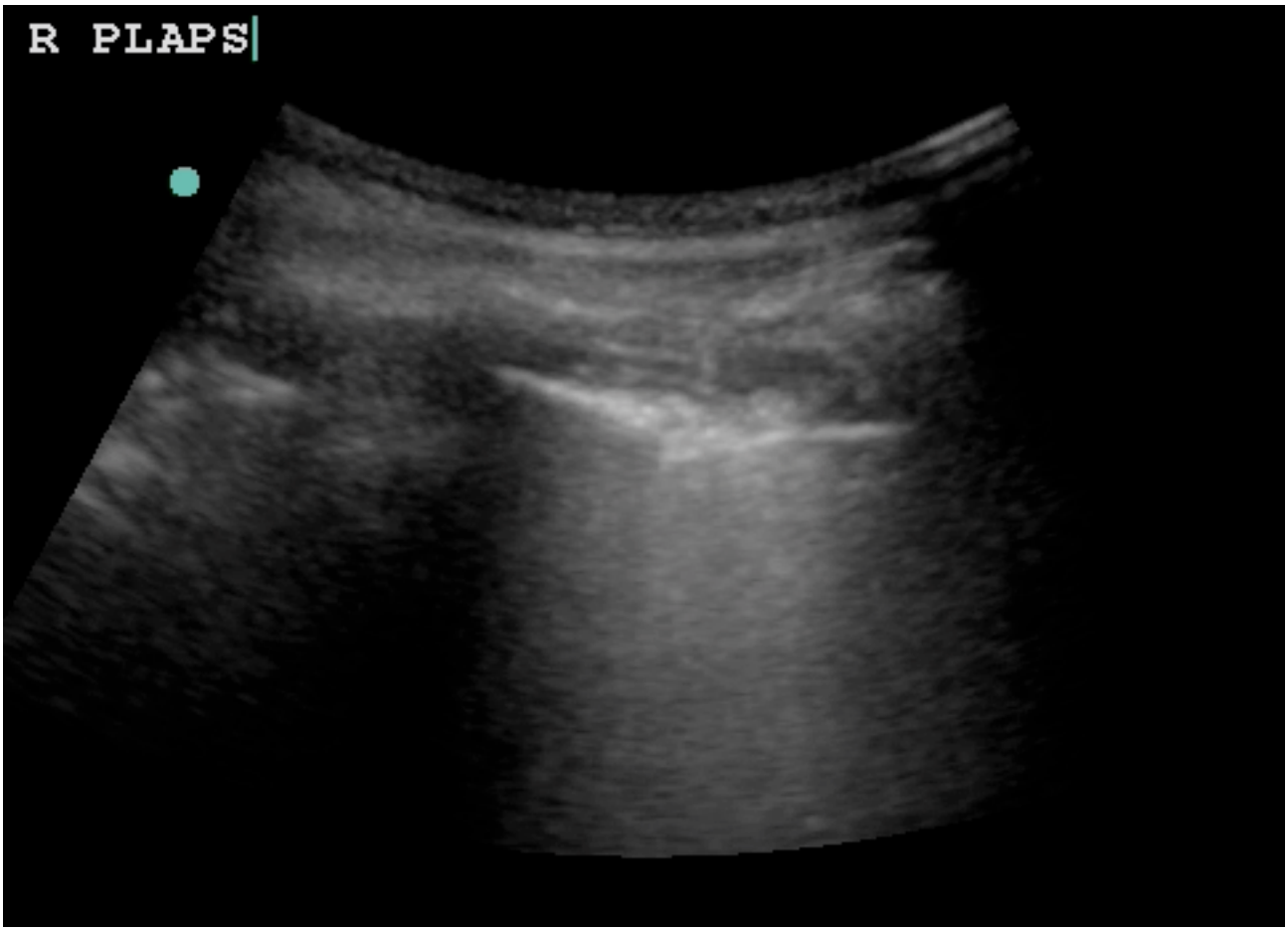


Note that areas of consolidation may be very small, and can give rise simply to a pleural line that appears ‘irregular’.

