# Focused Echocardiography in Emergency Life Support

## 2nd Edition 2013

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# Contents

# Glossary

| | |
|---|---|
| A4Ch | Apical four-chamber |
| ALS | Advanced Life Support |
| ANTS | Anaesthetists Non-Technical Skills |
| BSA | Body surface area |
| BSE | British Society of Echocardiography |
| Cx | Circumflex artery |
| EF | Ejection fraction |
| FATE | Focused assessment with transthoracic echocardiography |
| FEEL | Focused echocardiography in emergency life support |
| FEER | Focused echocardiographic evaluation in resuscitation |
| FS | Fractional shortening |
| HOT | Hands on training |
| ICU | Intensive care unit |
| IVC | Inferior vena cava |
| LAD | Left anterior descending |
| LVEDA | Left ventricular end-diastolic area |
| LVEDD | Left ventricular end-diastolic dimension |
| LVEDV | Left ventricular end-diastolic volume |
| LVESD | Left ventricular end-systolic dimension |
| LVESV | Left ventricular end-systolic volume |
| LVOT | Left ventricular outflow tract |
| LUS | Lung ultrasound |
| MI | Myocardial infarction |
| MV | Mitral valve |
| OM | Orientation marker |
| PEA | Pulseless electrical activity |
| PLAX | Parasternal long axis |
| PTX | Pneumothorax |
| PSAX | Parasternal short axis |
| RCA | Right coronary artery |
| RVEDA | Right ventricular end-diastolic area |
| SAM | Systolic anterior motion (of the mitral valve) |
| SC | Subcostal |
| SVC | Superior vena cava |
| TOE | Trans oesophageal echocardiography |
| TTE | Transthoracic echocardiography |
| US | Ultrasound |
| VF | Ventricular fibrillation |
| Vmax | Maximum velocity |
| VTI | Velocity-time integral |

# Introduction

FEEL is a learning programme, including a one day course, designed to introduce the student to the use of transthoracic echocardiography (TTE) and lung ultrasound in an emergency setting. If completed and followed by on-going study with a local mentor, FEEL certification, supported by both the Resuscitation Council (UK) and the British Society of Echocardiography (BSE), will be achieved.

A FEEL scan is a focused examination, intended to be used in a rapid manner at the point of care as an adjunct to clinical examination in the critically ill / peri-arrest patient and as a guide to further decision-making in patients receiving CPR for cardiac arrest in "non-shockable" rhythms. It is not an alternative to a full structured echocardiography examination by an expert – but completion of FEEL certification may be considered as appropriate introductory training for those intending to work towards full echocardiography accreditation.

In some patients who are acutely and critically ill (e.g. in shock) it may be difficult to be confident of the underlying cause from clinical assessment and initial bedside investigation, such as laboratory tests and electrocardiography. For example conditions such as severe myocardial dysfunction, severe hypovolaemia, pericardial tamponade and massive pulmonary embolism may all result in a shocked patient. Use of echocardiography as an extension of the clinical examination may help direct the clinician towards identifying the cause with minimal delay. This may permit early intervention to correct the cause, and avoid interventions that make the situation worse.

The situation is even more crucial in the patient who has suffered cardiorespiratory arrest in asystole or pulseless electrical activity (PEA). The survival from such arrests is lamentably poor (ref). Rescuers are encouraged to consider "the four Hs and four Ts" (see Box 1) to ensure that any correctable cause is recognised and treated without delay. If rapid echocardiography can be achieved during the brief interruptions to CPR for rhythm assessment without compromising the quality of CPR delivered, it may be possible to identify those with a reversible cause for their cardiac arrest. Treatment of reversible pathology may improve the chance of recovery, whilst minimising interventions that will be harmful or of no benefit.

| | |
|---|---|
| **Hypoxia** | **Thromboembolism (coronary or pulmonary)** |
| **Hypovolaemia** | **Tension pneumothorax** |
| **Hypokalaemia/hyperkalaemia etc. (metabolic)** | **Tamponade (pericardial)** |
| **Hypothermia** | **Toxins** |

**Box 1: Reversible causes of cardiorespiratory arrest: the 4 Hs and 4 Ts**

This manual is designed to be used in conjunction with additional on-line learning materials and should be read prior to attending the one-day course, which comprises a mix of lectures, small group (maximum 3 candidates per trainer) hands-on training (HOT) sessions with live models, simulator sessions and computer-based teaching.

# Basic Physics of Ultrasound

Chapter 1

## Learning outcomes

- To be able to describe the relationship between the frequency & wavelength of ultrasound and the image quality obtained; thus to understand how to optimise information obtained during scanning
- To understand why different ultrasound examinations require different types of probe

## What is Ultrasound?

Ultrasound is a form of mechanical energy transmitted by pressure waves through a medium – solid/liquid/gas. It occurs as result of mechanical vibrations of molecules (rarefaction compression waves) as they are propagated through the medium, disturbing it from its steady-state equilibrium.  Sound waves arising from vibrating objects (such as a tuning fork, or piezo-electric crystals) are composed of areas of compression (increased density) and rarefaction (decreased density) that propagate through a medium.

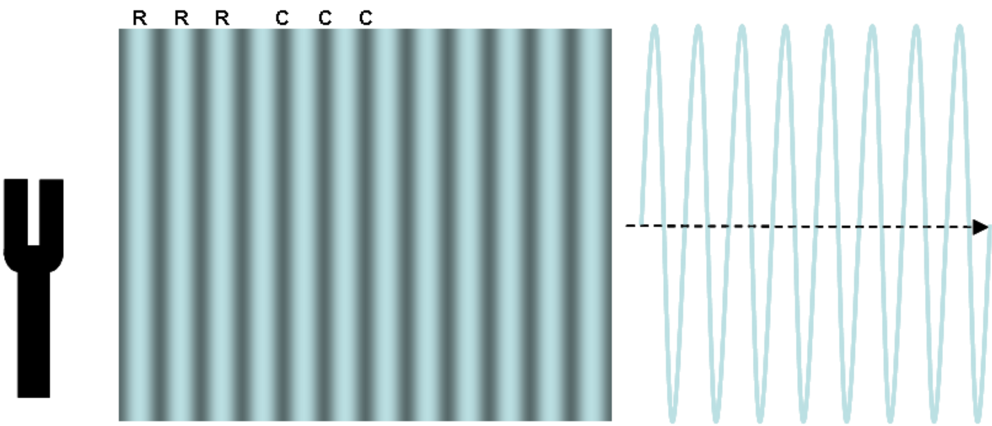


**Figure 1.1 sound generation from a tuning fork. The longitudinal wave generated by areas of compression (C) and rarefaction (R) is represented as a transverse wave propagating through a medium in the direction of the arrow**

Every sound is determined by a set of physical characteristics – acoustic parameters. For ultrasound, the basic acoustic parameters include:

- Cycle duration (period) measured in microseconds (µsec)
- Wavelength, measured in millimetres (mm)
- Frequency, measured in mega Hertz (MHz)
- Propagation velocity, measured in metres/second (m/sec)
- Amplitude, measured in decibels (dB)
- Power, measured in Watts
- Intensity, measured in Watts/centimetre2 (Watts/cm2)

The basic acoustic parameters used to describe ultrasound are shown in figure 1.2

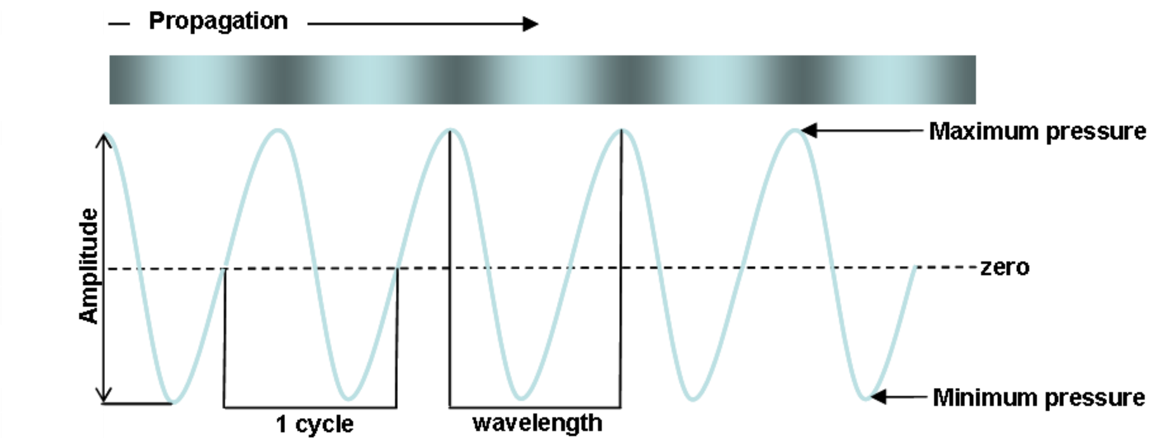


**Figure 1.2 The acoustic parameters used to describe ultrasound (modified from Støylen)**

- A **cycle** (period) is the time taken for completion of a peak to peak (or trough to trough) movement of the sound wave (μsec)
- The distance a sound wave travels in one cycle is the **wavelength** (mm)
- **Frequency** (Hz) is the number of cycles per second, and is the reciprocal of the cycle (period). Ultrasound (US) has frequencies greater than 20KHz (>20 000 Hz), and is inaudible to the human ear

The propagation velocity is frequently termed the **velocity** of sound, and is determined by the material through which the waves are travelling. As shown in table 1.0, sound travels faster through more solid materials.

| Medium | Speed of sound (propagation velocity) |
|---|---|
| Air | 330 m/s |
| Water | 1480 m/s |
| Heart (soft tissues) | ~1540 m/s |
| Bone | 2800 m/s |

**Table 1.0 Velocity of sound through various media**

Sound waves may displace more or less of the medium through which they propagate, resulting in a higher or lower **amplitude** (or "loudness"). The amplitude relates to the ability of ultrasound to transmit energy, where power/intensity (the time rate of flow of energy) is proportionate to the amplitude squared (P = K x amplitude$^2$).

US waves are described in terms of their **frequency (f), wavelength (λ), propagation velocity (v)** and **amplitude** and, which are important to optimise US images.

The wavelength, velocity and frequency are related by the equation: **v=f x λ**

Assuming that the velocity of US is constant through a medium, higher frequencies will therefore result in shorter wavelengths. This is important as the wavelength determines both:

- The spatial resolution of images
- The penetration of US beams (which determines the depth of structures that can be visualised)

Shorter wavelengths allow for an image with a higher resolution, but the penetration is poor – so near structures are visualised in greater detail but distant structures are less well imaged. Conversely longer wavelengths (as used during abdominal ultrasound scanning) will penetrate further, allowing visualisation of deeper structures but in less detail. Echocardiography is a form of US examination used to assess the anatomy and physiology of the heart. Focused echocardiography uses ultrasound at frequencies between 1.5 and 7.5 MHz (usually 3.5MHz in adults).

**Attenuation:** As ultrasound propagates through a medium it releases some of its energy (in the form of heat and tissue vibration) resulting in a progressive reduction in amplitude (attenuation, measured in dB). The higher the frequency of the wave, the more energy will be released, resulting in a higher attenuation coefficient (decrease in amplitude/centimetre of propagation).

**Reflection:** When ultrasound passes through a uniform medium (e.g. uniform soft tissue) it maintains its initial direction and is progressively absorbed or scattered. This inevitably leads to attenuation of the beam with distance travelled. When it arrives at a boundary with a different medium (such as an interface with air or fluid or with tissue of a different density) some of the wave is reflected back to the US transducer, resulting in image formation. The amount of reflection depends upon the reflectivity of the tissue boundary (**acoustic impedance**), which is the product of tissue density and propagation speed, and is measured in rayls. Non-reflected tissue is transmitted further until another tissue boundary is encountered, and the same process repeated.

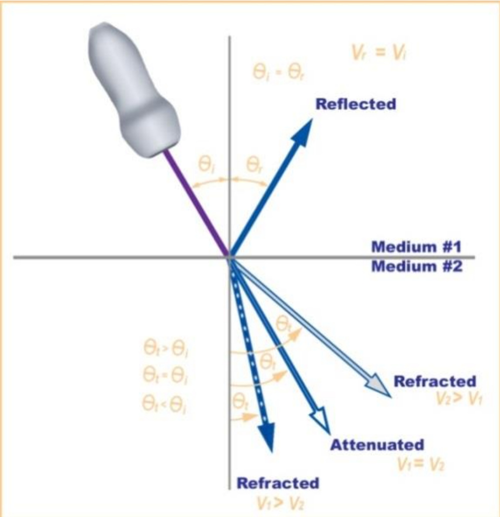


**Fig.1.3 Interaction of US waves at a interface between two different media (from StØylen)**

As the tissue boundaries get closer together, the ability of US to distinguish the distance between them reduces, with the minimal distance being known as **axial resolution** (usually 0.5mm in modern US systems), which cannot be better than two wavelengths.

**Refraction:** When US reaches a tissue boundary at an oblique incident angle, transmission with a change in direction occurs (refraction). This is similar to the phenomenon of light waves "bending" when passing from air to water.

**Focus:** US can be focused and directed in a manner similar to light, providing an US beam with a typical hourglass appearance, and the narrowest point being known as the focal point. This characteristic enables focussing of the US beam to enable discrimination between two side-by-side boundaries (lateral resolution), provided the distance between them is greater than the width of the focal point.

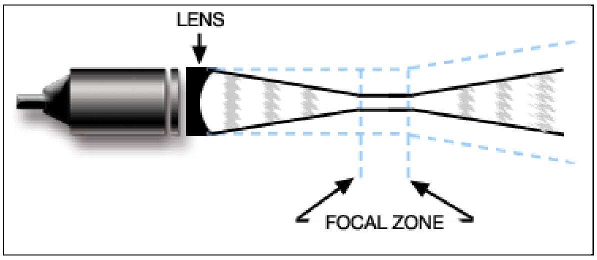


**Fig. 1.4 Location of the focal zone can be adjusted by the focus button to optimise image quality and lateral resolution (from** StØylen**)**

## Formation of images using ultrasound

Ultrasound is generated by piezoelectric crystals that vibrate when compressed and decompressed by an alternating current applied across the crystals. The same crystals act as receivers of returning, reflected US, where the vibrations induced by the returning US are processed by specialised software within the US machine and displayed as images on the screen.

These returning signals depend upon:

1. Time delay from impulse transmission to receipt of reflected signal
2. The intensity of the reflected signal

In terms of the US system, spatial and temporal resolution determine the image resolution. Axial resolution is limited by wavelength, and thus determined by US frequency. Lateral resolution is determined by the US focus width.

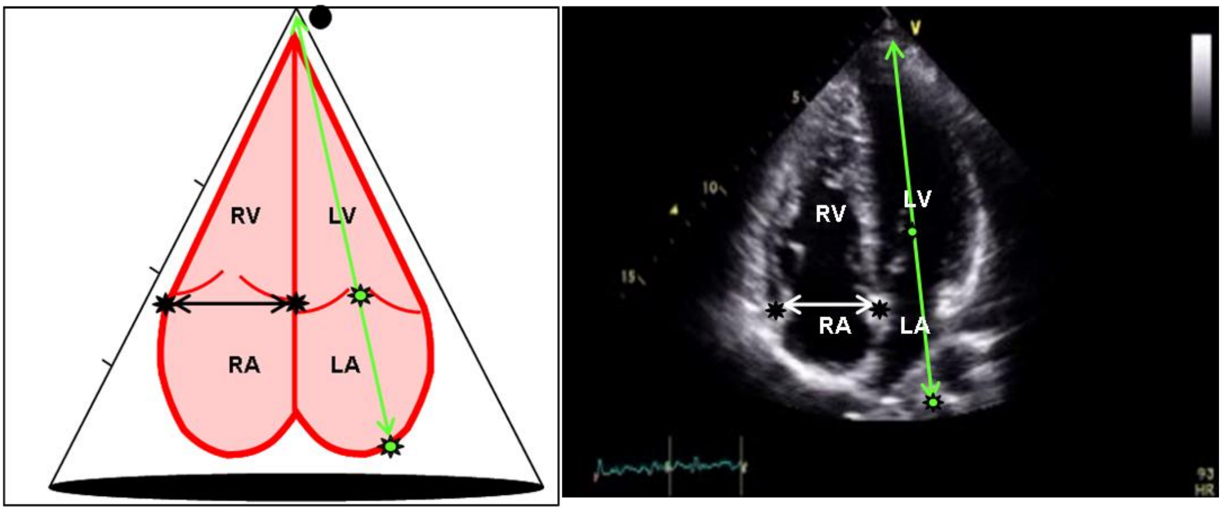


**Figure 1.5 Spatial resolution in a transthoracic image of the heart. On the left is a schematic of an US sector showing an apical four-chamber view (Chapter 3). Lateral resolution (black double-headed arrow) is the ability to discern two structures perpendicular to the beam. Axial resolution is the ability to discern two structures parallel to the US beam (green arrow). Axial resolution is optimal with high-frequency, short wavelength US, whereas lateral resolution is optimised by focusing the US beam to the zone of interest.**

Temporal resolution is determined by the frame rate and, in turn by the number of scan lines per sector and the sector depth and width. This, together with image optimisation is explained in more detail in Chapter 2.

## Summary

US is defined by its acoustic properties and its interaction with different media. Basic principles of US are important to understand the images acquired and how to optimise for interpretation.

# Ultrasound modes and controls

Chapter 2

**Learning outcomes**

- To understand how to manipulate the basic US controls to optimise image quality
- To understand how two-dimensional and M-mode images are made

## Basic settings

In order to obtain optimal images, the practitioner must select the correct probe, adjust the settings, and alter key controls on the echocardiography machine.

- Machine preset
- Probe selection
- Depth
- Sector width
- Focus
- Gain

### *Machine preset*

Many US machines in the critical care and emergency setting are used by a number of different practitioners, and for a range of imaging. Ideally, prior to cardiac scanning, the cardiac preset should be selected. This will automatically set the machine for scanning the heart of the average adult patient, with appropriate depth selection and screen orientation. It is important to check that the screen orientation marker is to the right of the display otherwise images will be reversed (Figure 2.1)

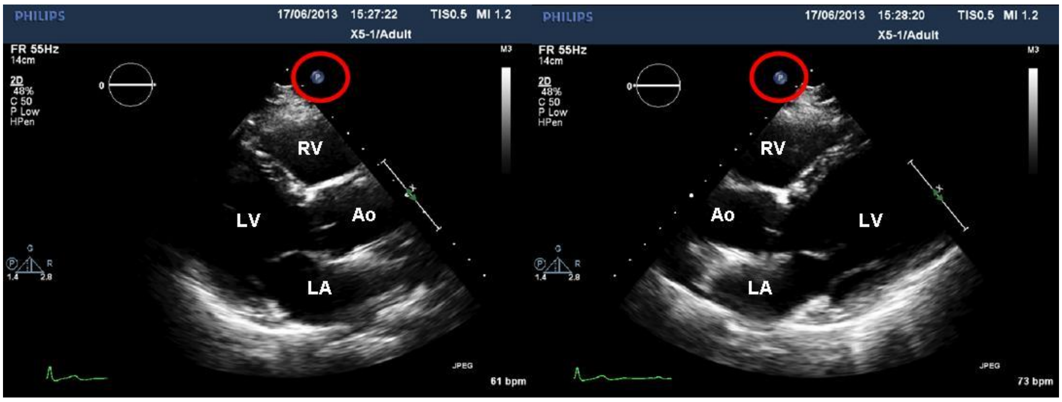


**Figure 2.1 Parasternal long-axis view showing the effect of reversing the screen orientation marker. In the image to the left, the machine is preset for cardiac scanning, and the screen orientation marker is to the right of the ultrasound sector display (circled in red). In the image on the right, the machine is incorrectly set up, with the orientation marker (circled in red) shown to the left of the ultrasound sector display.**

### *Probe selection*

Select the highest frequency cardiac probe that will provide imaging of the heart with adequate resolution, given the depth required (usually 3.5MHz in an adult). In practice, for emergency US there is limited/no choice of probes. If a probe of too high frequency is selected, although the axial resolution, and proximal resolution will be high, there will be limited imaging of deeper structures.

### *Depth*

The depth should be set according to what needs to be imaged. The depth is indicated on the side of the echocardiography display (Figure 2.6). A common error (particularly when imaging subcostal [SC] views in a large patient) is to underestimate the distance to the heart. In such cases, the image will not be seen on the display, and important pathology may be missed (Figure 2.2). Setting the excessive depth will reduce the temporal resolution (Figure 2.2). Imaging at the least depth possible will give the best resolution. A good starting depth is 15-18 cm for parasternal long-axis (PLAX) or 18-20 cm for subcostal (SC) views.

