Part II – Critical Care Ultrasound

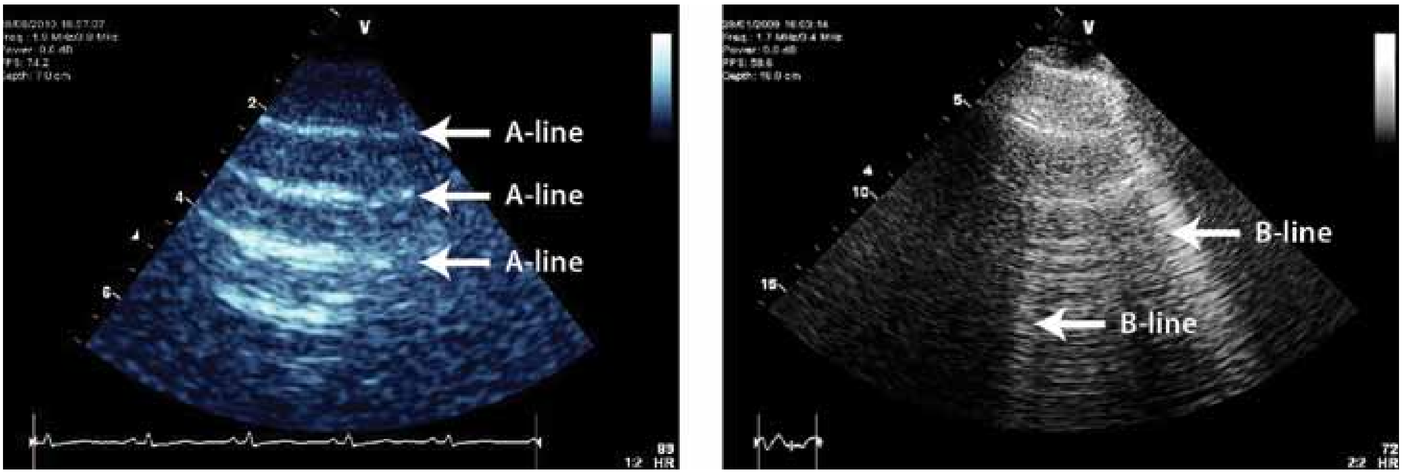

Figure 1: A-lines and B-lines in lung ultrasound. Left, A-lines are reverberation artifacts of transducer-pleural surface. Right, in pulmonary oedema, A-lines are replaced by B-lines (lung rockets).

The increased availability of good quality ultrasound machines in the critical care setting has encouraged the practicing clinician to utilise this rapidly applied, non-invasive, imaging modality to assist in patient management. The four main areas of non-cardiac applications are 1) ultrasound-guided vascular access, 2) lung ultrasound, 3) rapid abdominal assessment (including FAST) and 4) vascular ultrasound for rapid deep vein thrombosis assessment.

Ultrasound guided vascular access

Reliance on anatomical landmarks and palpitations in central venous catheterisation are associated with complications such as arterial puncture, pneumothorax, haemothorax and catheter malposition. Even though the complication rate declines with increasing expertise, the possibility is always present. Ultrasound guidance has become popular in assisting catheter insertion at the following sites: internal jugular vein, femoral vein, peripheral veins and to a lesser extent the subclavian vein.

The objectives of using ultrasound guidance include:

- Differentiation of vein from artery
- Identifying anatomical location and relative position of vessel
- Ascertaining the course of the vessel
- Checking for clearance
- Excluding deep vein thrombosis
- Assessing vessel patency
- Guiding needle insertion.