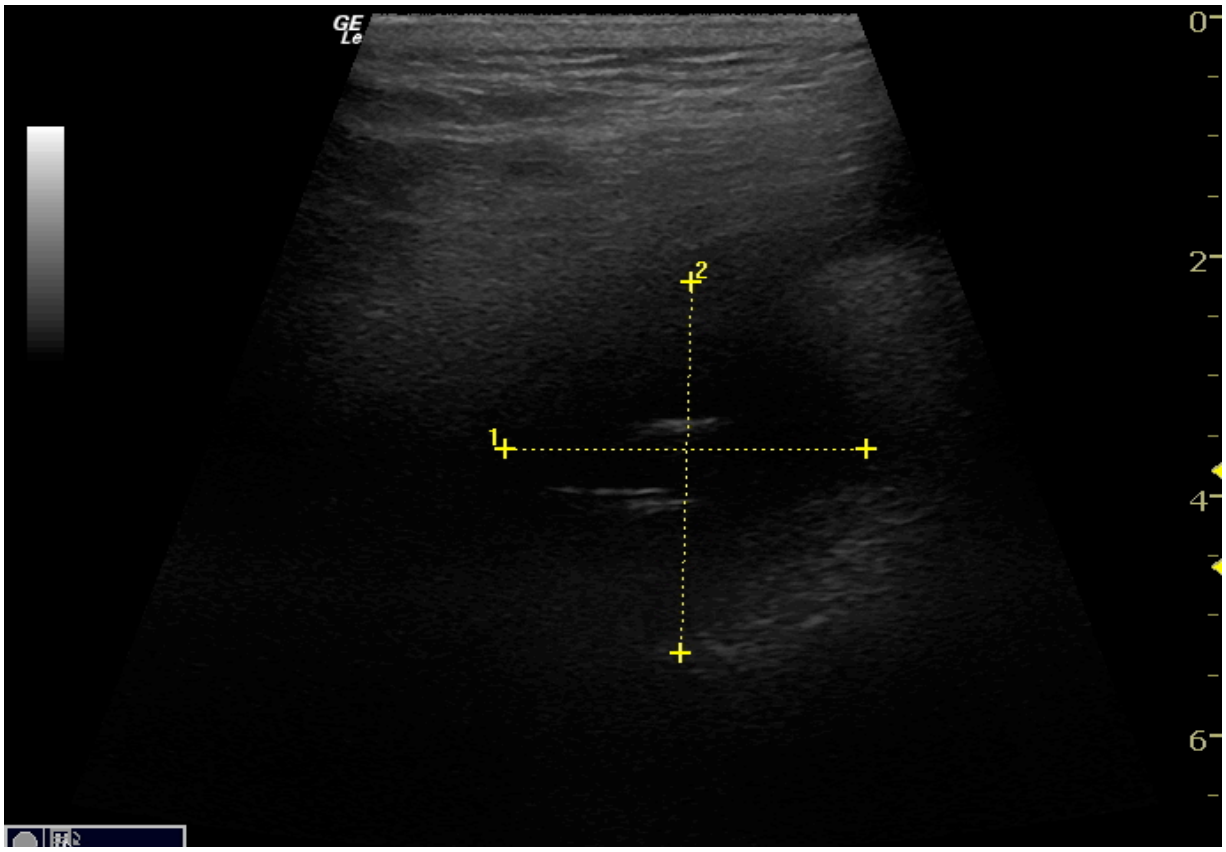
Irregular pleural line: pneumonia



Another irregular pleural line, this time at right PLAPS point: pneumonia

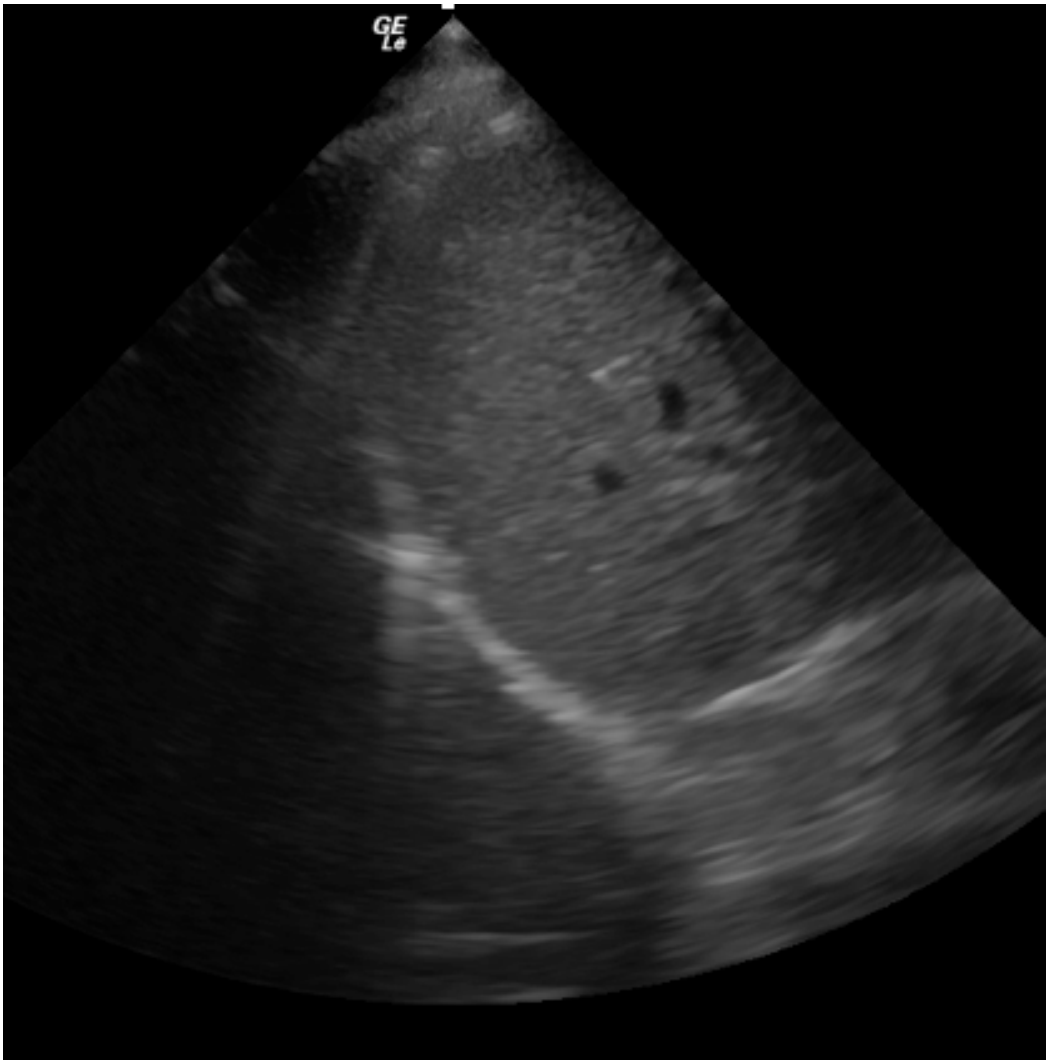


Hypoechoic pleural based malignancy, dimensions measured



NB at the lung bases, the presence of apparent consolidation is most often simply due to mirror artefact.

Mirror artifact: mirror image of liver tissue is seen just above the diaphragm, due to the reflector effect of the air/fluid interface between lung and diaphragm.



Matching the US findings with the disease:

Using the above findings, Lichtenstein made the following observations:

Normal lungs demonstrate predominantly A lines or no lines at all, associated with preserved lung sliding (termed the *A profile*)

Pneumothorax is associated with absent lung sliding and A lines (or no lines at all), termed the *A' profile* (as are other conditions: see PTX section above.)

APO is associated with preserved lung sliding and bilateral lung rockets in all lung windows (termed the *B profile*)

ARDS and pneumonia usually demonstrate one of the following on US:

- Reduced / absent lung sliding associated with widespread lung rockets (termed the *B' profile*)
- Patchy rockets, alternating with areas of normal lung (termed the *A/B profile)*
- Areas of consolidation (termed the *C profile*)
- Lungs which appear normal anteriorly but which demonstrate effusions or areas of consolidation in the most posterior, dependent regions: termed *posterolateral alveolar and/or pleural syndrome* or 'PLAPS-positive'. For this reason, he defined the most posterior, dependent regions of the lung as the PLAPS points.

Pulmonary embolus (PE) is associated with one of the following profiles:

- A profile (dry, apparently normal lungs)
- PLAPS positive
- C profile (i.e. occasionally areas of pulmonary infarct are seen)

Exacerbations of asthma and chronic obstructive pulmonary disease (COPD) are usually associated with the A profile.

Table: which disease, which profile?

Normal lungs	A profile: A lines or no lines at all, lung sliding preserved