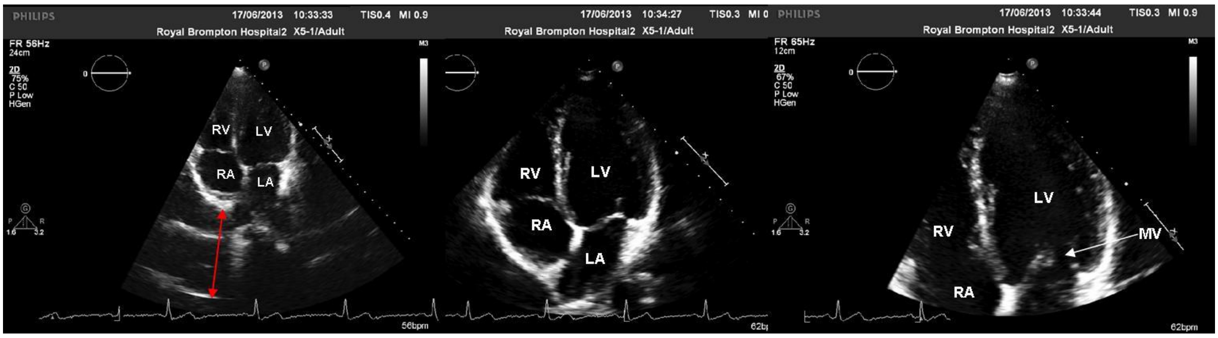


**Figure 2.2 Apical 4-chamber views showing the effect of altering the depth setting on the ultrasound machine. In the central image the depth setting is optimal to view all four cardiac chambers at 20cm. In the image to the left the depth setting has been increased excessively (28cm) and there is a large amount of "wasted" space in the sector (indicated by the red arrow). This will reduce the image quality. In the image to the right the depth setting has been reduced excessively (12cm) and the atria are only partially visible (for full explanation see text).**

### *Sector width*

This determines the number of scan lines that go to make one frame, with increasing number of scan lines reducing the temporal resolution (frames/second), Figure 2.3. Although temporal resolution is better with a narrow sector width, in peri-resuscitation echocardiography, best practice is to start with a large sector width to allow you to see as much of the heart as possible, and then reduce sector width if subsequent images are taken and the scenario allows.

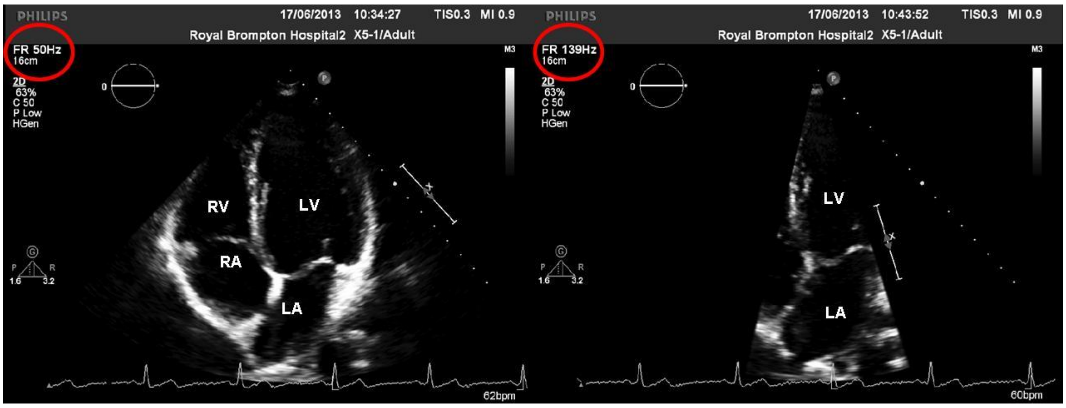


**Figure 2.3 Apical 4-chamber views showing the showing the effect of reducing the sector width on the ultrasound machine. In the image on the left, the sector width is optimal to view all four cardiac chambers. In the image on the right, the sector width has been reduced excessively so only part of the LV and LA are visible. Note that the frame rate has increased (circled in red) as a result of the reduction in sector width (for full explanation see text).**

### *Focus*

This is displayed to the side of the echocardiography display. In general, this will not need changing in peri-resuscitation echocardiography. If the depth is changed, in most ultrasound machines, the focus will change accordingly. If the image is unclear, it is worth reviewing where the focus position is.

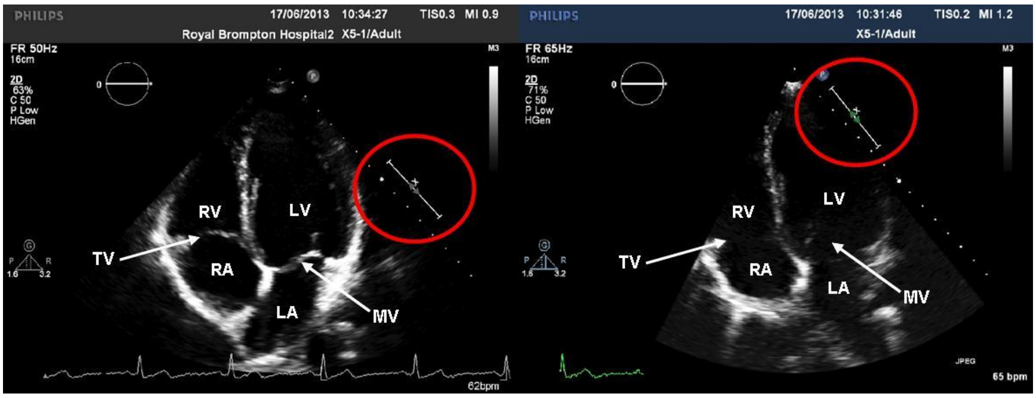


**Figure 2.4 Apical 4-chamber views showing the showing the effect of changing the focus position on image quality. In the image on the left, the focus is mid-depth (circled in red), and the mitral and tricuspid valve leaflets are seen clearly. In the image on the right the focus has been shifted (circled in red) towards the apex of the heart. The mitral and tricuspid valve leaflets are no longer visible.**

### *Gain*

This represents the power output from the transducer. Too little gain and the image is very dark, too much gain and the image is too light (leading to loss of tissue definition) (Figure 2.5). A common error in peri-resuscitation echocardiography is to have the gain too high. The usual range is 50-70.

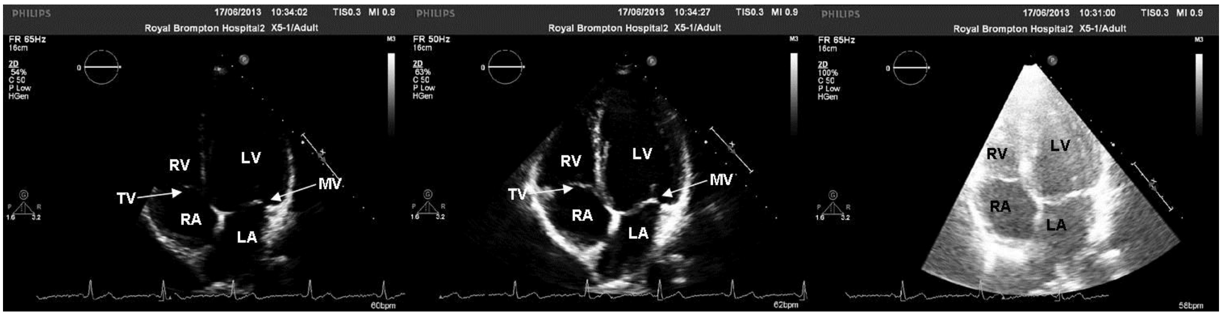


**Figure 2.5 Apical 4-chamber views showing the showing the effect of changing gain on image quality. The central image has optimal gain settings and the cardiac structures (including endocardial border and tricuspid and mitral valves) are visualised clearly. In the image on the left, the gain is too low, the image is dark and the left ventricular walls and tricuspid and mitral valves are not visualised clearly. In the image on the right the gain is too high, resulting in loss of definition of structures.**

A summary of the main echocardiography controls is shown graphically in Figure 2.6

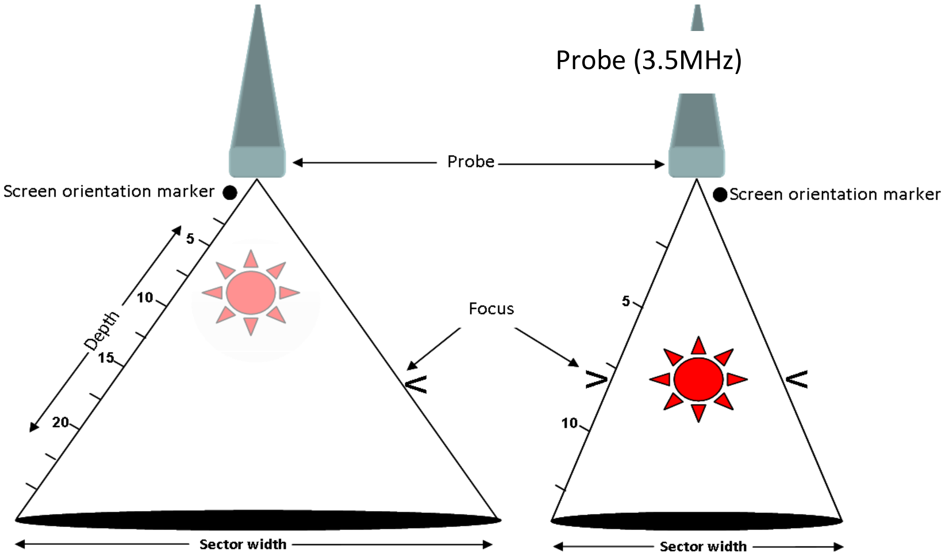


**Figure 2.6 Basic echo controls to optimise image resolution, with incorrect settings (to image the red star) on the left, and optimised settings shown on the right. The probe is depicted at the top of the US sector. In the image on the left; a) the screen orientation marker is to the left, the depth excessive, the focus not set to the correct part of the sector and the sector width excessively large. In the image on the right the screen orientation marker is correctly displayed to the right of the screen, the depth and focus are adjusted appropriately to image the red star, and the sector width is reduced.**

## Ultrasound Modes

The diagram below represents formation of US images using different modes. When the US pulse (P) is emitted from the transducer, it is reflected from tissue interfaces (A, B and C) with differing acoustic impedance, the received, reflected US is then used to form the image displayed. A & B are static interfaces with respect to the US pulse (P), and B is moving towards and away from P.

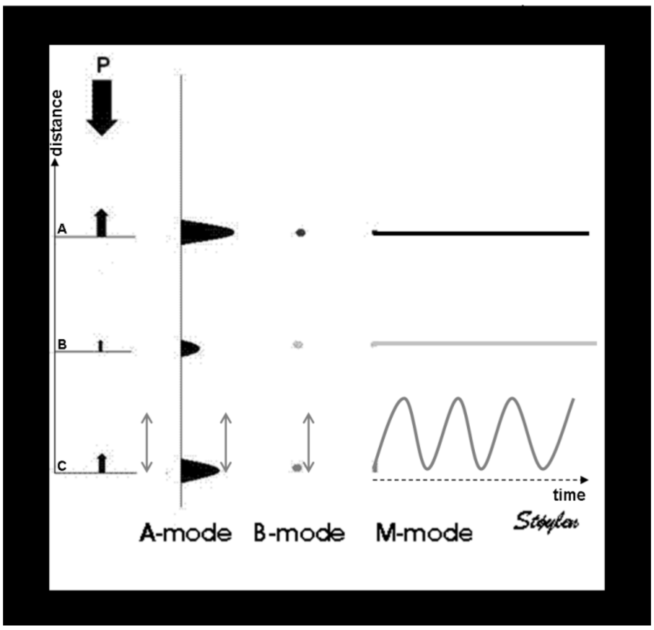


**Figure 2.7 Different modes of echocardiography**

**A-mode**: **A**mplitude mode: this is a plot of returned signal amplitudes against depth (time for signal to return)
**B-mode**: **B**rightness mode – plot of brightness against depth (time for signal to return)
**M-mode**: **M**otion mode where a plot of the brightness is shown against time (y axis)

The usual imaging modality in FEEL is 2D echocardiography. In FEEL, the main use of M-mode is to estimate right ventricular function (Chapter 5).

### *M-mode Echocardiography*

M-mode is derived by displaying the amplitude mode over time. Its temporal resolution means it is superior in demonstrating rapidly moving structures and timing events in the cardiac cycle (Figure 2.4). It is most frequently used for estimating fractional shortening and ejection fraction (Chapter 4), and right ventricular systolic function (Chapter 5).

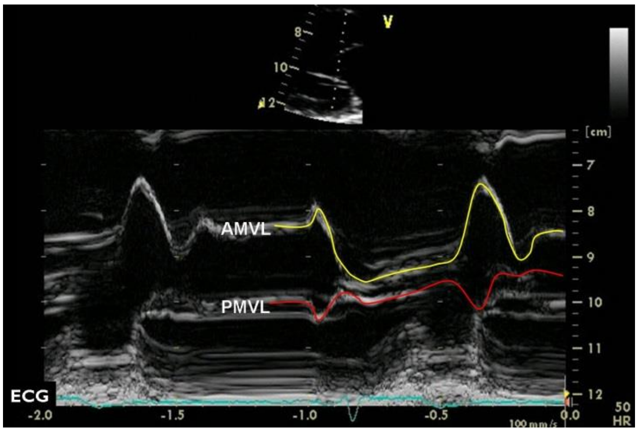


**Figure 2.8 M-mode across the mitral valve leaflets demonstrating the movement of the anterior (yellow) and posterior (red) mitral valve leaflets over time (y-axis). In early diastole, the leaflets move apart, they drift together and then are forced apart in late diastole by the extra blood moving through the valve as a result of atrial contraction.**
**AMVL; anterior mitral valve leaflet, PMVL; posterior mitral valve leaflet, ECG; electrocardiogram**

### *Two-Dimensional Echocardiography*

To display a two-dimensional representation of the heart, repeated sweeps of M-mode scans are performed electronically, and these are reconstructed to provide real-time two-dimensional images of the scanned anatomical structures (Figure 2.9).

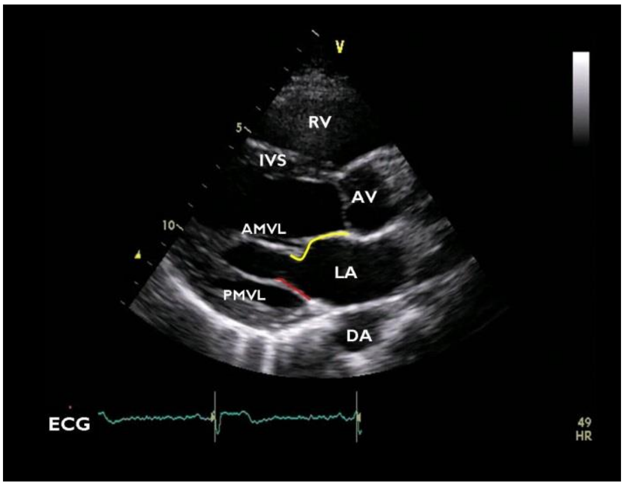


**Figure 2.9 Two dimensional image (parasternal long axis view) with the anterior (yellow) and posterior (red) mitral valve leaflets highlighted. The frame is taken in late-diastole, with the valve leaflets clearly separated.**
**AMVL; anterior mitral valve leaflet, PMVL; posterior mitral valve leaflet**

In general 128 lines scanned cover a $90^{\circ}$ sector, with each sector generating one frame. Thus, the time to generate one 2D frame (t) depends on the time taken for US to make the required number of return trips (dependent in turn upon the number of scan lines/sector, the depth of the scan, and the speed of propagation of US). This time to generate one frame determines the frame-rate and hence the temporal resolution of 2D echocardiography images. In practice this means that since each sector scan forms one frame, the temporal resolution is limited by the depth of scanning and the number of scan lines (sector width).

## Summary

A number of basic controls will influence the quality of US image obtained, and knowledge of the basic principles of US is required to be able to use these controls correctly. Most modern echo machines designed for focused studies will default to settings that are appropriate for FEEL, provided the cardiac preset is selected, together with a cardiac probe.

# Cardiac Anatomy

Chapter 3

## Learning outcomes

- To be able to describe the probe positions required for a FEEL scan
- To understand the orientation of the TTE probe & its relationship to the US image
- To know which structures can be assessed with each FEEL view

In order to standardise examination findings, internationally agreed nomenclature is used to describe the views required to perform echocardiography. In contrast to the emergency physician ultrasound examination, in echocardiography the orientation of the probe is varied for different views. The echocardiographic views used in the FEEL exam are described by:

1. Location of the probe on the patient:
    a. Parasternal – 2nd intercostal space at left sternal edge or
    b. Apical – cardiac apex or
    c. Subcostal – below the xiphoid process
2. The view obtained:
    a. Axis (short or long) or
    b. Number of chambers included

Thus the four FEEL cardiac views are:

- Parasternal long axis
- Parasternal short axis
- Apical 4-chamber
- Subcostal (long axis)

Conceptually, some students find the difference between long and short axis difficult to grasp. It may help to consider the ultrasound beam as a knife which cuts a three-dimensional object (e.g. a pear) in different planes. This is illustrated in the Figure 3.1.

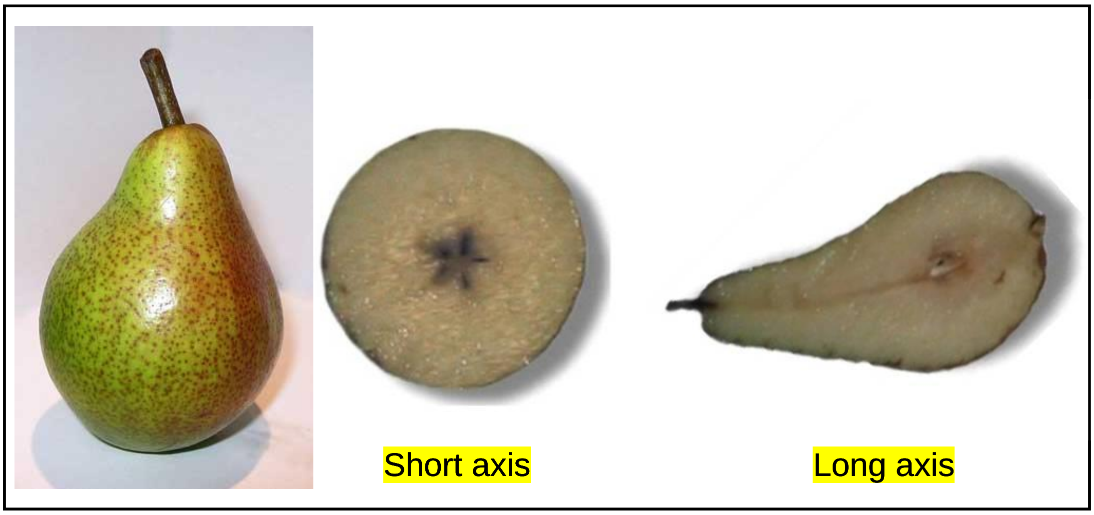


**Figure 3.1 A complete pear, and representative cuts demonstrating the short and long axis**

In a complete TTE examination there are many more views but those are beyond the scope of this course. The views required for lung and pleural ultrasound are more variable, and described in Chapter 6 (Lung US)

## Probe manipulation

The TTE probe has an orientation marker (OM). This will be a dot, groove or light depending on the make of the machine. This is used to ensure correct left-right orientation of the probe. In echocardiography the OM should correspond to the right-hand side of the screen when viewing images. This is confirmed by seeing the screen right-left marker (individualised appearance according to the manufacturer) to the right of the ultrasound sector on the screen.

In figure 3.2 the probe OM is a green light (indicated by the broken arrow), which is orientated towards the patient's right shoulder. Figure 3.3 demonstrates the corresponding ultrasound image with the screen orientation marker as a yellow V (solid yellow arrow) to the right of the display.