A linear probe is the preferred choice for ultrasound-guided access due to its high frequency, large footprint and a flat transducer head. The pointer on the transducer should always be pointing cephalad or to the patient's right side which leads to the marker on the screen being on the operators left side. The steps involved in ultrasound guided CVC insertions can be described as Pre-scan, Equipment, Preparation, Puncture, Evaluation and Record (PEPPER). Pre-scan refers to a vascular ultrasound examination to assess whether the site is suitable for a catheter insertion. The Equipment for catheter insertion should be carefully worked out in advance and the Preparation should be undertaken in a methodical manner. In regard to the Puncture there are two approaches for line insertions, using the longitudinal view method or the transverse view method. Evaluation deals with ensuring there is appropriate blood flow through the catheter and confirmation that the catheter is in the lumen of the vessel. Every procedure should be Recorded.

Lung and pleural ultrasound

For many years ultrasound assessment of the lung was ignored because of the inability of ultrasound to penetrate air/tissue interfaces. Interestingly it is the ultrasound artifacts in the chest that reveal very important pathologies and the procedure can usually be performed within minutes and non-invasively. The transducer choice includes phased-array and curvilinear probes although a microconvex probe with a smaller footprint and higher frequency bandwidth (3.5–7 mgh) is ideal, it is not commonly available. The patient can be scanned in the upright or supine position. In a normal lung there are classical features of the ribs, rib shadow artifacts, and the pleural interface with lung sliding apparent between the visceral and parietal pleura during inspiration and expiration. Reverberation artifacts known as A-lines are seen between the rib shadows. These lines take place between the parietal interface and the transducer surface, being characterised by equidistant hyperechoic lines parallel to the pleural interface. If M-mode is performed, then a characteristic "sea-shore" pattern can be obtained.

In a number of clinical situations such as pulmonary oedema, acute respiratory distress syndrome and pneumonia there are interstitial changes in the lungs. The A-lines seen in normal lungs are absent and in their place are multiple B-lines, also known as lung rockets (Figure 1). The exact origin of the B-lines is unknown but they are believed to be artifacts originating from the reverberations of ultrasound between the oedematous tissues between the alveoli. The number of B-lines to intercostal space is proportional to the amount of fluid in the lung and the extent of pulmonary oedema. Although very sensitive, they are not