Pneumothorax	A' profile: A lines or no lines at all, lung sliding absent
APO	B profile: lung rockets in all lung windows, lung sliding preserved
ARDS or pneumonia	B' profile: lung rockets in all windows, lung sliding absent (and usually pleural line irregular) A/B profile: patchy rockets, alternating with areas of normal lung C profile: areas of consolidation A profile anteriorly, plus PLAPS positive
Pulmonary Embolus	A profile (dry, apparently normal lungs) ± PLAPS positive C profile (i.e. occasionally areas of pulmonary infarct are seen)
Asthma/ COPD	A profile

Lichtenstein created the 'BLUE Protocol' in 2007, which merged the above observations into a single flow sheet. The details of the BLUE protocol (for example the 'BLUE' and 'PLAPS' points recommended for probe placement) are covered in the section on the breathless patient.

Two points must be noted at this stage:

1. The BLUE Protocol's stated accuracy of 90-95% applies only to patients in extreme respiratory distress. It has not yet been trialed in those with mild-moderate illness. For example, although lung rockets are found throughout the lung fields in APO, perhaps they are only found in the lower zones in CCF.
2. The BLUE protocol awaits multi-centre validation studies.

That said, the following statements appear to be reasonable in the acutely breathless patient:

- B profile = APO (or occasionally interstitial fibrosis)
- B' profile = pneumonia or ARDS
- Patchy or localised rockets = localised disease process (fibrosis, pneumonia, contusion)

- C profile = areas of fluid-filled lung tissue eg pneumonia, contusion, pulmonary infarct)
- Perhaps most important for the novice scanner: the above findings should be approached as a 'rule-in' rather than 'rule-out' guide (that is, if absent they may not reliably rule out disease)

Note that the presence of lung rockets can also be used to guide fluid resuscitation and diuresis. For example, when rockets start to appear during aggressive intravenous fluid resuscitation, one should cease fluids.