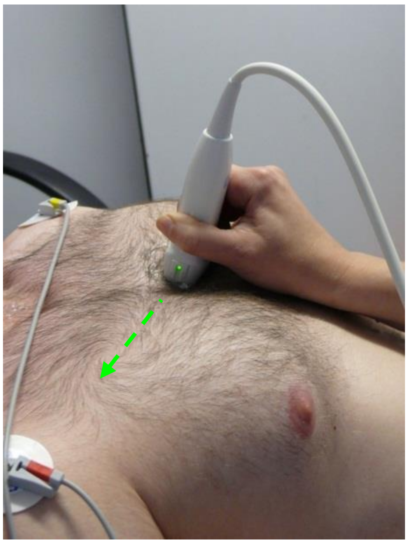

**Fig 3.2 Probe orientation**
**The image shows probe in a parasternal position with a marker (green light) orientated towards the right shoulder.**

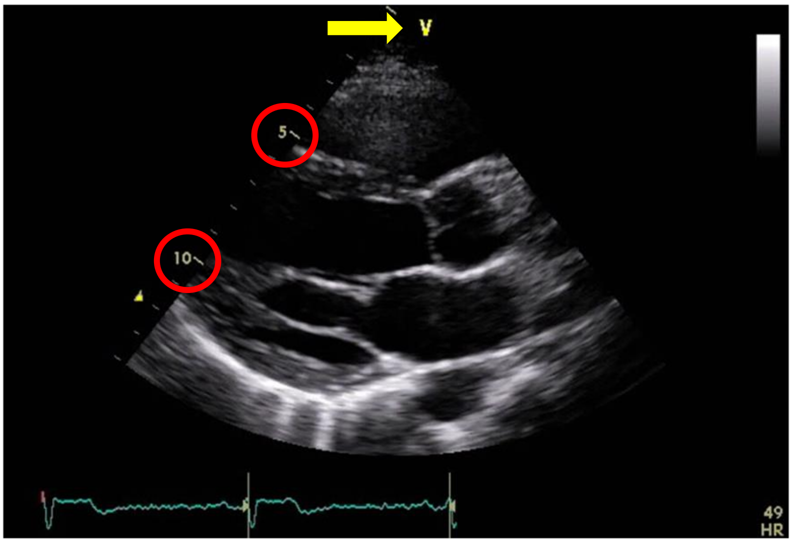


**Fig 3.3 Ultrasound image in the parasternal long-axis view. The image shows the correct screen orientation with the marker (yellow V) to the right of the ultrasound sector**

If the student wishes to check that they have the correct right-left orientation of the probe and image, tapping one side of the scanning portion of the probe (footprint) should cause distortion on the corresponding side of the screen image.

Before starting, ensure that the depth is set at 12 to 18 cm as this will maximise the chance of a good image being achieved in the average-sized person. The depth can be confirmed using the centimetre marks to the left of the ultrasound sector. These can be seen on the left side of the image sector in figure 3.3 (circled in red). The structures to be assessed should be centred on the screen by moving the probe laterally or medially or moving up or down an intercostal space. To achieve the correct view the probe may be turned clockwise or anticlockwise, and/or tilted caudally or cranially.

Each of the standard views in FEEL is now described in detail, together with how they should be obtained.

## *Parasternal Long-Axis (PLAX) View*

Fig 3.4 **PLAX view - Probe position**

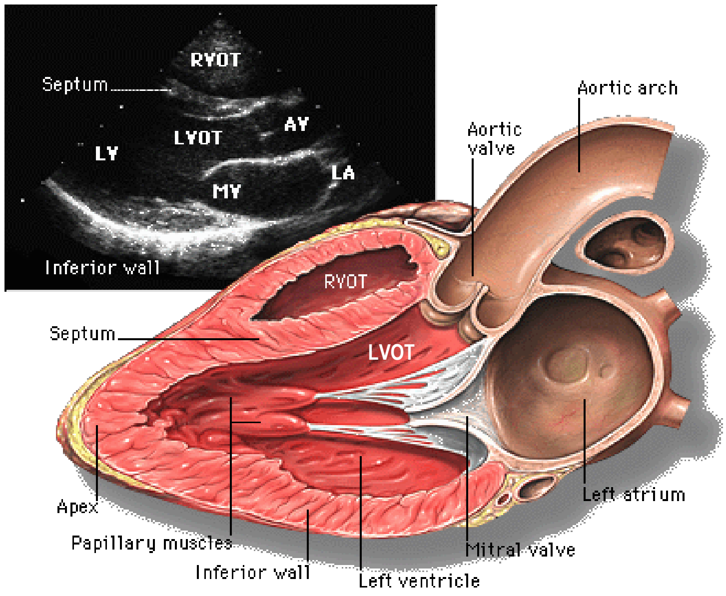


**Fig 3.5 PLAX view - US image and anatomy**

### Location

Although this view is usually achieved best with the patient lying in a left lateral position, it can be achieved in a supine patient, and this is often the only option in the critically ill. The probe is placed in the 2nd intercostal space just lateral to the left sternal border. The OM on the probe points towards the patient's **right** shoulder. This is the only echocardiography image in FEEL where the OM points towards the right of the patient. Depending on the patient's physique it may help to move down an intercostal space.

### Anatomy

This view is useful to examine the left ventricle (LV), left atrium (LA), proximal aortic root, aortic and mitral valves and the pericardium. The RV and its outflow tract (RVOT) lie just behind the sternum, so the RVOT is closest to the probe at the top of the picture. The LV is seen behind the RV, and the LA behind the aorta at the level of the aortic valve.

## *Parasternal Short Axis (PSAX) View*

**Fig 3.6 PSAX View - Probe position**
**The OM is now directed towards the left of the patient (direction of OM arrowed)**

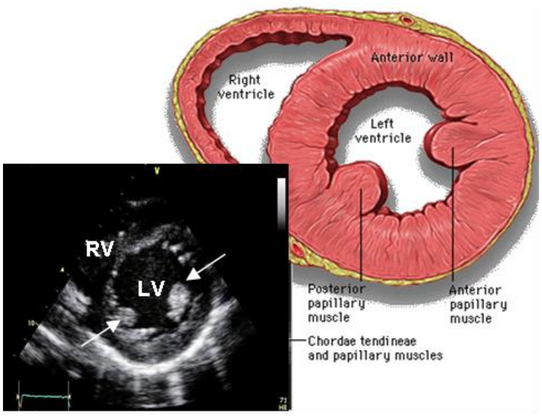


**Fig 3.7 PSAX view at the level of the papillary muscles (arrowed in the echo image)**

### Location

This view also is usually achieved best with the patient lying in a left lateral position but it can also be achieved in a supine patient. The probe is placed in the 2nd intercostal space just lateral to the left sternal border. The OM on the probe points towards the patient's **left** shoulder. From the PLAX view this is achieved by turning the probe 90° clockwise.

### Anatomy

This view is useful to examine the LV cavity and LV walls. Tilting the probe on the chest demonstrates different PSAX "slices" through the heart. The view in figure 3.7 is at the level of the papillary muscles. Tilting the probe such that the ultrasound beam travels in a more cranial direction will bring the mitral, and then the aortic valve into view. Tilting the probe such that the ultrasound beam travels in a more caudal direction will show the apex of the LV. The RV is a thin-walled structure compared to the LV. In its short axis the RV is D-shaped. The RV curves around the relatively thick-muscled, circular LV. The PSAX view of the LV is the only view that demonstrates all coronary artery territories in the left ventricle, when considering myocardial ischaemia or infarction.

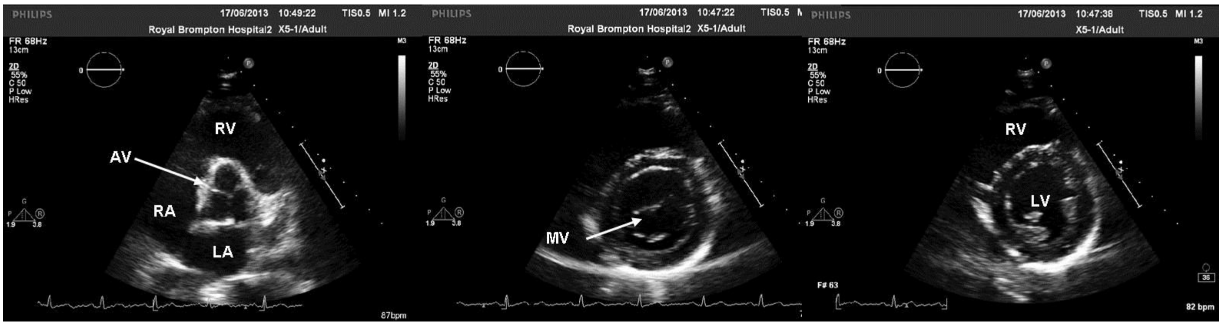


**Figure 3.8 Parasternal short axis views showing the showing the effect of tilting the ultrasound beam.. On the image to the left the US beam has been tilted superiorly, demonstrating the aortic valve (AV) which is seen at the centre of the heart. In the central image the US beam has been tilted inferiorly to show the leaflets of the mitral valve in the centre of the circular LV. In the image on the right, the US beam is tilted more inferiorly, bringing the papillary muscles into view. This is the optimal parasternal short-axis view for imaging the LV.**

## *Apical Four-Chamber (A4Ch) View*

**Fig 3.9 Apical views – Probe position**
**OM directed towards the left axilla (arrowed). Note that the position of the apex varies on an individual patient basis, and in cardiomegaly may be significantly displaced laterally and/or inferiorly**

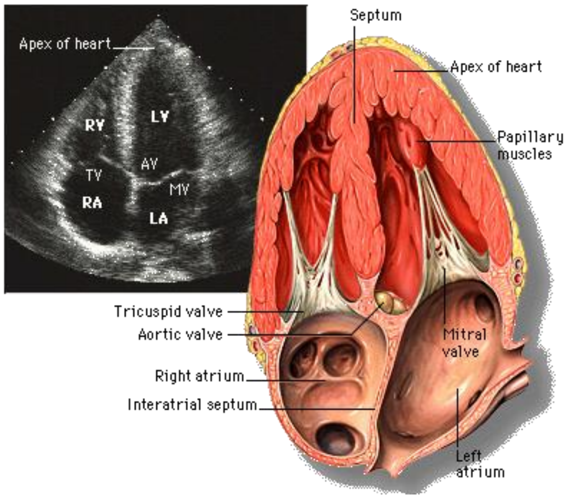


**Fig 3.10 Apical "5-chamber" view – US image and anatomy. Here the US beam is tilted slightly superiorly and the aortic valve (AV) comes in to view**

### Location

As with parasternal views the apical views are usually achieved best with the patient lying in a left lateral position, but in the critically ill it is often necessary to obtain images with the patient supine. The probe is placed over the patient's cardiac apex. The marker on the probe points towards the patient's **left**.

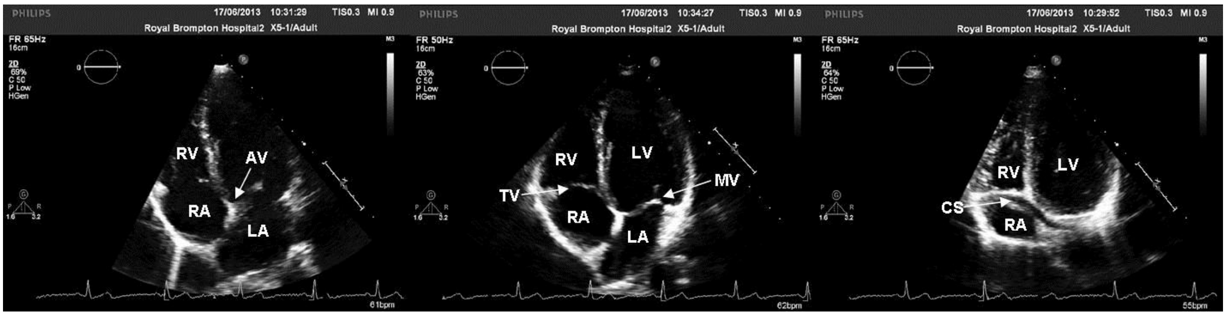


**Figure 3.11 Apical four-chamber views showing the effect of tilting the ultrasound beam. In the centre is an optimal four-chamber view. On the image to the left the US beam has been tilted superiorly, opening up the aortic valve (AV) which is seen at the centre of the heart. On the image to the right, the US beam is tilted too inferiorly, bringing the coronary sinus (CS) into view – seen as a linear black structure as it drains blood into the RA. The LA is foreshortened and not seen in this image.**

### Anatomy

This view is useful to examine all 4 cardiac chambers, RA, RV, LA, LV, the mitral and tricuspid valves and the pericardium. The RV is a smaller thinner-walled chamber than the LV and is orientated on the left-hand side of the screen. Tilting the probe such that the ultrasound beam travels in a more cranial direction will bring the aortic valve in to view - the so-called "5-chamber view" (figure 3.11). Tilting the probe such that the ultrasound beam travels in a more caudal direction will show the coronary sinus.

### *Subcostal (SC) View*

**Fig 3.12 SC View - Probe position**
**The OM is directed to the left. The probe is held from above, almost flat on the patient's abdomen**

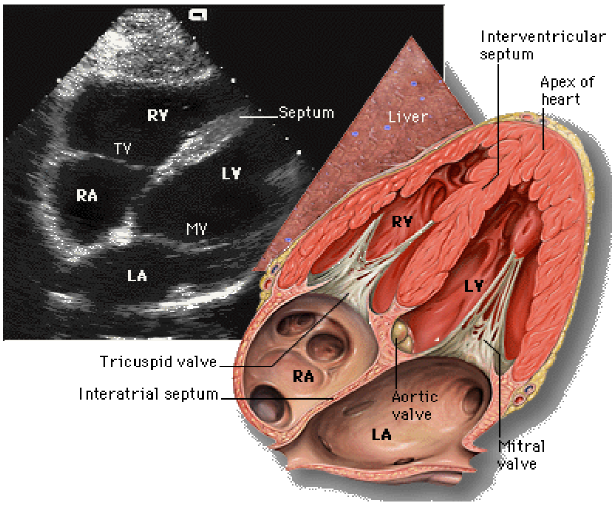


**Fig 3.13 SC View – US image and anatomy**

## Location

This view is usually best achieved with the patient lying in a semi-recumbent position, but the fully supine position may be the only option in a critically ill patient. The probe is placed under the xiphoid process almost flat on the patient's abdomen slightly to the right of the midline, aiming to use the liver as an acoustic window. The OM on the probe points towards the patient's **left**. The probe should be angled slightly to point towards the heart. Outside the cardiac arrest scenario a slight flexion of the patient's knees may relax the abdominal muscles and enhance ease of imaging.

## Anatomy

This view is useful to examine all 4 cardiac chambers, RA, RV, LA, LV and the pericardium. Also seen are the mitral and tricuspid valves and the IVC. Rotation of the probe OM superiorly, whilst directing the ultrasound beam rightwards towards the liver will bring the IVC into view.

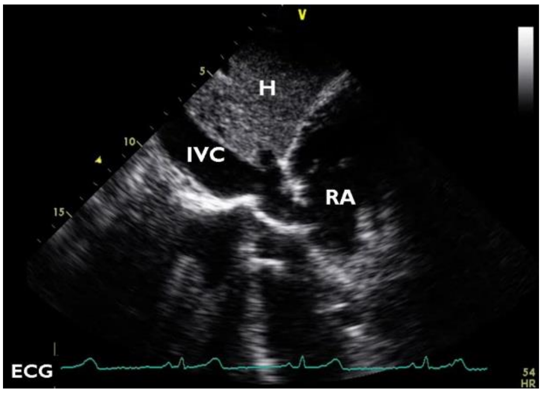


**Figure 3.14 Subcostal view of the inferior vena cava as it enters the right atrium.**

# Summary

The echocardiographic images required for FEEL are standardised to the nomenclature used by cardiologists and cardiac physiologists in the performance of comprehensive echocardiography, although the number of views required is limited. In a cardiac arrest setting, the subcostal view is recommended as it is remote from the area of chest compression and any defibrillation pads, and is additionally the easiest view for novice sonographers to learn. In other settings, all views should be obtained where possible, and interpretation integrated to form a final report.

# LV assessment

Chapter 4

## Learning outcomes

- Know the normal dimensions of the LV
- Describe the principles of quantitative assessment of LV function
- Understand how to make qualitative assessment of LV function
- Be able to describe the abnormalities of LV function
- Understand the distribution of coronary artery flow with respect to LV anatomy

There are several methods used to assess left ventricular function during a complete echocardiography examination, using M-mode, 2D and Doppler imaging. In FEEL however, only the simplest validated method for global estimation of function is used: "eye-balling" 2D images.

This entails consideration of the following aspects of the myocardium:

- Cavity size
- Wall thickness
- Changes in wall thickness between systole and diastole
- Wall movement in the different regions

LV dimensions vary with gender, body habitus and disease. The internal dimensions of the LV depending on the severity of impairment are shown below.

| LV dimension | Normal | Mild | Moderate | Severe |
|---|---|---|---|---|
| LVIDd (cm): male | 4.2–5.9 | 6.0–6.3 | 6.4–6.8 | ≥6.9 |
| LVIDd (cm): female | 3.9–5.3 | 5.4–5.7 | 5.8–6.1 | ≥6.2 |

Healthy LV wall thickness in an adult is usually 6–12mm in diastole.
Heart disease may cause the walls to become hypertrophied or thickened (e.g. in hypertensive disease, hypertrophic cardiomyopathy, aortic stenosis). Severe LV hypertrophy would be considered present with a wall thickness >20mm.
The LV may additionally become dilated, with or without wall thinning <6mm (e.g. in dilated cardiomyopathy, previous myocardial infarction, severe aortic and/or mitral regurgitation).

The change in LV dimensions/volumes between systole and diastole can be used as a measure of contractility.
The most common ways to measure LV contractility are:

- Fractional Shortening
- Ejection Fraction

## Simple measures of global LV function: fractional shortening and ejection fraction

In the simplest methods, these are both calculated from a 2D PLAX view, (Figure 4.1) with an M-mode placed just beyond the mitral valve leaflet tips in the LV cavity.

Fractional shortening is the percentage change in ventricular size during contraction.

In Figure 4.1, on the left the PLAX view is shown, with the level at which measurements are made shown as a green arrow. On the right the corresponding M-mode is shown. This shows the change in LV internal dimensions between diastole (a) and systole (b).

Fractional shortening = [(a-b)/a] x 100%
Normal >25-43%
Severely impaired <15%

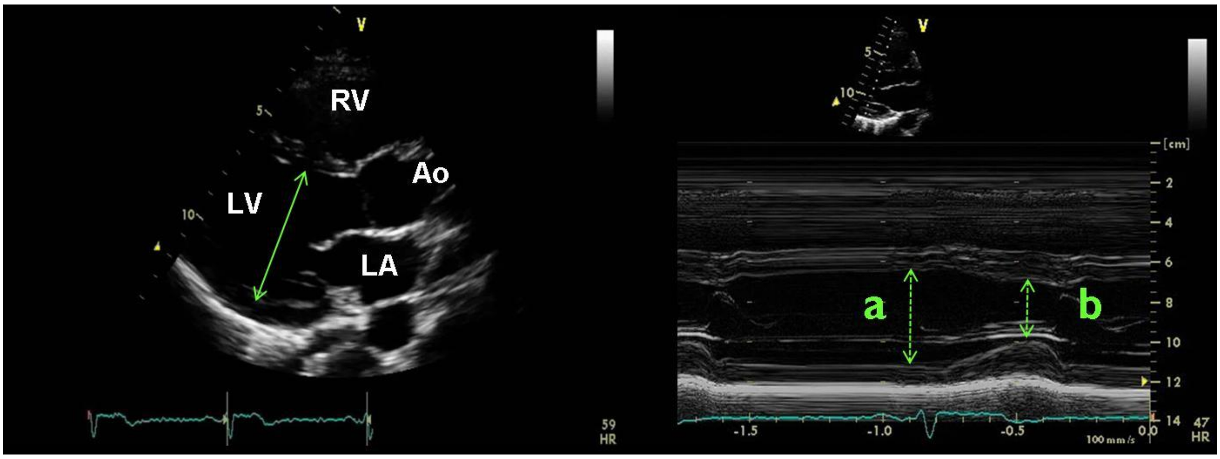


**Figure 4.1 Measurement of Fractional Shortening and of Ejection Fraction (Teichholz method)**

## Measurement of Ejection Fraction

Ejection fraction is the percentage of blood volume ejected during contraction, and is estimated using a number of methods. The simplest, but often extremely inaccurate, (Teichholz method) is also taken from a 2D PLAX view, with the M-mode cursor positioned at the same point.

The two dimensions that are measured to calculate EF by this method are shown in the right-hand panel
a. LV dimension at end-diastole
b. LV dimension at end-systole.

The end-diastolic and end-systolic volumes, are then calculated, and used to calculate the EF:
End-diastolic volume = [7 / (2.4 + a)] x a [ml]
End-systolic volume = [7 / (2.4 + b)] x b [ml]

Ejection fraction = (LVEDV – LVESV) x 100/ LVEDV
Normal >55%
Severely impaired <35%

Small LV volumes can in some circumstances relate to the volaemic status of the patient. This is discussed in Chapter 7 (Pathology).