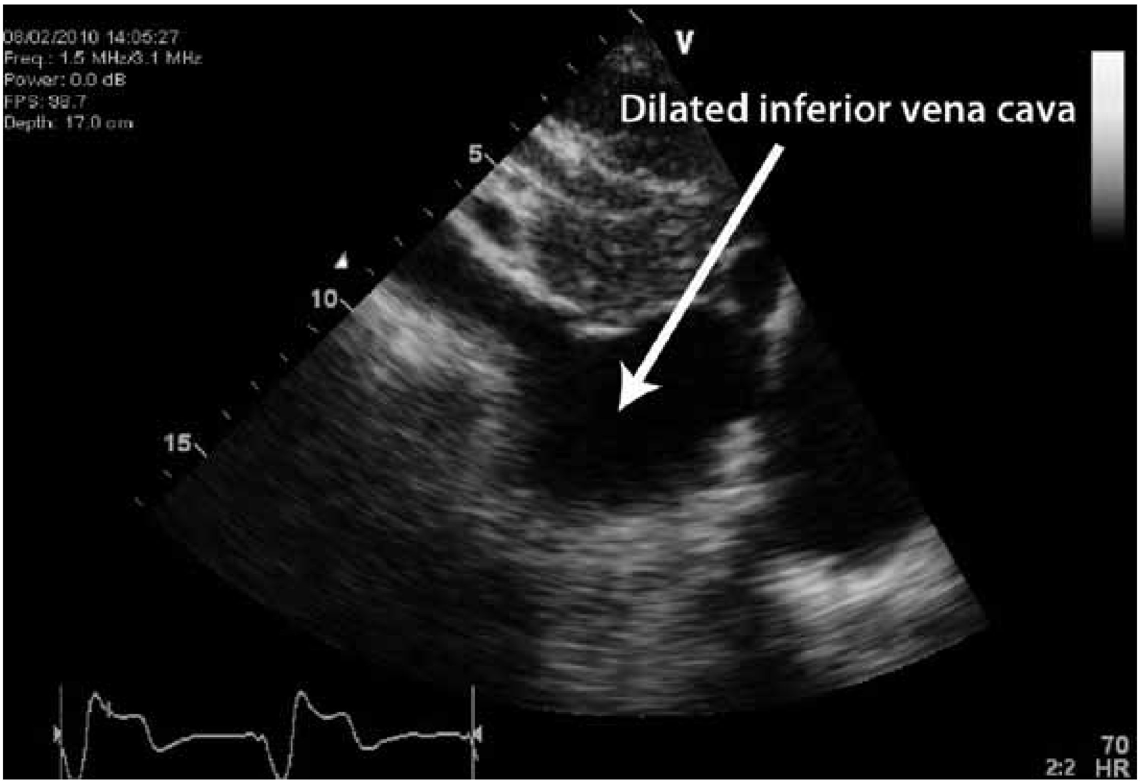

Figure 2: Dilated inferior vena cava (IVC) A subcostal longitudinal view of the IVC. Dilated IVC is associated with increased risk of thrombus formation.

very specific because they indicate interstitial fluid, not the cause of the extravascular fluid. The fluid could result from cardiac pulmonary oedema, non-cardiogenic pulmonary oedema or pneumonia. However, combined with a cardiac ultrasound it is often very easy to differentiate cardiogenic from non-cardiogenic causes of pulmonary oedema. The pneumothoraces are identified with the absent of lung sliding and the presence of 'lung point' which refers to the phenomenon where the boundary of the non collapsed part of the lung moves into the air filled thorax, replacing the signs of pneumothorax. Alveolar consolidation exhibits an ultrasound appearance similar to that of liver and spleen. Pleural effusions, quite often seen on echocardiogram examination, can be better evaluated by performing a proper lung ultrasound.

Rapid critical care abdominal ultrasound (including FAST)

The application of abdominal ultrasound by the critical care physician should be regarded as a limited examination with a full abdominal ultrasound requiring the expertise of the radiologist. However in the acute situation the application of ultrasound can assist in identifying pathologies in a decompensating patient in the middle of the night that requires urgent attention.

These include:

- Dilatation and dissection of aorta
- Dilation of the inferior vena cava (Figure 2)
- Presence of thrombus in the inferior vena cava
- Dilation of the hepatic veins
- Acute cholecystitis
- Acute obstructive uropathy.

The focused assessment with sonography for trauma (FAST) examination has been well established since the 1990s. This is particularly useful for a haemodynamically unstable patient who has unexplained hypotension and equivocal physical examination. Being non-invasive, rapid, portable and repeatable it can often assist the clinician in deciding whether a CT abdominal scan is urgently required.

The objective of the standard FAST is to provide a rapid and non-invasive detection of free fluid in the:

- Pericardial space
- Pleural space
- Peritoneal cavity.

Vascular ultrasound rapid deep vein thrombosis assessment

Although the search for a deep vein thrombosis (DVT) can often be performed in daylight hours in the hands of a skilled vascular sonographer, there are occasions in the critical care setting where the diagnosis of a DVT greatly assists management. An obvious example is the suspicion of a pulmonary embolus in a hypotensive patient. It is also known that hospitalised patients are at a great risk of developing DVT, particularly in intensive care unit patients.

The objectives of the rapid DVT assessment are:

- To exclude/identify proximal deep vein thrombosis
- To determine the location of thrombosis.

The first step is to differentiate a vein from an artery and the three methods used to achieve this are 2D imaging, compressibility test (Figure 3), and colour flow (Doppler) imaging.

The ultrasound image characteristics of a DVT may depend on the stage of thrombosis, with acute thrombosis often having different ultrasound characteristics to a chronic one. Resistance to compression (or non collapsibility in response to compression) is the most reliable criterion for thrombosis.