Although frequently quoted as a measure of ventricular function, the inherent inaccuracy of the Teichholz method has led to the development of a number of more sophisticated echocardiographic techniques to assess LV function.

*Visual estimation (eyeballing) of global LV function has been shown to correlate well with measured values of ejection fraction. In the peri-arrest situation this is the method most appropriate to use.*

### Regional wall motion abnormalities

The various regions of the myocardium are supplied by different coronary arteries. In coronary artery disease there may therefore be regions of myocardium that are affected differentially. It is important to look at and assess each segment of the LV wall independently, and then compared with other segments. Marked abnormality in regional contractility may indicate that the cause of the arrest/peri-arrest situation may be coronary artery disease.

The American Society of Echocardiography (ASE) criteria define a widely-used score for these wall motion abnormalities. The definitions are:

- Normal wall motion (↑thickness in systole >50% thickness in diastole)
- Hypokinesia (↑thickness in systole <40% thickness in diastole)
- Akinesia (↑thickness in systole <10% thickness in diastole)
- Dyskinesia (outward motion + wall thinning in systole)

These abnormalities may be global, or regional. Regional abnormalities in function are most commonly due to regional ischaemia but other pathological processes can cause regional wall motion abnormality. One view (PSAX) shows myocardium in all three coronary artery territories at once.

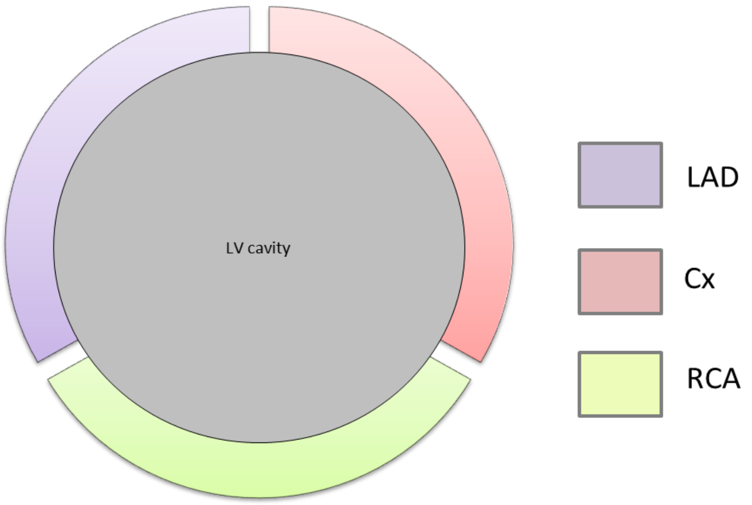


**Figure 4.2 Schematic illustration of left ventricular coronary artery territories visualised in PSAX view. (LAD –left anterior descending artery, Cx – circumflex artery, RCA - right coronary artery)**

Interpretation of regional wall motion abnormalities is challenging, in particular in the context of pre-existing myocardial disease and in the context of inotropic support. This requires specialist knowledge and skills.

## Summary

In the peri-resuscitation and/or cardiac arrest situation, eyeballing is used to assess LV function. The main questions to be answered are:

1. Is the LV moving?
2. If the LV is moving, is it doing so in a co-ordinated way or is ventricular fibrillation (VF) present?
3. Is the LV severely dilated?
4. Is the LV severely underfilled (kissing walls)?
5. When the LV is contracting, is it doing so normally, or is it severely impaired?
6. Are all segments of the wall thickening normally and to the same degree?
7. Is the LV grossly hypertrophied?

# RV assessment

Chapter 5

## Learning outcomes

- Know the normal dimensions of the RV
- Describe the principles of quantitative and assessment of RV function using TAPSE
- Understand how to undertake qualitative assessment of RV function using TAPSE
- Understand how to assess for RV hypertrophy
- Understand the changes in RV geometry in response to increasing pulmonary pressures

The right heart is a complex three dimensional structure, making echocardiographic assessment of size and function challenging. Further, its pattern of contractility is complex. There are several methods used to assess RV function during a complete echocardiography examination, using M-mode, 2D and Doppler imaging. In FEEL however, only the simplest validated method for global estimation of function is used: "eye-balling" 2D and M-mode images.

This entails consideration of the following aspects of the myocardium:

- RV dimensions
- Presence/absence of any RV hypertrophy
- RV contractility
- RV geometry (with respect to the LV)

### *RV dimensions*

Although in comprehensive echocardiography there are nine recognised dimensions that can be measured using TTE, in focused echocardiography two views are used; the PLAX and A4Ch.

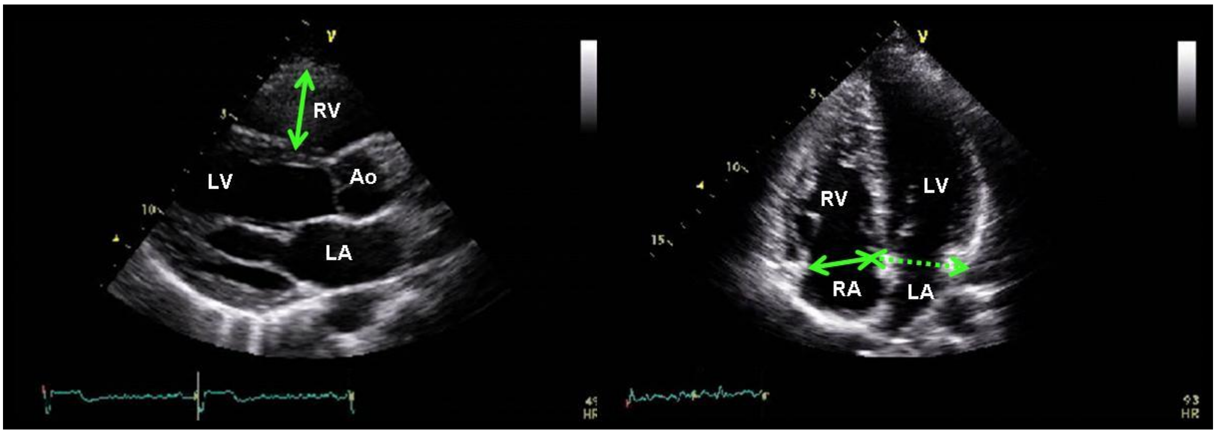


**Figure 5.1 RV dimensions estimated in focused echocardiography. In the image on the left (PLAX view), the RV cavity dimension (arrowed, green) is estimated at end-diastole. In the image on the right (A4Ch view), the inlet dimension of the RV (solid green arrow) is compared with that of the LV (broken green arrow).**

In the parasternal long axis view, RV dimensions measured/estimated using TTE are:

- <2cm normal
- >2cm dilated
- >3cm severely dilated

In practice these can be eyeballed from the centimetre scale to the left of the ultrasound sector, or by comparison with the ascending aorta. Under normal circumstances the RV in this view should not be significantly larger than the ascending aorta.

In the apical four-chamber view, RV dimensions measured/estimated using TTE are:

- Ratio RV inlet:LV inlet <0.6 normal
- Ratio RV inlet:LV inlet >1.0 severely dilated

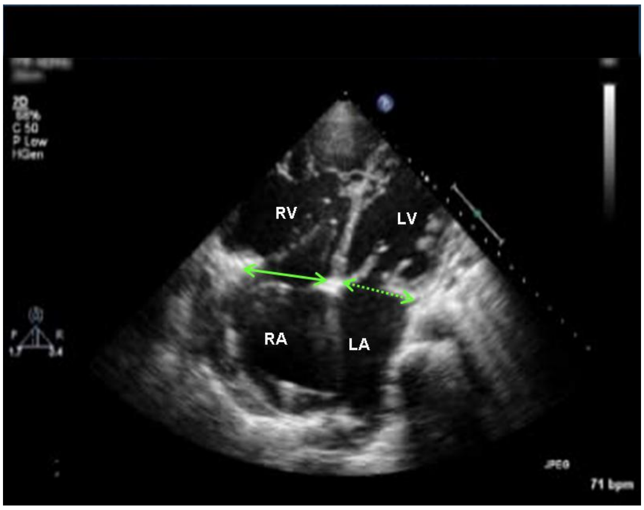


**Figure 5.2 Apical 4-chamber view in a patient with a severely dilated RV. Here, the RV is so dilated the LV appears small, and the apex of the heart is occupied predominantly by the RV rather than being shared between the two ventricles. The inlet dimension of the RV (solid green arrow) is clearly larger than the LV (broken green arrow).**

It is also possible to estimate the ratio of RV:LV areas in diastole:

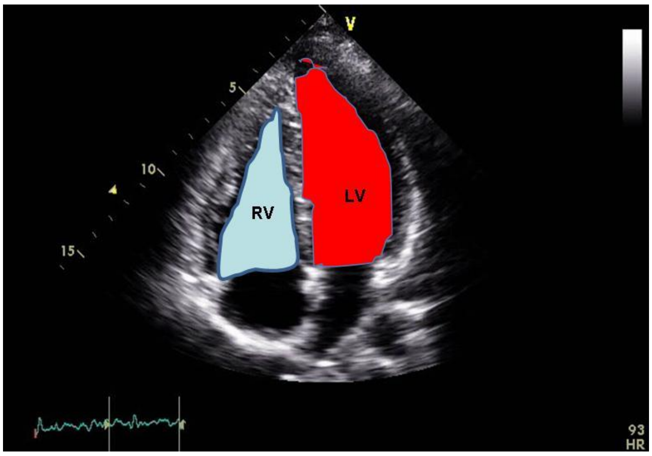


**Figure 5.2 Apical 4-chamber view showing comparison of RV and LV end-diastolic areas.**

Here, the ratio of RV end-diastolic area : LV end-diastolic area should also <0.6. RV areas in systole and diastole can be used to calculate RV ejection fraction, however they do not correlate well with cardiac magnetic resonance volumes (the gold standard) and are not required for focused echocardiography.

## *RV hypertrophy*

The chronic response of the RV to increased afterload is to hypertrophy. Eyeballing the RV wall thickness in all FEEL views should be performed. This will help distinguish acute from chronic pathology in the right heart, and is important when considering echocardiography in the diagnosis of pulmonary embolism (Chapter 7). If the RV inferior wall dimension is >5mm, this indicates significant hypertrophy. In addition to chronic pressure overload, the RV wall may become hypertrophied as a result of hypertrophic cardiomyopathy or infiltrative myopathies. The cut-off for diagnosis of significant hypertrophy is an RV inferior wall diameter > 5 mm.

### RV contractility

There are many sophisticated techniques to assess RV function, most of which are beyond the scope of peri-resuscitation echo. However, echocardiographic assessment of RV function can be performed looking simply at the longitudinal displacement of the free wall of the RV towards the apex, in the A4Ch view. This is called tricuspid annular plane systolic excursion (TAPSE) and correlates reasonably well with magnetic resonance estimations of RV contractility.

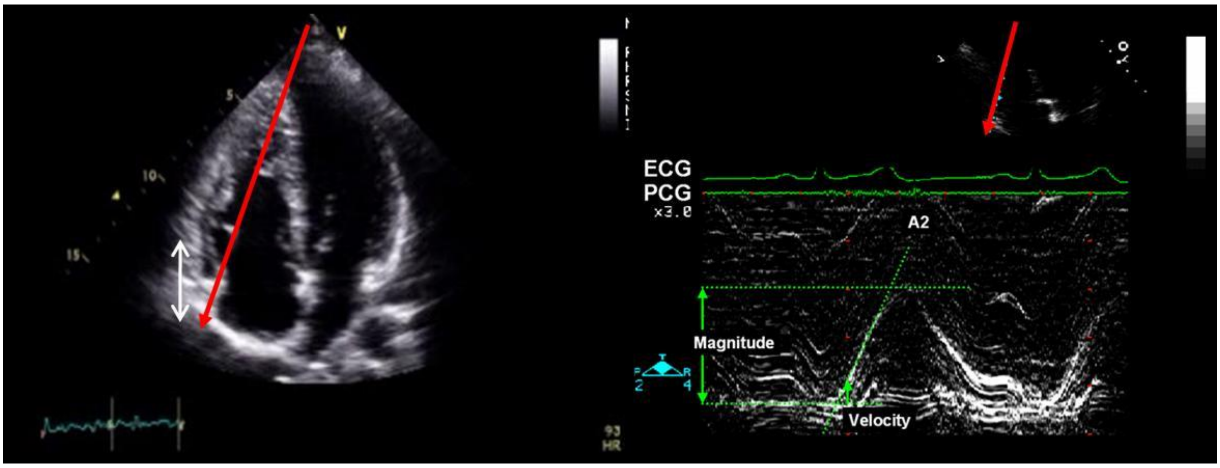


**Figure 5.3 Estimation of RV contractility. On the left in an apical four-chamber view, the movement of the insertion of the tricuspid valve at the tricuspid annulus is shown (white arrow). In order to measure this, M-mode (red arrow) is placed across the tricuspid annulus. The resulting M-mode (on the right) shows the three components of TAPSE (see text for details)**

If measurements are needed, the M-mode cursor is aligned through the TV annulus, shown on the right (Figure 5.3). It has 3 components: amplitude, velocity and timing (shown in green on the right of the figure). For the purposes of peri-arrest echocardiography, we are only interested in gross reductions in the amplitude. Amplitude can estimated by eyeballing a moving apical four-chamber view, and comparing the apical excursion of the TV annulus with the centimetre mark to the left.

In estimating RV contractility using TAPSE:

- >2cm normal
- >1.5cm normal after all forms of bypass surgery
- <1cm severely impaired

However, any reduction in TAPSE in the presence of significant pulmonary hypertension should be considered an indicator of severe RV impairment until proven otherwise. Further, in estimating the contractility, sonographers must ensure that the US beam is well lined up with the annular motion, as otherwise they may underestimate the value.

### RV geometry

The RV and LV share the pericardial space, and any increase in pressure and dimensions of one ventricle will affect the other. This is particularly important in pulmonary hypertension, where the increase in dimensions of the RV, together with the elevated RV pressures result in progressive flattening of the inter-ventricular septum, with the LV becoming progressively more D-shaped and smaller.

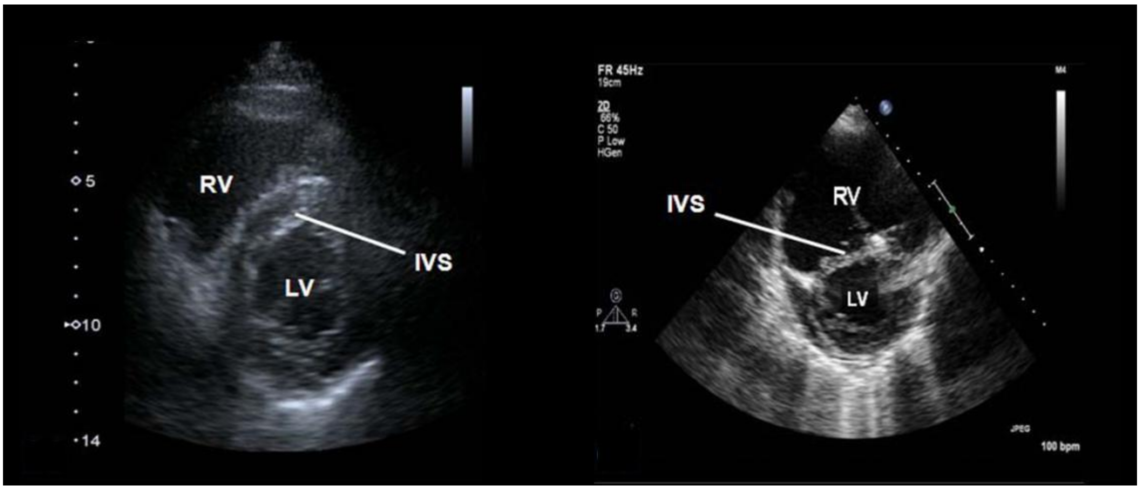

**Figure 5.4 Changes in RV geometry and size in response to pulmonary hypertension, parasternal short axis views. On the left in a normal patient, the RV and LV are of similar internal dimensions, and the LV is round in shape. On the right in a patient with pulmonary hypertension the RV is significantly dilated and the inter-ventricular septum is flattened, giving the LV a D-shaped appearance.**

## Summary

In the peri-resuscitation and/or cardiac arrest situation, eyeballing is used to assess the RV. The main questions to be answered are:

1. Is the RV significantly dilated?
2. Is the RV significantly hypertrophied?
3. Is RV contractility normal or abnormal?
4. What is the RV and LV geometry? Is there any evidence of septal flattening?

# Lung US

Chapter 6

## Learning outcomes

- To be able to describe the US features of pneumothorax
- To understand the use of US in detecting and assessing pleural collections

Lung ultrasound (LUS) has been generally regarded previously as either not possible, or not relevant. Increasingly however, the literature provides evidence of its usefulness. The principles of LUS involve obtaining and interpreting images (including artefacts).

## Lung Ultrasound

The ideal probe for LUS is the micro-convex or the convex probe, but in an emergency a cardiac probe can be used. The patient should be scanned in the anterior, antero-lateral and inferior parts of the chest on both sides. This would usually be the second, third and fourth intercostal spaces between the parasternal and the mid-clavicular lines.

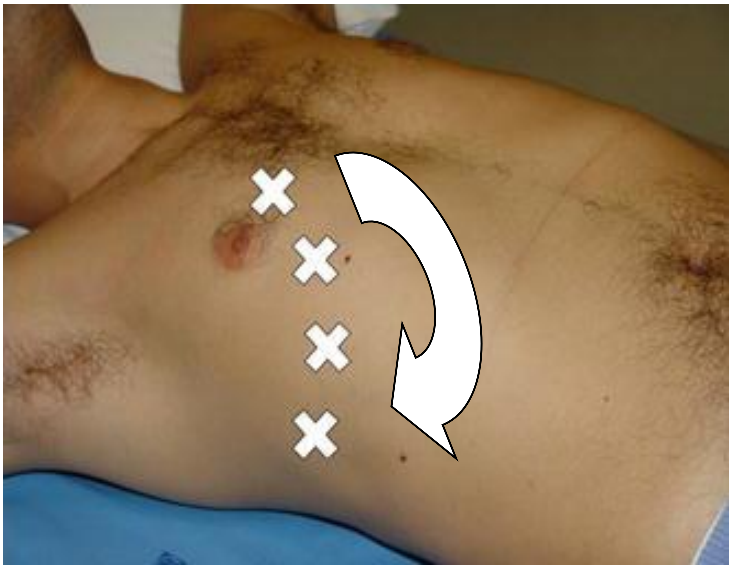

**Figure 6.1 Direction of probe movement (arrow) from medial to lateral to image the lung at different locations (white crosses)**

The probe is initially positioned with the OM pointing cranially, positioned between two rib spaces.
On the US image (see Figure 6.2), features of normal lung are shown (annotated on left). Below each rib (pink arrows), a black area of echo drop-out is seen (arrowed in green). This is due to US being almost totally reflected by bone. Between the two ribs normal lung is seen. The normal US features of lung include the presence of a pleural line (comprising the parietal and visceral pleura, highlighted in yellow). These features (rib shadowing and pleural line) are thought to resemble a bat in flight (see image) and are called the "bat sign". Due to artefact, in normal lung the bright white pleural line always appears to be repeated (arrowed in white), with identical distance between each line. These repeated artefacts are known as A lines.

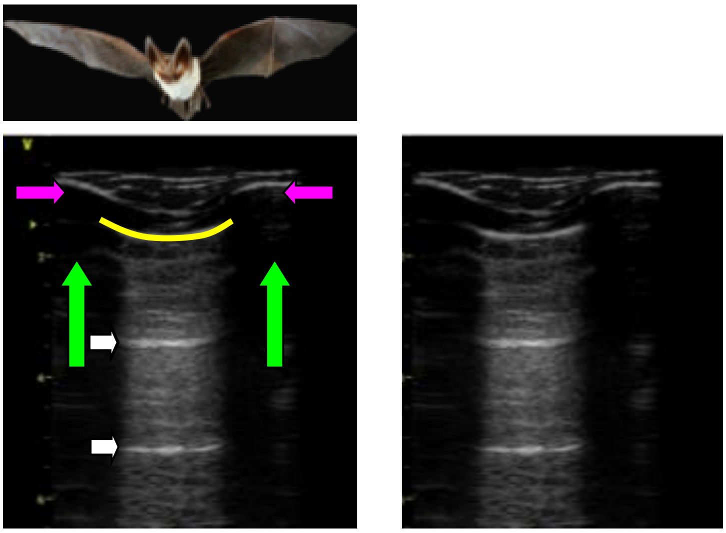

**Figure 6.2 Features of normal lung US showing the bat sign, the pleural line (yellow) A lines (white arrows) and ribs (pink arrows). For further details see text.**

Once the bat sign and pleural line are identified, the probe is rotated through 90 degrees to show the lung in its transverse (longitudinal) axis (Figure 6.3).

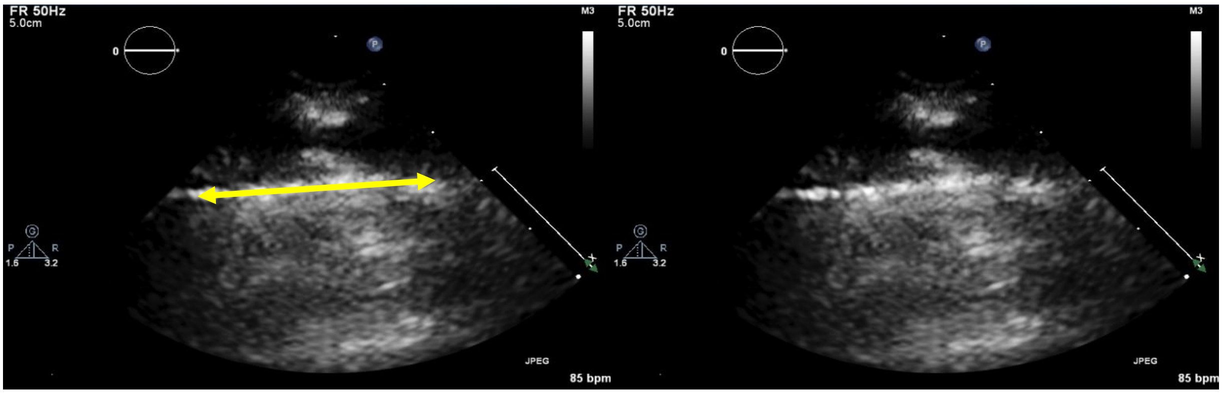


**Figure 6.3 The pleural line (highlighted in yellow on the left) imaged in its transverse (longitudinal) plane. During inspiration and expiration the line will appear to move – lung sliding (see text below for full explanation)**

In the peri-arrest and cardiac arrest setting, the most important lung-related diagnosis to exclude is pneumothorax. As with all ultrasound in this critical setting, it should be used as an extension of the clinical examination, not a substitute. If tension pneumothorax is suspected on clinical grounds, treatment must not be delayed in order to perform confirmatory lung US.

## *Diagnosis of pneumothorax*

There are four key features that are used to diagnose pneumothorax using ultrasound:

- Absence of lung sliding
- Absence of B-lines
- Presence of lung point(s)
- Absence of lung pulse

### Lung sliding

During inspiration and expiration, as the visceral pleural layer moves across the parietal pleura and the pleural line appears to move horizontally (arrowed in figure y). This horizontal movement is known as pleural sliding. If a pneumothorax is present pleural sliding is not seen. This is because although the parietal pleura is still seen and as air separates it from the visceral pleura (which moves during respiration) pleural sliding is not seen.
The detection of pleural sliding on the anterior and inferior areas of both hemithoraces in the supine patient excludes pneumothorax with a negative predictive value of 100%.

## *Confirmation of lung sliding*

M-mode of the lung tissue may help clarification where there is uncertainty regarding the presence of any lung sliding. In normal lung, using M-mode three regions of movement are seen at different depths. These three regions have been likened to the view obtained looking out over a sandy beach towards the sea.

- the immobile chest wall: the sea (blue below)
- the pleural line (the breakers on the seashore, arrowed in yellow below)
- the sliding pleura and natural irregularity of lung tissue generating an inhomogeneous granular pattern (the sand, orange below)

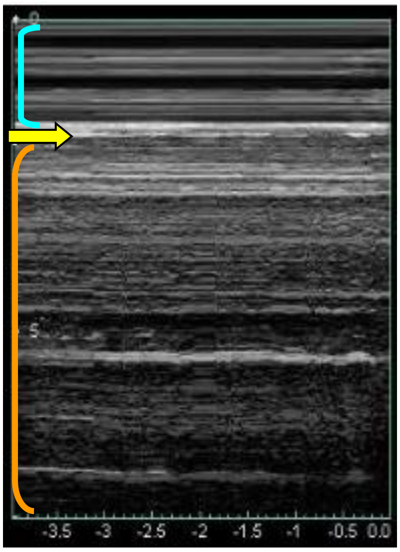


**Figure 6.4a M-mode of normal lung demonstrating the three regions of movement: chest wall, pleura and lung tissue**

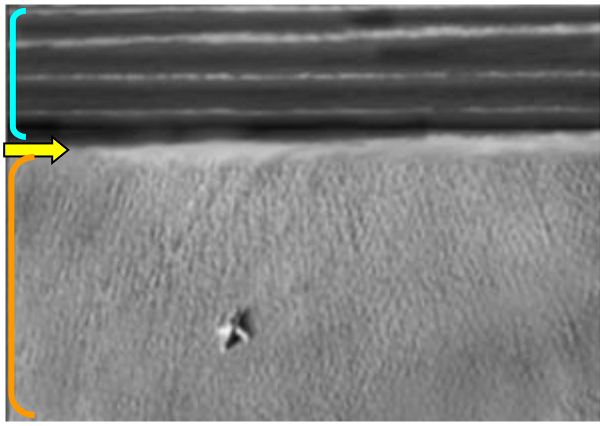

**Figure 6.4b Image of a seashore with corresponding regions: sea, breakers and sandy beach**

## *Absence of lung sliding*

In the presence of a PTX the M-Mode pattern consists exclusively of featureless horizontal lines- stratosphere sign. The chest wall and pleural line are still visualised, but the inhomogeneous granular pattern seen in normal lung disappears.

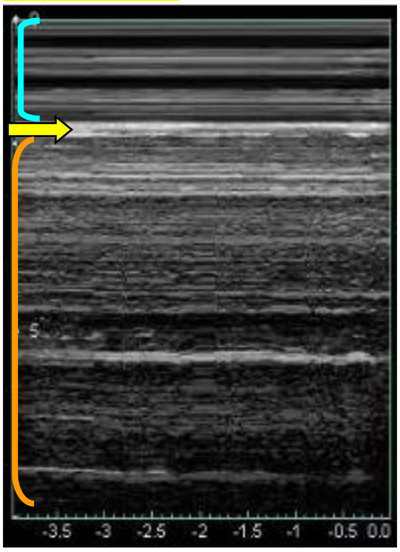


**Figure 6.5a M-mode of normal lung**

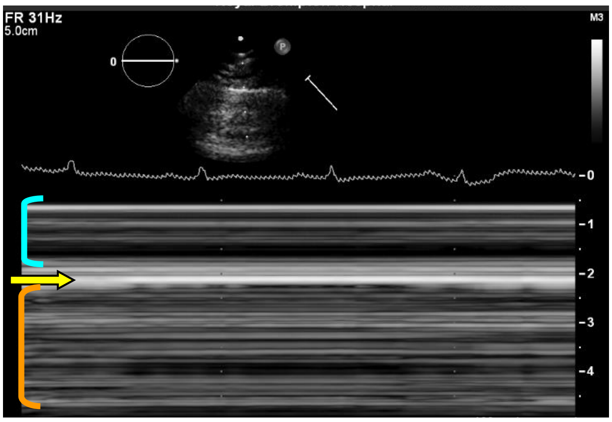


**Figure 6.5b M-mode of pneumothorax demonstrating the loss of granularity of lung**

The absence of lung sliding alone does not confirm PTX. Other conditions which may cause a motionless pleural line include pulmonary oedema, extensive atelectasis, bronchial intubation, pulmonary contusion, ARDS, and pleural adhesions.

**B-lines**
These are artefacts shaped like a comet tail, which propagate vertically from the pleural line (figure x yellow) and extends the full depth of the US sector (highlighted in green below).

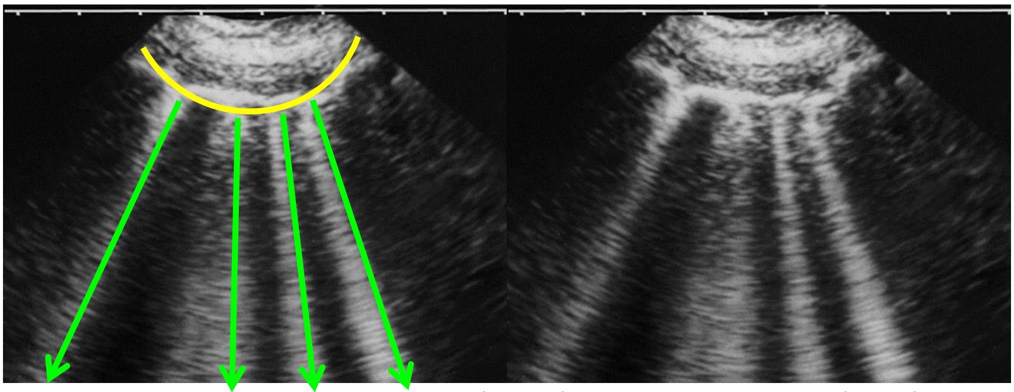
**Figure 6.6 Longitudinal view of pleural line (yellow) with associated B-lines (green), with corresponding 2D image on right.**

B lines have previously been disregarded as acoustic shadows, but are important in lung ultrasound. They are the result of multiple reflections of the US beam between two elements with different acoustic impedance; in this case, the alveolar air and the fluid of the intra-lobular septa.

B-lines obscure pleural sliding as they originate from the visceral pleura, and also obscure A lines. They move synchronously with respiration.

When present, they prove that the visceral pleura is opposing the parietal, thus excluding pneumothorax at the point of imaging (negative predictive value 100%). Their presence in excessive numbers indicates the presence of interstitial oedema.

**Lung point**
This is the position where lung sliding appears and disappears with respiration. It corresponds to the margins of a pneumothorax.
The lung point is detected by sliding the probe along the rib space, towards the lateral inferior chest area and finding the point where the normal US pattern (presence of lung sliding and/or B lines) is seen again.

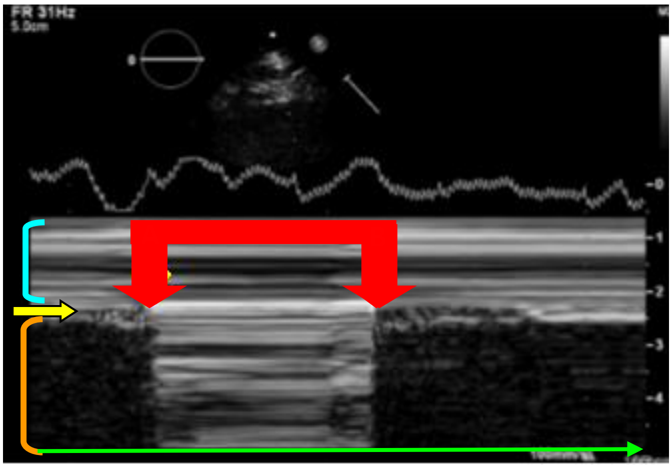
**Figure 6.7 M-mode demonstrating the lung point. Normal lung US is seen at the start of the image (on the left) with the chest wall (blue) pleural line (yellow) and lung tissue (orange). Time is shown along the x axis (arrowed in green). With respiration, the normal pattern disappears (point A, arrowed in red) and features of a pneumothorax are seen (stratosphere sign). At time point B, the features of normal lung return (seashore sign).**

Demonstration of the lung point confirms PTX with 100% specificity.
The sensitivity is low, as in cases of massive PTX with complete collapse of the lung, no lung point will be detected.

### Lung pulse

The lung pulse is a vertical movement of the pleural line synchronous with the cardiac rhythm. It is caused by the transmission of cardiac movement through normal lung during breath holding, and/or through consolidated lung.

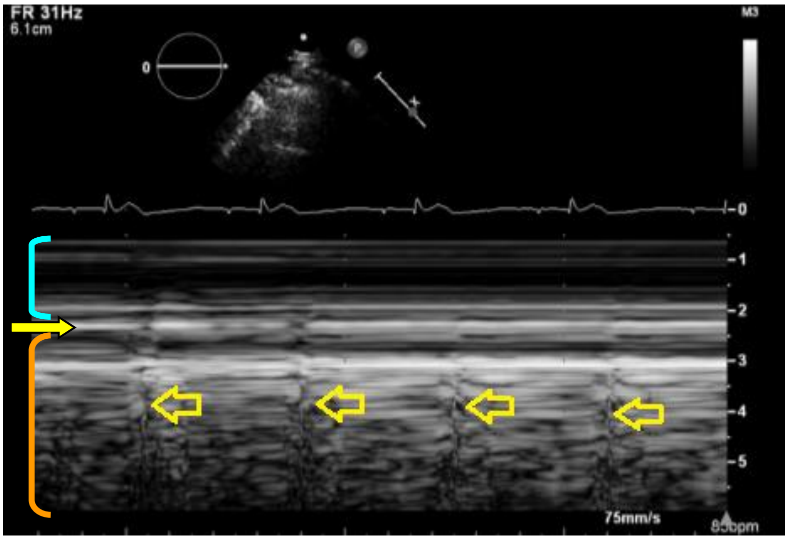


**Figure 6.8 M-mode of normal lung with breath holding. The lung pulse is seen as a small movement, synchronous with the heart beat (arrowed in red). This is differentiated from movement artefact (of the probe or patient) as the chest wall signal is featureless (highlighted in blue) as in the seashore sign**

Demonstration of the lung pulse rules out PTX because the inter-pleural air layer does not allow the transmission of cardiac pulsation.

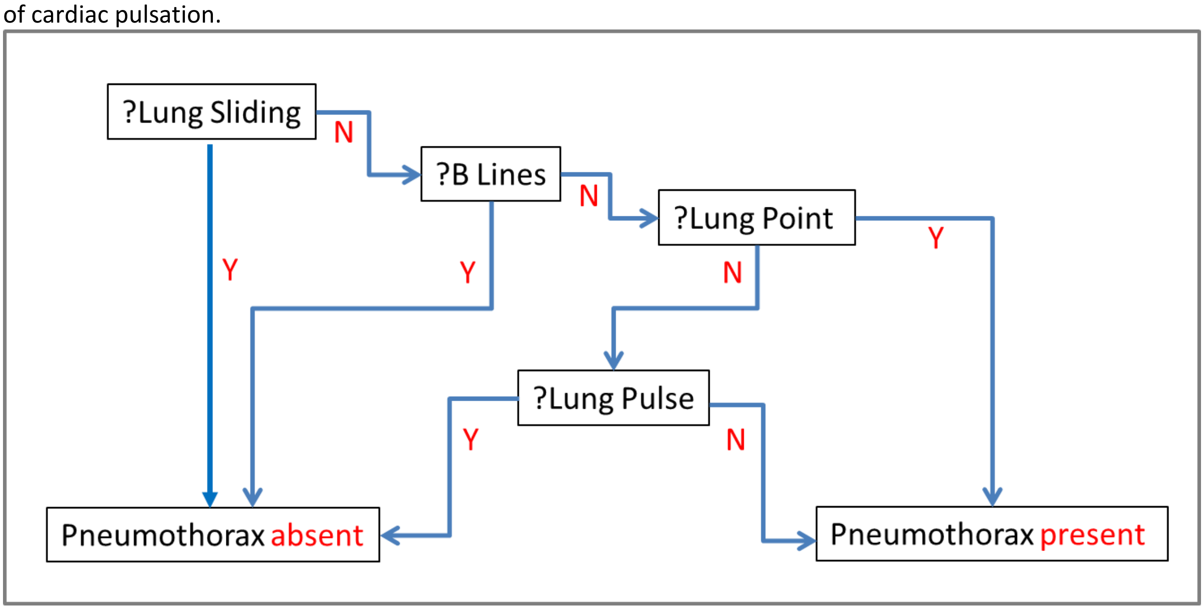


**Figure 6.9 Algorithm for pneumothorax using lung US**

## Pleural Effusion

The probe is initially positioned with the OM pointing cranially, positioned between two rib spaces. The first image should demonstrate the diaphragm and the organ immediately caudal (liver or spleen).

**Figure 6.10 Imaging right side to interrogate the pleural space for fluid collection. Imaging the left side requires a much more posterior position.**

The diagnosis of pleural collection is one of the easier US diagnoses and should include demonstration of a space (usually echo-free) between the parietal and visceral pleura, and movement of the lung within the collection.

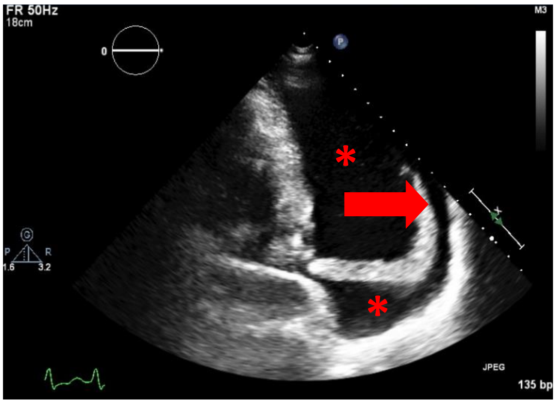


**Figure 6.11 US demonstrating a pleural effusion (red asterisks) which is echo-free (black). A portion of lung is seen floating within the effusion (red arrow).**

In the case of haemothorax or empyema the effusion may not be a single echo-free space but often appears as a loculated collection (Figure 6.12) or even a solid object (mimicking liver or spleen in its echogenicity).

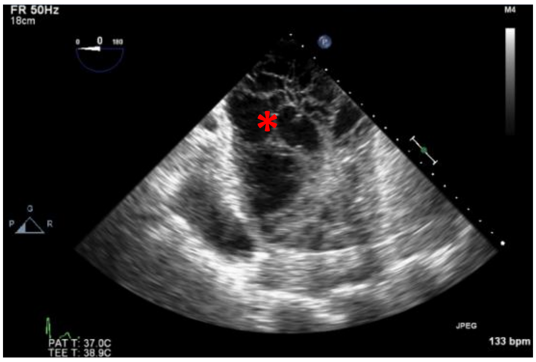


**Figure 6.12 A loculated pleural collection. (red asterisk).**

## Summary

Ultrasound can be used to diagnose/exclude pneumothorax with a high sensitivity and specificity. Where tension pneumothorax is suspected in a cardiac arrest setting, treatment should not be delayed by attempts to confirm the diagnosis using US.

Pleural collections (unless massive haemothorax or effusion) are unlikely to be the cause of cardiac arrest. Interrogation of the pleural spaces as an extension to clinical examination can be undertaken as part of assessment of critically ill patients.

# Pathology

Chapter 7

## Learning outcome

- To understand which of the potential causes of cardiac arrest and critical illness may be confirmed or excluded by the use of FEEL

In the shocked patient and during cardiac arrest, basic focused ultrasound can be used to rule in/rule out a number of different diagnoses. The FEEL course teaches candidates to distinguish these:

- Severe hypovolaemia
- Severe right heart dilatation +/- paradoxical septal motion (suggestive of massive pulmonary embolism)
- Pericardial effusion (which may cause tamponade)
- Severe myocardial dysfunction with or without evidence of ischaemia
- Pneumothorax
- Massive pleural effusion

Practitioners should remember that a FEEL scan is not a prerequisite to diagnosis and must not delay treatment if the clinical picture is suggestive. For example pneumothorax maybe diagnosed clinically in the presence of unilateral absence of breath sounds and high airway pressures.

The FEEL scan may be used to supplement ALS, and also in non-arrested critically ill patients. Where used as part of the ALS algorithm, FEEL is intended to be applied in the non-shockable pathway. Despite this, on occasion focused cardiac ultrasound may reveal an unexpected diagnosis that may require intervention in the shockable pathway.

## PEA = Pulseless Electrical Activity

In so-called 'true PEA' there is electrical activity that would be expected to produce a cardiac output, but no cardiac movement is seen on echocardiography. This carries a very poor prognosis and was previously termed electro-mechanical dissociation.

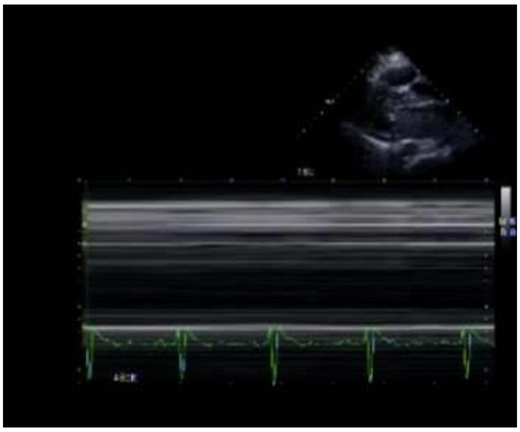

**Figure 7.1 M-mode across the LV cavity in a patient with cardiac arrest. Electrical activity can be seen (on the ECG) however, there is no movement of the LV walls. This is "true PEA" and carries a poor prognosis.**

In so-called 'pseudo PEA' there is electrical activity that would be expected to produce a cardiac output and co-ordinated cardiac activity that is seen by echocardiography to be generating some cardiac output that is not translated to a palpable central pulse.