The lower limb extremities are the most common site for

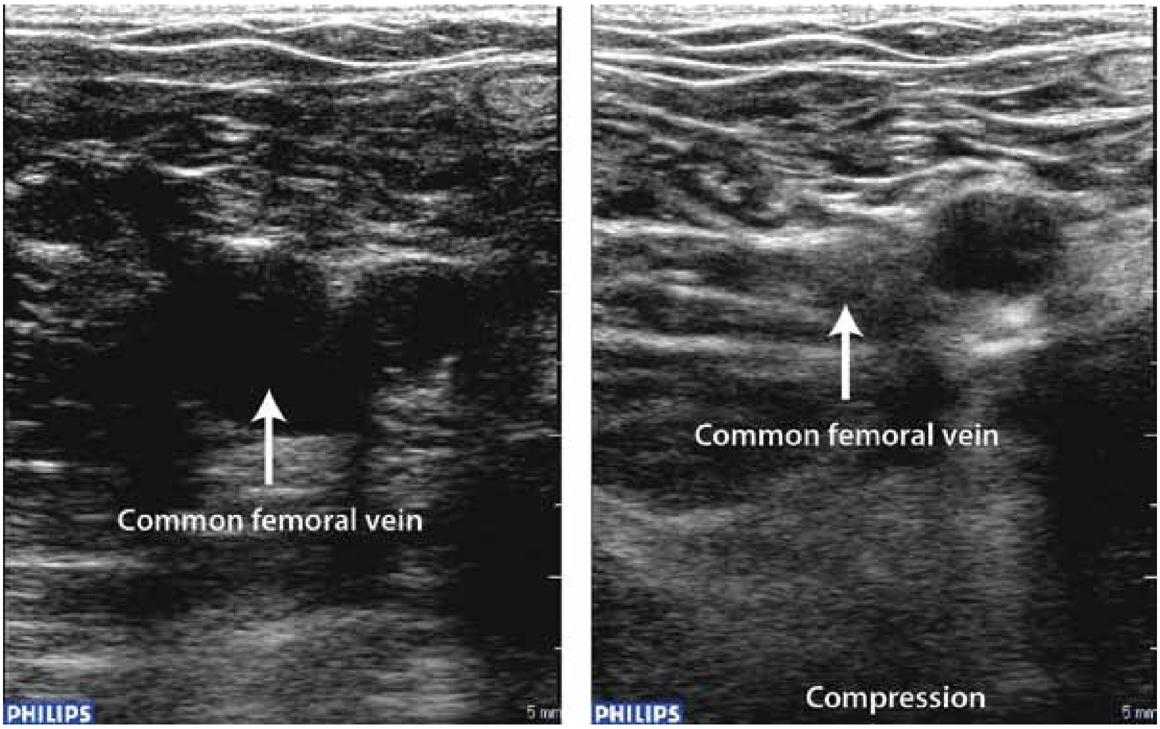

Figure 3: Compressibilty test for DVT.
The figure shows the cross-section of the common femoral vein. Apply pressure on the transducer compresses the vein whereas the artery remains patent. Vein with thrombus would resist the compressibility test.

DVTs and the major deep veins include the iliac veins, common femoral vein, femoral vein, deep femoral vein, and popliteal vein. The great saphenous vein (superficial vessel) can also be examined if the clinician wishes. Upper extremity DVT assessment should also be considered with investigation of the internal jugular vein, subclavian vein, axillary vein and brachial vein.

Summary

The routine use of ultrasound in daily critical care practice has extended beyond echocardiography and the indications continue to grow. In addition to those outlined above some clinicians are applying it when performing percutaneous tracheostomies and optic nerve measurements in the evaluation of elevated intracranial pressure.

It is important to define the role in the critical care setting and determine not only its strengths but also the weaknesses.

Drawing on the greater experience and expertise of our radiology colleagues when their support is available is very important. This is countered by fewer demands on them in the acute setting after hours when urgent management decisions need to be undertaken.

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