Without echocardiography it is not possible to differentiate "true PEA" from "pseudo PEA". Pseudo PEA may be potentially reversible with prompt therapy. However, even if the initial pathology causing arrest is reversed, or especially if treatment is delayed, the outcome may still be poor.

## Severe hypovolaemia

Inadequate circulating volume is a common cause of PEA. Echocardiographic assessment of volume status is based on:

- Baseline findings (single-measure dimensions and flows)
- Dynamic indices used to determine volume responsiveness (VR)

VR is assessed by measuring variation in flows and dimensions after manoeuvres such as spontaneous or mechanical respiratory loading, passive leg-raising and/or fluid challenge.

### *Detection of severe hypovolaemia*

The following parameters have been suggested to indicate severe hypovolaemia in the critically ill. These should be assessed routinely when assessing for volume responsiveness using echocardiography:

- Small hyperkinetic LV (in the presence of a normal RV), with end-systolic cavity obliteration
  Caution is needed in patients with severe valve regurgitation, high dose inotropic support or marked left ventricular hypertrophy
- Left ventricular end-diastolic area < 5.5 $cm^2/m^2$ BSA

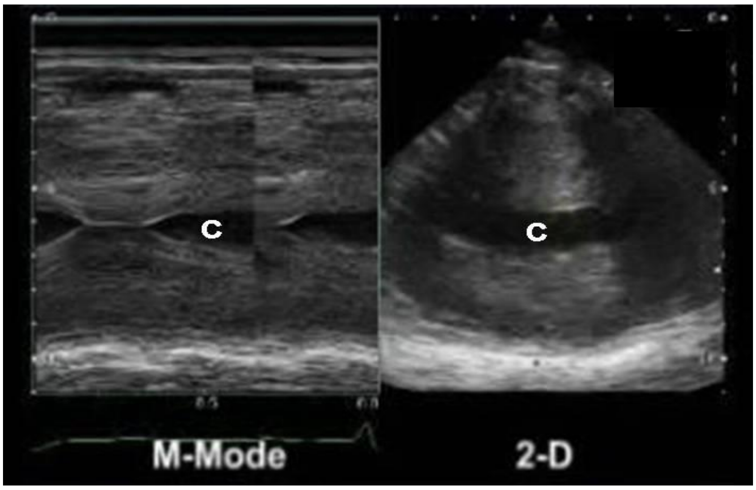


**Figure 7.2 M-mode and 2D echocardiography in a patient with severe hypovolaemia. On the left, at end-systole the ventricular walls come together, and a tiny LV cavity is seen (c). On the right a 2D short axis of the same LV is shown. The calculated left ventricular end diastolic area is < 5.5 $cm^2/m^2$ BSA .**

Additional features of hypovolaemia relate to the size of the IVC:

- Small IVC with inspiratory collapse in spontaneously breathing patients (<10mm)
- Small IVC at end-expiration with variable (depending on adaptation to ventilation) respiratory change, in patients receiving positive pressure ventilation

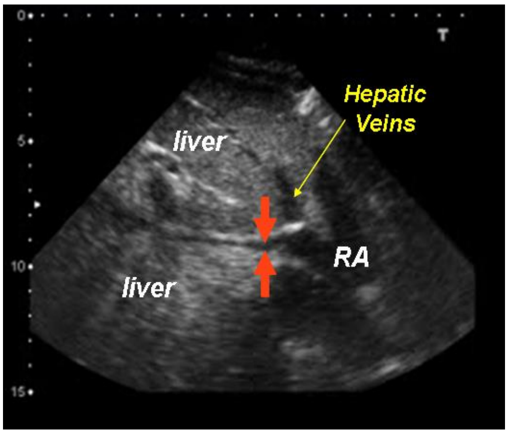


**Figure 7.3 2D echocardiogram (subcostal view) in a shocked patient. In this patient who is breathing spontaneously the IVC (arrowed) collapses on inspiration, suggesting severe hypovolaemia.**

In the critically ill the following considerations must be taken into account:

- Assessment of volume status requires measurement of multiple parameters
- LV and RV end-diastolic dimensions alone are unreliable predictors of volume status
- The effects of intermittent positive pressure ventilation (versus spontaneous ventilation) must be considered when looking at changes due to respiration
- Where a patient is not in sinus rhythm or is ventilated but has intermittent spontaneous respiratory activity, assessment of volume status may not be accurate.

### Screening for low tolerance to volume loading

The following features suggest that the patient will tolerate volume loading poorly and that this should be avoided:

- Severe right ventricular impairment (RVEDA/LVEDA > 1)
- Signs of systemic venous congestion (dilated fixed-diameter IVC and SVC) in the absence of tamponade
- High estimated LV filling pressures.*

### Heart-lung interactions

In fully mechanically ventilated patients in sinus rhythm, predictors of VR are:

- Superior vena cava collapsibility index > 36%
- Inferior vena cava distensibility index > 18%
- LV ejection variations: LVOT Vmax variation > 12%, LVOT VTI variation > 18%. *

Determination of volume responsiveness beyond these parameters (and including estimation of LV filling pressures* and LV ejection variation*) requires the use of Doppler echocardiography, and is therefore beyond the remit of basic echocardiography.

Importantly, raised pericardial and/or pleural pressures may lead to apparent "underfilling" of the ventricle(s) on echocardiography.

In a cardiac arrest, **severe hypovolaemia** is therefore suggested by a hyperkinetic LV, where the cavity is almost occluded with every contraction i.e. an almost-empty LV. It must be remembered that other causes for the ventricle to appear "empty" exist, including profound vasodilatation and severe mitral regurgitation. An important caveat to drawing the conclusion that the LV is "empty" from cavity occlusion in systole is the presence of severe left ventricular hypertrophy, where the LV walls may be seen to be "kissing" in systole in the absence of severe hypovolaemia.

## Pulmonary embolism

The only way to diagnose pulmonary embolism confidently with echocardiography is to demonstrate embolic material moving through the right heart into the pulmonary artery. This is not seen commonly on TTE.

In the case of cardiovascular collapse, pulmonary embolism is likely to be massive or fulminant, indicating that >50% of the pulmonary vascular bed has been obstructed. The immediate response of the RV to increased afterload is to dilate. Assessment of RV size and function are detailed in Chapter 5.

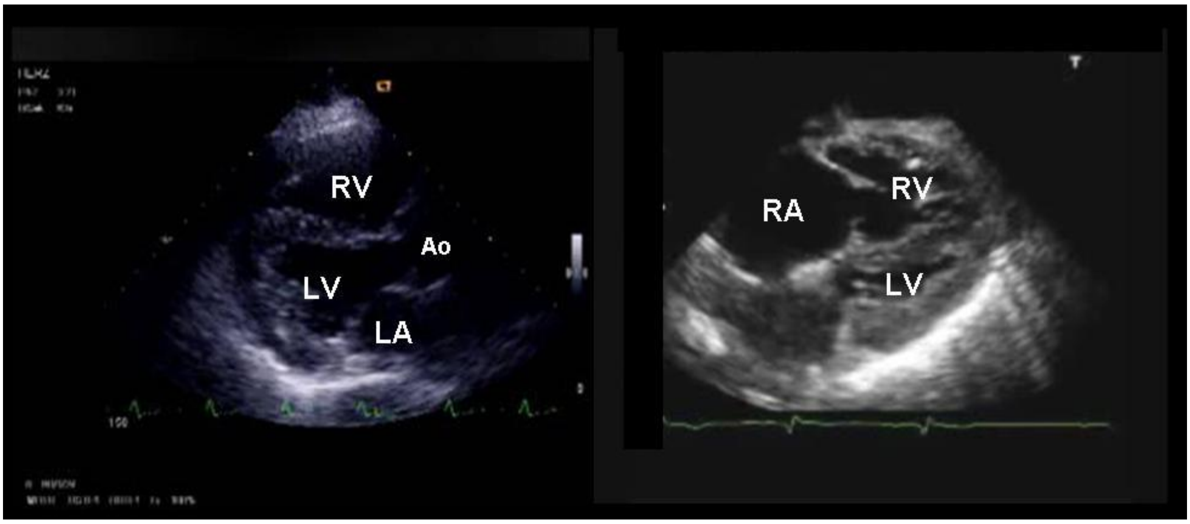


**Figure 7.4 Right heart dilatation in the presence of massive pulmonary embolism in a critically ill patient**
**To the left is a parasternal long axis view, showing the RV to be dilated (eyeballing, it can be compared with the size of the ascending aorta or left atrium in this view). To the right is a subcostal four-chamber view. The right heart is dilated, and the left ventricle appears small and squashed.**

Surrogate markers of RV dysfunction in the presence of pulmonary embolism include RV dilatation (end-diastolic dimension in PLAX view >30mm), interventricular septal flattening with paradoxical motion (i.e. the septum moves towards the RV in systole) , increased RV/LV ratio (>0.9) in the A4Ch view, and reduction in TAPSE. The absence of RV dilatation and impairment on echocardiography in a patient with shock or hypotension virtually rules out acute pulmonary embolism as a cause of the haemodynamic instability.

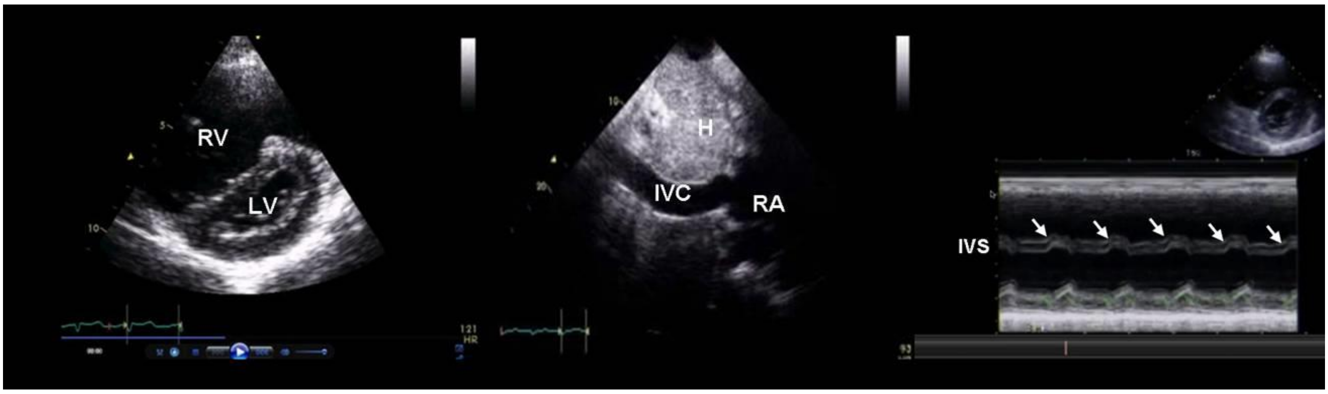


**Figure 7.5 Additional echocardiographic features suggestive of right heart pressure overload secondary to pulmonary embolism. On the left is a PLAX view showing a dilated right ventricle, and a small, D-shaped LV with a flattened interventricular septum. The central image is a subcostal view of the IVC, which is dilated. On the right is an M-mode of the interventricular septum, showing it to move towards the RV during systole: paradoxical septal motion.**

Other features demand more sophisticated echocardiographic modalities and are not required for focused studies in the context of shock or cardiac arrest.

Thus, certain echocardiographic features do suggest that pulmonary embolism may have occurred. These include the combination of:

- A dilated right heart
- Paradoxical septal motion (M-mode)
- D-shaped LV cavity (in short axis view)
- A dilated IVC

It is important to note that these features are not specific to pulmonary embolism. Similar echocardiographic features can be seen in chronic right ventricular disease, chronic pulmonary hypertension, large atrial septal defect and severe tricuspid regurgitation. As with every use of focused echocardiography, it must be applied in the clinical and historical context of the patient (when these are available).

## Pericardial collection & tamponade

There are a number of causes of pericardial collection, including pericardial effusion and haemopericardium. The more common causes seen in the critically ill include:

- **Acute pericarditis (idiopathic, infective or due to other inflammatory processes)**
- **Acute MI** (due to haemorrhage, acute pericarditis or Dressler's syndrome)
- **Neoplasia** (primary and secondary)
- **Trauma**
- **Aortic dissection**
- **Cardiac surgery** (due to haemorrhage or post-pericardiotomy syndrome)
- **Interventional cardiology procedures** (including catheterisation, percutaneous coronary interventions, device implantation, electrophysiology studies, ablation and myocardial biopsy)

The pericardium is formed of two layers, between which exists a small volume of pericardial fluid whose purpose is primarily to allow easy movement of the heart with each beat. The normal volume of pericardial fluid is 5-15ml, with normal pericardial pressures of 5-15mmHg. The pericardium is attached superiorly to the great vessels and inferiorly to the diaphragm. The pericardial reflection at the posterior AV groove means the pericardial space extends only rarely behind the LA.

The first step in the diagnosis of tamponade is to demonstrate an abnormal collection in the pericardial space. This normally relies on the demonstration of a black, echo-free space between the two layers of pericardium.


**Figure 7.6 Pleural and pericardial collections. To the left is a 2D echocardiogram (parasternal long axis view) from a patient with both pericardial (Pc) and pleural (Pl) collections. The two layers of the pericardium are clearly seen as bright white lines (arrowed) with a black, echo-free space between. To the right is a 2D echocardiogram (parasternal long axis view) from a patient with a large pleural effusion. There is a small amount of fluid in the pericardial space (white arrow). A pleural effusion can be differentiated from pericardial by virtue of its anatomical relationship to the descending aorta (black arrow). A pericardial effusion will not be seen posterior to the descending aorta.**
**Pc; pericardial collection, Pl; pleural collection, DA; descending aorta.**

Tamponade is defined as elevated clinical-haemodynamic syndrome of cardiac compression caused by pericardial effusion with increased intra-pericardial pressure, irrespective of the volume of the collection. Pericardial collection resulting in clinical tamponade depends on the rate of accumulation of fluid, as well as the amount of fluid, as tamponade is due to a sufficient increase in intra-pericardial pressure to compromise cardiac filling. Thus even a small amount of fluid accumulating over a few hours may result in significant clinical deterioration. Conversely, a large collection that accumulates over weeks or months may not have major haemodynamic effects. The differential haemodynamic effects seen as a result of rate of accumulation are due to the ability of the pericardium to adapt and stretch when the collection occurs only slowly. This allows accumulation of a large amount of pericardial fluid with only a small associated rise in intrapericardial pressure – until the capacity of the pericardium to stretch is exceeded.

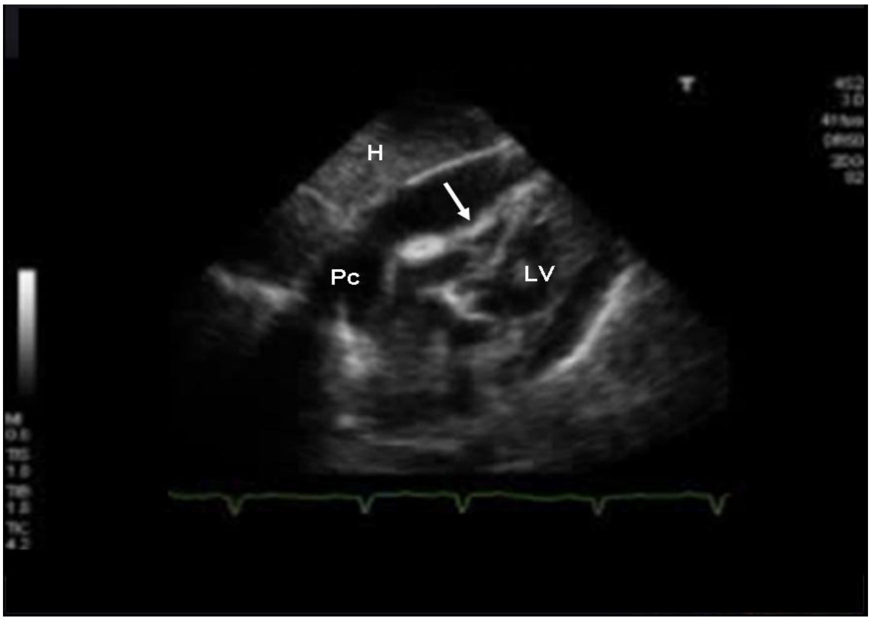


**Figure 7.7 A significant pericardial collection in a hypotensive patient (subcostal view). The right ventricle is almost unidentifiable as it is compressed by the collection (arrowed).**
**H; liver, Pc; pericardial collection**

The classical clinical features of tamponade are described classically in Beck's triad

- Increasing CVP / JVP
- Muffled heart sounds
- "Pulsus paradoxus" (Arterial paradox)

These are notably usually absent or difficult to ascertain in the arrest situation. In a peri-arrest setting the more usual clinical features relate to the associated low-cardiac-output state

- Tachycardia
- Hypotension despite filling
- Low urine output
- Increasing base deficit

However these features are not specific, whereas basic echocardiography can allow rapid confirmation or exclusion of a large pericardial collection.

Echocardiographic features of tamponade include:

- RA diastolic collapse
- RV cavity compression/diastolic collapse
- Swinging heart within a fluid-filled pericardial sac
- Dilated, non-pulsatile IVC
- MV pseudo-prolapse, pseudo-SAM and delay in opening

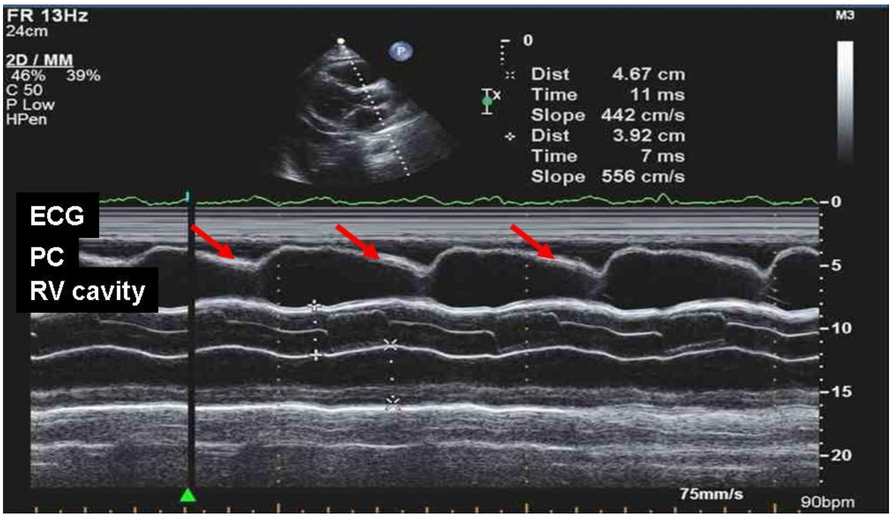


**Figure 7.8 M-mode in a patient with hypotension and a small pericardial collection (seen in the miniaturised 2D image at the top of the image). In diastole the free wall of the RV moves inwards (arrowed in red), indicating that the pericardial pressure at this time in the cardiac cycle is exceeding that of the RV, and therefore impeding RV filling. ECG; electrocardiogram, PC; pericardium, RV cavity; right ventricular cavity.**

Other echocardiographic features of tamponade depend upon more advanced modalities, and are not required in the peri-arrest setting. These include features and measures of the variation in cardiac flows with respiration, including:

- Right heart flows increase more than normal during inspiration
- Left heart flows decrease during inspiration
- Reciprocal variation in size of ventricles
- Arterial paradox

## LV impairment

Assessment of LV function is described in Chapter 4. Severe LV impairment may be acute or chronic, and occur as a result of the cardiac arrest as well as being a cause for cardiac arrest. Some of the commoner causes include:

- Coronary heart disease
- Dilated cardiomyopathy
- Myocarditis (infective/ toxic / radiotherapy/ autoimmune)
- Arterial hypertension
- Tachycardia-induced cardiomyopathy
- Post-partum cardiomyopathy

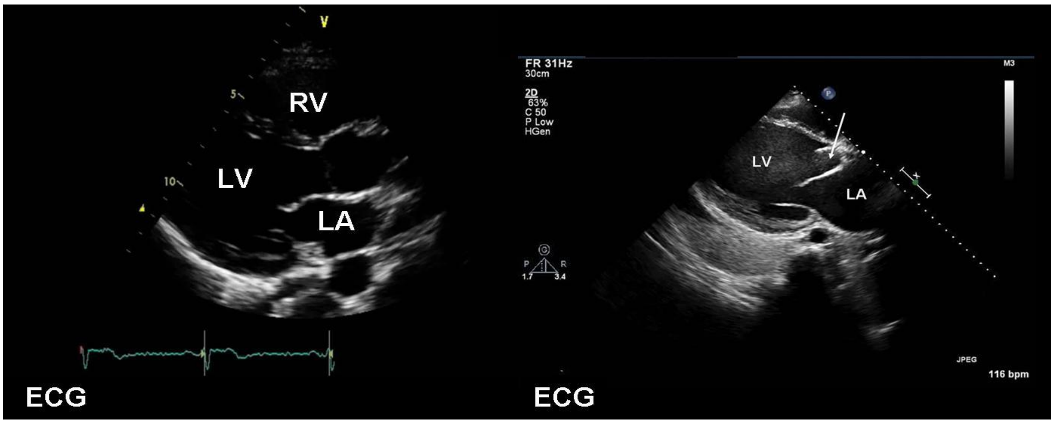


**Figure 7.9 LV dilatation, PLAX views. On the left a normal ventricle is seen (depth marker showing the posterior pericardium at approximately 12cm. On the right is a patient with severe LV dilatation. Here, the depth is set to 28cm, and the posterior pericardium is at 18cm.**

Unlike the RV, the LV does not dilate immediately in response to damage or to pressure or volume overload. Where significant LV dilatation is seen, the cause is likely to be at least partly chronic, with possibly an additional reason for the patient's acute deterioration.

When striking regional wall motion abnormalities are seen, coronary artery disease should be suspected. If seen, associated abnormalities (such as intracardiac thrombus) may be noted.


**Figure 7.10 Apical 4-chamber view in a patient with a normal heart (left) and a patient with myocardial infarction (right). Note the dilated, globular shaped LV. At the apex (which was akinetic) there was seen a round, independently mobile mass, consistent with thrombus (Th, arrowed).**

## Pneumothorax and pleural collection

Assessment of pneumothorax and pleural collections are described in Chapter 6.

## Ventricular Fibrillation

Although echocardiography is not recommended for the diagnosis of ventricular fibrillation (this is an ECG diagnosis), on occasion the heart may be seen to be fibrillating in any of the views obtained. If demonstrated, the decision whether or not to defibrillate should be made by the team leader. There is no evidence yet to indicate whether or not defibrillation is effective and appropriate when apparent VF is seen on echocardiography unexpectedly when it was not obvious on ECG.

## Summary

In the shocked patient and during cardiac arrest, basic focused ultrasound can be used to rule in/rule out a number of different diagnoses. The pathology leading to such profound haemodynamic compromise is likely to be severe, and can be recognised using basic focused echo. Several pitfalls do exist, however and these are discussed in Chapter 9.

# ALS compliance

Chapter 8

## Learning outcomes

- To be able to describe the place of FEEL in the "non-shockable" limb of the ALS algorithm
- To be able to describe the place of FEEL in the "shockable" limb of the ALS algorithm
- To understand the importance of teamwork and effective communication (using appropriate communication tools) during resuscitation, including the use of FEEL

Focused TTE is ideally suited for the shocked patient or when a patient has suffered a cardiac arrest. Here echocardiographic examination may help to identify reversible causes of cardiac arrest (hypovolaemia, tamponade, pulmonary embolism and severe LV dysfunction) or recognise a ventricle is fibrillating rather than still. In view of clear evidence that minimising interruptions to chest compressions during resuscitation increases the likelihood of a successful outcome, it is essential that focused TTE in this situation is performed swiftly and competently.

**FEEL examinations must be performed without interrupting the ALS protocol**

In reality, even within a well-equipped and adequately staffed clinical department, medical assessment and treatment take time to deliver. In the presence of cardiorespiratory arrest the first priority is always to commence CPR, following current national and international guidelines and using the ABCDE approach to assessment and treatment. The FEEL examination is performed as part of the "non-shockable" limb of the algorithm, during the brief interruptions to CPR for assessment of rhythm.

The team leader should identify one competent person (sonographer) and delegate to them the responsibility for preparation and FEEL scanning so it does not adversely impact upon performance of high-quality CPR. If the team leader is the most experienced scanner, he/she should delegate team leadership appropriately to another member of the resuscitation team prior to taking over responsibility for preparation and FEEL scanning.

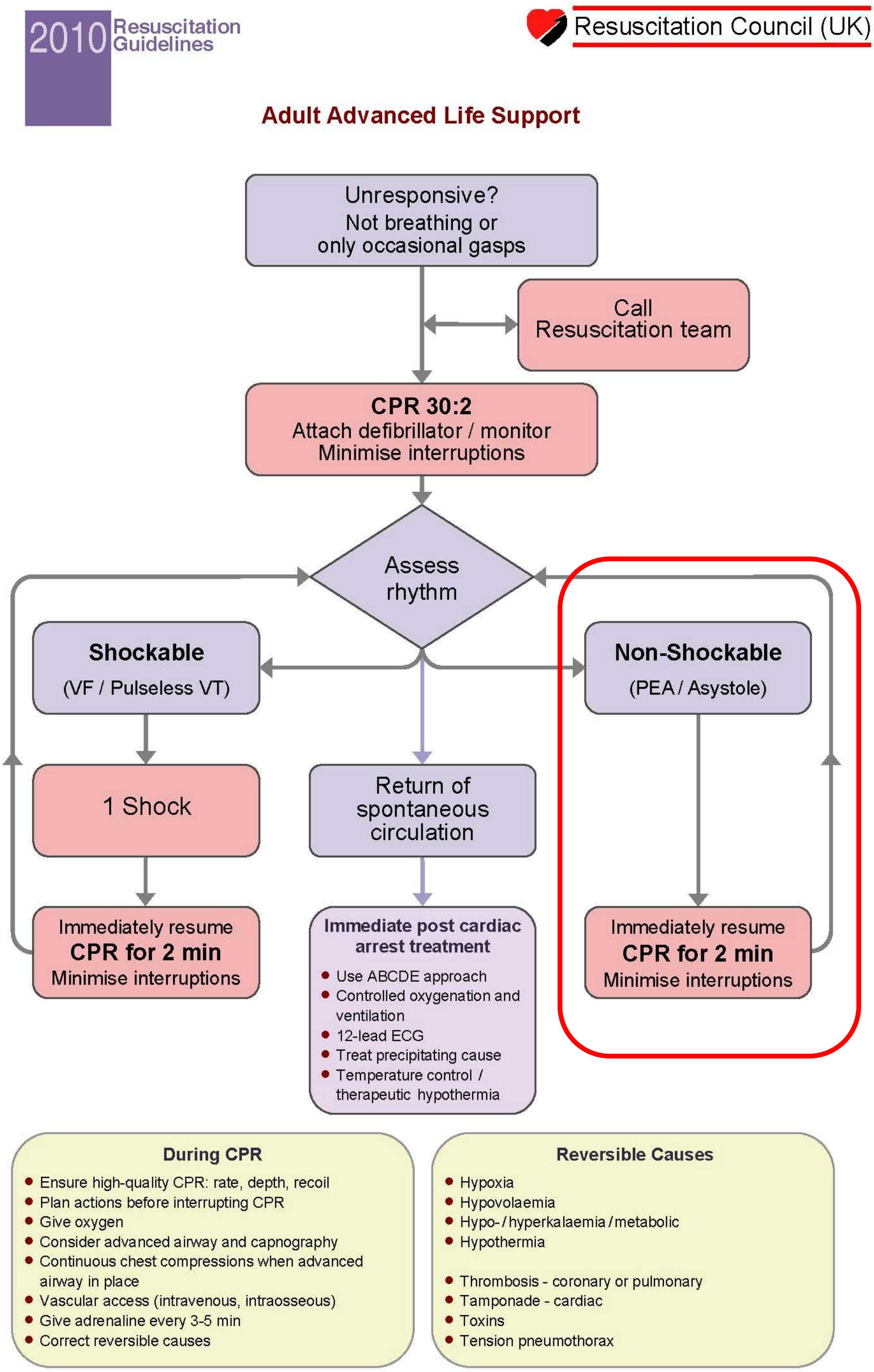


**Fig 8.1 Adult ALS algorithm – focused echocardiography may be considered in the assessment of a non-shockable rhythm. It is not suggested as part of the "shockable" limb of the algorithm.**

**Echocardiography must never detract from delivery of effective on-going CPR**

Once CPR has been established, in the presence of adequate personnel and equipment, FEEL scanning may be considered. Should the only person trained to perform a FEEL scan already be performing part of the resuscitation effort, their role must be allocated to someone else to allow them to perform the scan.

When ready the sonographer should warn the team of the intention to scan during the next brief interruption to CPR for rhythm/output assessment.

As a member of the team counts out loud the 10 seconds of the rhythm/output assessment, during this 10-sec period the sonographer should perform a subcostal TTE and acquire and record the best possible picture.

Whatever the image obtained – at the end of the 10 sec countdown CPR ***must*** be restarted. It is the responsibility of the entire team to ensure that effective CPR is re-started without delay after the 10 sec pause.

While CPR is continued the recorded TTE images may be reviewed.

The steps to performing an integrated scan are shown in Table 8.1

**Table 8.1.** Focused Echocardiographic Evaluation in Resuscitation (FEEL) management examination in ten steps

| Phase | |
|---|---|
| High quality CPR, preparation, team information | 1. Perform immediate and high-quality CPR according to RC(UK)/ERC/ILCOR guidelines<br>2. Tell the CPR team: "I am preparing an echocardiogram" under direction of the team leader<br>3. Prepare portable ultrasound I machine: check it is working and ready to record<br>4. Prepare the patient and the team (e.g. plan best position of patient and echocardiographer, expose patient's chest if not already done), be ready to start<br>5. Inform the rest of the team: "In the next rhythm check I am ready to perform echocardiography" |
| Obtaining the echocardiogram | 6. Ask another member of the resuscitation team to count down 10 sec and to reassess rhythm simultaneously during the FEEL examination<br>7. Place the probe gently on to the patient's sub-xiphoid region during chest compressions<br>8. As soon as chest compressions are interrupted for rhythm assessment perform a subcostal (long axis) echocardiogram as quickly as possible. If you cannot identify the heart after 3 sec, stop the interruption and repeat again after 2 minutes and/or with the parasternal approach. |
| Resuming CPR | 9. Tell the team after 9 sec at the latest: "Restart CPR" |
| Interpretation and consequences | 10. Communicate (after re-starting chest compressions) the findings to the resuscitation team leader (e.g. presence of cardiac contraction, details of wall motion if present, VF, cardiac standstill, (massive) pericardial effusion, suspected pulmonary artery embolism, hypovolaemia, no conclusive finding). *Explain* the significance of the findings and any resulting recommended intervention. As with ALS, it is recommended that the SBAR or RSVP communication tool is used (see chapter 9) |

If adequate images have been obtained then the team should consider the following questions:

1. Is the myocardium moving?
   - Ventricles are contracting in a co-ordinated manner = PEA → consider potential causes
   - No myocardial movement = Asystole → consider potential causes
   - Myocardium is fibrillating (with ECG showing apparent asystole) = fine VF → consider defibrillation
2. Is there a reversible / treatable pathological process?
   - Severely under-filled ventricles = ?hypovolaemia → try volume loading

- Severely dilated right heart = ?massive pulmonary embolism → consider fibrinolytic therapy
- Pericardial collection = ?pericardial tamponade→ consider pericardiocentesis
- Severe LV impairment = ?regional/global → consider inotropic support/emergency revascularisaion/mechanical circulatory support

Reporting the findings to the team leader should be performed in a clear, binary fashion, answering each of the questions above. The FEEL report sheet can be used as an aide-mémoire. If the images are inadequate, the team may consider re-scanning during the next rhythm assessment, either by repeating a subcostal view or attempting another view, depending on the clinical circumstances.

**Good teamwork is vital to success in achieving useful ultrasound images without compromising the effectiveness of CPR**

# Pitfalls

Chapter 9

## Learning outcomes

- To recognise the potential pitfalls in using focused echocardiography
- To be able to recognise common potential sources of misdiagnosis using FEEL

The use of medical ultrasound has developed over many years to provide detailed information about the anatomy and physiology of the heart. In some circumstances demonstration of myocardial perfusion may even be possible. However a comprehensive echocardiographic examination requires time and significant expertise. Although echocardiography has remained the remit of cardiologists and cardiac physiologists, there is increasing support for its use by practitioners caring for the critically ill. This includes pre-hospital, emergency department, acute medicine and intensive care scenarios. Here the evidence suggests that appropriately trained practitioners can use focused echocardiography as an extension to the clinical examination to exclude or diagnose some of the potential causes of shock and/or cardiac arrest.

Despite this, it is important to remember that using as complex a skill as echocardiography in a focused manner does not equate with “easy” or “substandard” echocardiography. There are many potential pitfalls to its use – including the following areas:

- Ability to acquire images
- Ability to interpret images including artefacts
- Interpretation of images in the clinical context
- Appreciation of the diagnostic limits imposed by performing only a focused study
- Appreciation of the limits of one’s own knowledge
- Ability to communicate findings effectively

Further, the patients being imaged are often on complex cardiopulmonary support, which significantly changes cardiac physiology and echocardiographic findings. Even seemingly simple questions such as:

- “does this patient have tamponade?”
- “what is the ventricular function like?”
- “is there evidence of pulmonary embolism?”
- “is this patient adequately filled?”

can sometimes be difficult in the most experienced hands when assessing the critically ill or collapsed patient.

Knowledge is required not only of anatomy and physiology, but also of the echocardiographic features of the more common pathologies found in cardiac arrest and the peri-arrest setting, and the effects that resuscitative measures can have on these findings. Indeed, many of the published normal values and findings have not been described in this patient population.

## Pitfalls in the diagnosis of tamponade

Tamponade represents a significant adverse change in cardiac physiology secondary to an increase in intrapericardial pressure – and is usually diagnosed on the basis of clinical suspicion. Echocardiography can be used to confirm the diagnosis (as described in Chapter 7). However in some patients the diagnosis can be difficult. First, in demonstration of a collection in the pericardial space, the considerations include:

- Is the collection in the pericardium or elsewhere?
    - Pleural or pericardial?

        - Intramural or pericardial?
    - Is it a collection, or an artefact?
    - Is it a normal anatomical variant (e.g. large coronary sinus)
    - Where the collection is small, it may still cause tamponade (due to rapid accumulation)

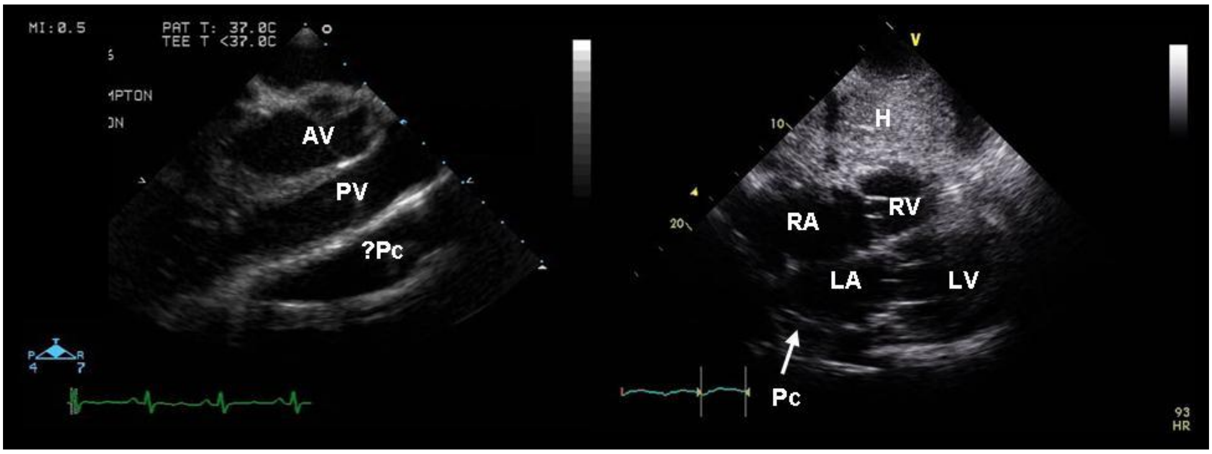


**Figure 9.1 Some pitfalls in the diagnosis of pericardial collection and tamponade. In the figure on the left (taken from a trans-oesophageal echocardiogram-TOE) there is clearly an echo-free space between what appear to be two layers of pericardium, suggesting a pericardial collection (?Pc). This is, however an artefact, due to the very bright pericardium next to the very black blood. In the image on the right (subcostal view) there is a small pericardial collection (Pc, arrowed), unusually positioned posterior to the left atrium (LA). Although small, this was causing profound haemodynamic compromise, as it had accumulated rapidly following a percutaneous coronary intervention.**

Second, having demonstrated the presence of a collection, echocardiographers are trained to look for additional features that suggest the collection is haemodynamically significant (i.e. causing tamponade). These include:

| **Occurring in all parts of the respiratory cycle** | **Varying with respiration** |
|---|---|
| RA diastolic collapse | Reciprocal variation in size of ventricles |
| RV cavity compression/diastolic collapse | Right heart flows increase on inspiration |
| Swinging heart | Left heart flows decrease on inspiration |
| Enlarged, non-pulsatile IVC | Arterial paradox |
| MV pseudo-prolapse, pseudo-SAM and opening delay | |

It is important to understand the pathophysiological basis of these changes before one can interpret the echocardiogram correctly. It is also important to understand the effects any intervention on these patients may have on the features – for example reversal of the changes in right and left heart flows with ventilation. Further, although presence of one or more of these features in a patient with haemodynamic instability and a pericardial collection confirms the diagnosis of tamponade, the absence of any one or more (or all) of these features does NOT mean the patient does not have tamponade. This particularly applies following cardiac surgery, where up to 50% of collections in patients with tamponade can be missed by TTE, and the majority of cases early following surgery have no echocardiographic features of tamponade, despite profound haemodynamic compromise.
An example is shown in Figure 9.2.

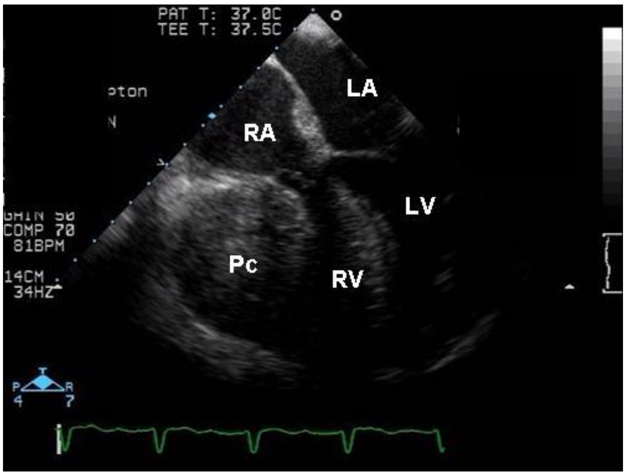


**Figure 9.2 Trans-oesophageal echocardiogram (4-chamber view) in a patient with circulatory collapse 48 hours following cardiac surgery. TTE was negative, with no collection seen, and no echocardiographic features of tamponade documented. Here a large collection (Pc) can be seen compressing the right ventricle which is slit-like.**

## Pitfalls in the diagnosis of ventricular function

Assessment of ventricular function is complex. The mechanism of LV function in systole and diastole is complex, with differing orientation of fibres in different muscle layers. Contractility has a number of components; minor and long axis contraction, rotation and differential basal and apical LV rotational vectors.

In measuring or estimating fractional shortening or ejection fraction, thickening of the myocardium is not assessed, but rather the change in internal dimensions of the LV as a substitute for a measure of contractility. Further, normal values of fractional shortening and ejection fraction are not known for the critically ill patient population, and values remain highly variable depending upon critical care/resuscitation interventions, as well as the inherent contractility of the myocardium. Thus, a ventricle that is severely impaired may have a normal ejection fraction measured after institution of positive inotropic agents – but the ventricle remains inherently severely impaired.
Common errors in estimation of LV function include failure to take into account:

- Level of inotropic support (artificially increases contractility)
- Mechanical circulatory support (offloads the ventricle, therefore improves appearance of contractility)
- Volume status (profound hypovolaemia improves the appearance of contractility)
- Ventricular hypertrophy (may look as if contractility is good, but other axes of contraction may be severely impaired. LV hypertrophy may be associated with important diastolic impairment, leading to an impaired ability to tolerate tachycardia (especially arrhythmia where there is associated loss of atrial transport), fluid depletion of volume overload)
- The presence of severe mitral or aortic regurgitation (makes the LV look dynamic, even in the presence of myocardial impairment, due to volume overload)

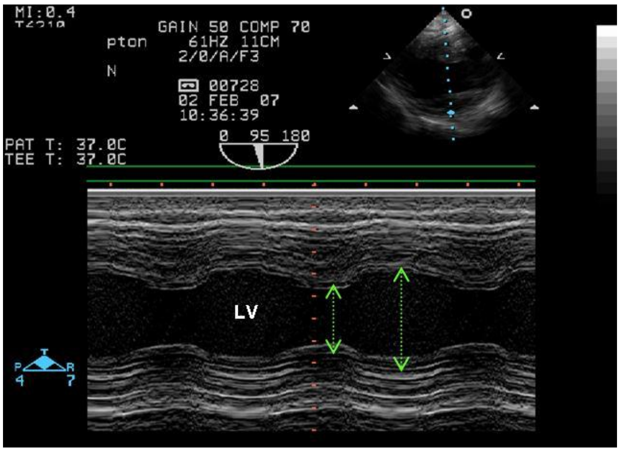


**Figure 9.3 M-mode echocardiogram in a patient with severe LV impairment receiving 4 inotropic agents, and with left and right ventricular assist devices and an intra-aortic balloon pump in situ. The arrows indicate systolic and diastolic measurements for estimation of ejection fraction or fractional shortening. The LV function does not look severely compromised when the echocardiogram is regarded in isolation. Reduction in any of the mechanical circulatory support resulted in profound hypotension, worsening of M-mode parameters and VF.**

RV function is more challenging to assess than LV function. The gold standard for assessment of RV contractility is cardiac magnetic resonance scanning, and even with this technique, assessment remains challenging. It is exquisitely sensitive to increases in afterload, and reduction in coronary perfusion, and will fail due to either of these factors or both.

## Pitfalls in the diagnosis of pulmonary embolism

The gold standard for diagnosis of PE is CT pulmonary angiography, due to its speed of scanning, widespread availability and high sensitivity and specificity (>90%), with some studies report a false negative rate of 5%. In the majority of cases, echocardiography provides only indirect signs of PE (predominantly consisting of signs of RV pressure overload, Chapter 7). Even with the application of more advanced echo methods (including Doppler echocardiography) and exclusion of patients with prior cardio-respiratory diseases, the sensitivity and specificity are only 93% and 81% respectively. Further, although the echocardiographic features of PE tend to be seen where the embolus causes a major rise in pulmonary vascular resistance due to the size of the PE, it is possible that a relatively small PE may result in pulmonary artery vasoconstriction. The biggest pitfall however, is failure to recognise the presence of pre-existing disease.

An example of how echocardiography can mislead is shown in Figure 9.4, taken from a patient with haemodynamic collapse after a prolonged hospital stay.

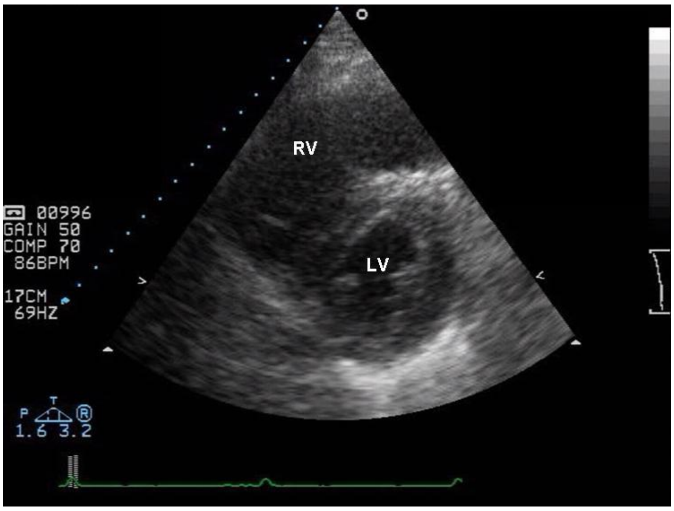


**Figure 9.4 Short-axis view of the left and right ventricles in a patient following resuscitation after a cardiac arrest. The RV is dilated, the septum flattened and the LV is D-shaped. The patient did not have a pulmonary**

**embolism as a cause of his cardiac arrest, and the echocardiographic features were due to chronic obstructive pulmonary disease with associated pulmonary hypertension.**

The place of echocardiography in the diagnosis of pulmonary embolism is not definitely established outside national and international recommendations except that in an acutely unstable patient echocardiography may be helpful. The echocardiographic findings in such patients must always be interpreted in the clinical context, and the sonographers must be aware that pre-existing cardiac and/or pulmonary disease reduce the usefulness of echocardiography in suspected PE.

## Pitfalls in the diagnosis of filling status

The literature regarding assessment of the filling status of patients is extensive, and includes simple static and dynamic parameters (Chapter 7). In the critically ill the following considerations must be taken into account:

- Assessment of volume status requires measurement of multiple parameters
- LV and RV end-diastolic dimensions alone are unreliable predictors of volume status, particularly in the presence of cardiac and/or pulmonary disease
- The effects of intermittent positive pressure ventilation (versus spontaneous ventilation) must be considered when looking at changes due to respiration
- Where a patient is not in sinus rhythm or is ventilated but has intermittent spontaneous respiratory activity, assessment of volume status may not be accurate

In a patient with cardiac arrest, where severe hypovolaemia is suspected as a cause, advanced assessment of tolerance to volume loading is probably irrelevant, and Doppler parameters are likely to be uninterpretable.

The situation in a critically ill (non-arrested) patient is much more complex. Echocardiography can be used to estimate left atrial pressure, however, the literature is generally based upon out-patient or TOE evaluation and all use a number of advanced echocardiographic techniques. Basic echocardiographic parameters of potential volume responsiveness are invalid in many critically ill patients as they depend upon the patient breathing spontaneously (or being fully ventilated with no spontaneous respiratory effort), the absence of cardiac disease or arrhythmia and of pulmonary disease , and do not predict the potential harm caused by inappropriate volume loading. Situations that merit particular consideration include:

- LV under-filling due to RV failure (over-filling may worsen RV dilatation and failure)
- Severe LV impairment Severe MR (where the LV may appear underfilled and dynamic even with high filling pressures)
- Severe LVH (where the LV may appear underfilled with kissing walls, even with high filling pressures)
- Right heart impairment (where the IVC may be fixed and dilated despite underfilling)
- Extreme protective ventilatory strategies (i.e. veno-venous extracorporeal membrane oxygenation or NovaLung) where there may be a false negative evaluation of changes in SVC/IVC dimensions in response to ventilation due to the low volumes and pressures applied
- Extreme spontaneous respiratory efforts (e.g. asthma or chronic obstructive pulmonary disease) which may result in a false positive evaluation of changes in SVC/IVC dimensions in response to ventilation due to the high generated negative thoracic pressures

In such situations, advanced echocardiography by an expert is warranted.

## Summary

An explanation of the potential pitfalls, and of all the potential uses of echocardiography in the critically ill is beyond the scope of this manual, but an outline will be given during the course. An echocardiogram is a diagnostic test on which treatment decisions may be based. Practitioners must only perform within their competence. Attendance at a course is the first step, which must be followed by on-going mentored training if practice is to be maintained at a safe level for patients.

# Certification and Training

Chapter 10

## Learning outcomes

- To understand the different levels of certification and accreditation recognised in echocardiography practice
- To know the requirements for FEEL certification

This course is an introduction to focused echocardiography in the shocked or cardiac arrest setting, including ALS-compliance when appropriate and required. Like any skill, ongoing practice and training is necessary to achieve and maintain competence. It is the most basic level of echocardiography certification. The next level which is recognised by the BSE is full accreditation. Full accreditation is the level required to be an independent practitioner in echocardiography, and demands a high level of training and expertise.

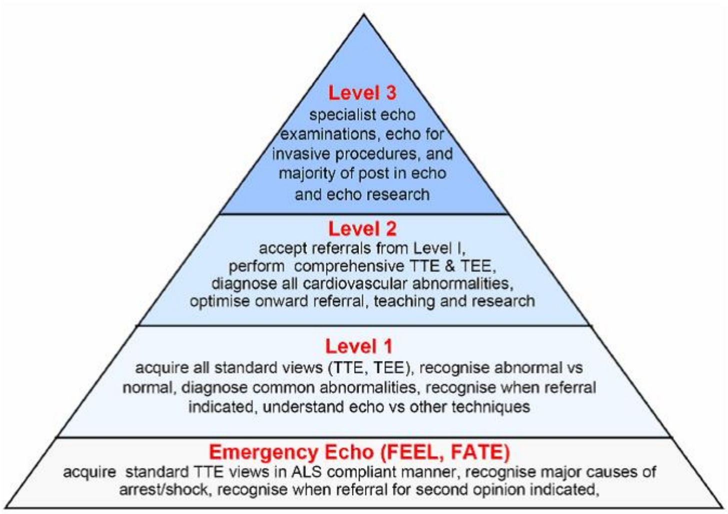


**Fig 7.1 Proposed Levels of competence in echocardiography in ICU. 4 levels of competence have been proposed for echocardiographic examinations performed in the setting of an ICU. Note that Emergency Echo represents an "entry" level; a first, very basic step in echocardiographic competence. It does not even equate to Level 1 competence.**

## FEEL certification

Having completed this course you should be able to return to work and feel confident that you have undertaken the first step in training in order to perform a focused peri-resuscitation echocardiogram, and acquire all the necessary views. However, you are not fully trained, and interpretation and practical skills improve with more scanning and review of images obtained with an experienced practitioner.

You will now need a local mentor – who may be a cardiologist or a cardiac physiologist (echocardiographer) or another colleague accredited in echocardiography who is willing to support your on-going training.
Most echocardiography machines have facilities to record images. Any scans should be recorded appropriately and findings, even if negative, should be communicated to the treating team and documented in the patient's health record.

You must keep a logbook of scans that you have performed along with your findings; a sample report sheet is shown in the appendix. Your initial scans should all be reviewed by your mentor. Once 50 scans have been completed and reviewed, if you are judged as competent in peri-resuscitation echocardiography, your mentor can sign your logbook to confirm that you have completed FEEL certification. You must then contact the course director from your course and send them the original front sheet from your completed logbook. The course director will then contact the Resuscitation Council (UK) and inform them that you have completed the minimum number of scans required and your certificate of completion of FEEL will then follow.

## On-going training and practice

FEEL certification is only the entry-level competency for echocardiography. This is the most basic level of scanning for minimally trained operators. Further courses are available to teach other skills, such as valve assessment, Doppler studies, etc. If you wish to pursue your training further then full accreditation via the BSE (or equivalent national/international society) may be sought. This will involve on-going training and a much more detailed logbook.

BSE accreditation will not be necessary for all, especially if your remit is only to scan in the peri-resuscitation situation, in which case it will be necessary to maintain a logbook and perform a minimum number of 25 scans per year in order to maintain your skills.

As with all medical practice, on-going practice and training in echocardiography should not be performed isolation, but within existing clinical governance structures and with close collaboration with the relevant experienced and accredited practitioners.

# Human factors and quality in resuscitation

Chapter 11

## Learning outcomes

- To understand the role of human factors in resuscitation
- To know how to use structured communication tools such as SBAR and RSVP
- To recognise the role of safety incident-reporting and audit to improve patient care

## Human factors

The skills of chest compressions, defibrillation, intravenous cannulation and rhythm recognition are considered typically to be the most important factors in managing a cardiac arrest. These are all technical skills that are learned from books, lectures, courses or from training by other healthcare professionals. Although they are important for the successful resuscitation of a patient, there is another group of skills that is becoming recognised increasingly in medicine - human factors or non-technical skills. Non-technical skills can be defined as the cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance. More simply, they are the things that affect our personal performance.

Deficiencies in the requisite non-technical skills are a common cause of adverse incidents. The introduction and practice of non-technical skills has been one of the key factors in increasing aviation safety - pilots undergo regular, rigorous assessment of their non-technical skills in order to maintain their licence. Until recently little attention had been paid to the importance of non-technical skills in medicine. The pioneers of this aspect of training in medicine were anaesthetists. Analysis of adverse incidents in anaesthesia showed that in up to 80%, failures in non-technical skills such as communication, checking drug doses, planning and team organisation were responsible, rather than equipment failure or lack of knowledge. As a result the Anaesthetic Crisis Resource Management course was developed in America, followed by the Anaesthetists Non-Technical Skills (ANTS) system, pioneered by a team of anaesthetists and psychologists in Scotland (www.abdn.ac.uk/iprc/ants). The principles used to promote good non-technical skills in the ALS course and in the FEEL course are based on the principles of ANTS:

- Situational awareness
- Decision-making
- Team-working, including team leadership
- Task management

## *Situational awareness*

This can be described as an individual's awareness of the environment at the moment of an event and the analysis of this to recognise how an individual's actions may impact on future events. This becomes particularly important when many events are happening simultaneously (e.g. at a cardiac arrest). High information input with poor situational awareness may lead to poor decision-making and serious consequences. At a cardiac arrest, all those participating will have varying degrees of situational awareness. In a well-functioning team, all members will have a common understanding of current events, or shared situational awareness. It is important that only the relevant information is shared among team members otherwise there is too much distraction or noise.

At a cardiac arrest, important situational awareness factors include:

- Consideration of the location of the arrest, which can give clues to the cause
- Obtaining information from staff about the events leading up to the arrest, to try to identify the cause
- Confirmation of the diagnosis of cardiorespiratory arrest
- Determining who is present at the arrest – including names and roles, in particular who is leading the resuscitation attempt
- Noting of actions already initiated e.g. chest compressions
- Checking that a monitor has been attached and interpreting what it shows
- Communicating with the team and gathering information
- Implementing any immediate action necessary
- Consideration of the likely impact of interventions
- Determining the immediate needs

## *Decision-making*

In this context the term refers to the cognitive process of choosing a specific course of action from several alternatives. At a cardiac arrest, the many decisions to be made usually fall to the team leader. The leader will assimilate information from the team members and from personal observation, and will use this to determine appropriate interventions. Typical decisions made at a cardiac arrest include:

- Diagnosis of the cardiac arrest rhythm
- Choice of shock energy to be used for defibrillation
- Likely reversible causes of the cardiac arrest
- At what point a resuscitation attempt should cease

Once a decision has been made, clear unambiguous communication with the team members is essential to ensure that it is implemented.

## *Team-working, including leadership*

This is one of the most important non-technical skills that contribute to successful management of critical situations. A team is a group of individuals working together with a common goal or purpose. In a team, the members usually have complementary skills and, through co-ordination of effort, work synergistically. Teams work best when everyone knows each other's names, when they are doing something they perceive to be important, and when their role is within their experience and competence. Optimal team function requires a team leader. There are several characteristics of a good resuscitation team member:

- Is competent – has the skills required at a cardiac arrest and performs them to the best of their ability
- Has commitment – strives to achieve the best outcome for the patient
- Communicates – is open
  - – indicates their findings and actions taken or intended
  - – is prepared to raise concerns about clinical or safety issues
  - – contributes to effective communication by listening to briefings and instructions from the team leader
- Is supportive – allows others to achieve their best
- Is accountable – for their own and the team's actions
- Is prepared to admit when help is needed
- Is creative – suggests different ways of interpreting a situation
- Participates in providing feedback

## ***Team leadership***

A team leader provides guidance, direction and instruction to the team members to enable successful completion of their stated objective. They lead by example and integrity. Team leaders need experience and competence in leadership, not simply seniority. Team leadership can be considered a process; it can become available to everyone with training and is not restricted to those with instinctive leadership traits. There are several attributes recognisable in good team leaders:

- Knows everyone in the team by name and knows their capability
- Accepts the leadership role
- Is able to delegate tasks appropriately
- Is knowledgeable and has sufficient credibility to influence the team through role-modelling and professionalism
- Stays calm, keeps everyone else focused and controls distractions
- Is a good communicator – not just good at giving instructions, but also a good listener
- Is decisive
- Is empathic towards the whole team
- Is assertive and authoritative when appropriate
- Shows tolerance towards hesitancy or nervousness in the emergency setting
- Has good situational awareness; has the ability to monitor the situation constantly, provide an up-to-date overview, whilst listening to others and deciding on a course of action

During a cardiac arrest, the role of team leader is not always immediately obvious. The leader should state early on that they are assuming the role of team leader. Specifically, at a cardiac arrest the leader should:

- Follow current resuscitation guidelines or explain a reason for any significant deviation from standard protocols
- Consult with the team or call for senior advice and assistance if appropriate in the event of uncertainty
- Play to the strengths of team members and allow them some autonomy if their skills are adequate
- Allocate specific roles and tasks throughout the resuscitation, avoiding several people or nobody attempting any particular task
- If FEEL skills are available communicate with sonographer and team to ensure appropriate positioning and maintenance of 10-second duration of sonography – to ensure that CPR is not compromised
- Use the 2-minute periods of chest compressions to plan tasks as new information becomes available; including information from sonography if FEEL is used
- Maintain safety aspects of the resuscitation attempt with the team
- At the end of the resuscitation attempt, thank the team and ensure that staff and relatives are being supported
- Complete all documentation and ensure an adequate handover and feedback/debriefing

## ***Task management***

During the resuscitation of a patient, either in a peri-arrest or full cardiac arrest situation, there are numerous tasks to be carried out by the team members, either sequentially or simultaneously. The co-ordination and control, or management, of these tasks is the responsibility of the team leader. They include:

- Planning and briefing the team, where appropriate, prior to the arrival of the patient
- Being inclusive of all other team members
- Being prepared for both the expected and the unexpected
- Identifying the resources required
- Ensuring that equipment is checked and that specific actions are organised and delegated
- Prioritising actions of the team
- Watching out for fatigue, stress or distress amongst the team
- Managing conflict
- Communicating with relatives
- Communicating with experts for safe handover both by telephone and in person
- Debriefing the team
- Reporting untoward incidents, particularly equipment or system failures (see below)
- Participating in audit

### *Resuscitation teams*

The resuscitation team may take the form of a traditional cardiac arrest team, which is called only when cardiac arrest is recognised. Alternatively, hospitals may have strategies to recognise patients at risk of cardiac arrest and to summon a team (e.g. medical emergency team) before cardiac arrest occurs. The term resuscitation team reflects the range of response teams. As the members of the team may change daily or more frequently, especially as shift working is introduced, members may not know each other or the skill-mix of the team members. If possible, the team should therefore meet at the beginning of their period on duty to:

- Introduce themselves to each other; communication is much easier and more effective if people can be referred to by their name
- Identify everyone's skills and experience
- Allocate the team leader role. Skill and experience takes precedence over seniority
- Allocate responsibilities; if key skills are lacking (e.g. nobody skilled in tracheal intubation) work out how this deficit can be managed
- Review any patients who have been identified as 'at risk' during the previous duty period

Finally, every effort should be made to enable the team members to meet to debrief, for example to discuss difficulties or concerns about their performance and problems or concerns with equipment. Incident reports can also be completed at this time to ensure systematic learning. When possible it is desirable to carry out a formal handover to the incoming team.

| SBAR | RSVP | Content | Example |
|---|---|---|---|
| SITUATION | REASON | • Introduce yourself and check you are speaking to the correct person<br>• Identify the patient you are calling about (who and where)<br>• Say what you think the current problem is, or appears to be<br>• State what you need advice about<br>• Useful phrases:<br>- The problem appears to be cardiac/ respiratory/neurological/sepsis<br>- I'm not sure what the problem is but the patient is deteriorating<br>- The patient is unstable, getting worse and I need help | • Hi, I'm Dr Smith the medical F2<br>• I am calling about Mr Brown on acute medical admissions who I think has a severe pneumonia and is septic<br>• He has an oxygen saturation of 90% despite high-flow oxygen and I am very worried about him |
| BACKGROUND | STORY | • Background information about the patient<br>• Reason for admission<br>• Relevant past medical history | • He is 55 and previously fit and well<br>• He has had fever and a cough for 2 days<br>• He arrived 15 minutes ago by ambulance |
| ASSESSMENT | VITAL SIGNS | • Include specific observations and vital sign values based on ABCDE approach<br>• Airway<br>• Breathing<br>• Circulation<br>• Disability<br>• Exposure<br>• The early warning score is… | • He looks very unwell and is tiring<br>• Airway - he can say a few words<br>• Breathing - his respiratory rate is 24, he has bronchial breathing on the left side. His oxygen saturation is 90% on high - flow oxygen. I am getting a blood gas and chest X-ray<br>• Circulation - his pulse is 110, his blood pressure is 110/60<br>• Disability - he is drowsy but can talk a few words<br>• Exposure - he has no rashes |
| RECOMMENDATION | PLAN | • State explicitly what you want the person you are calling to do<br>• What by when?<br>• Useful phrases:<br>- I am going to start the following treatment; is there anything else you can suggest?<br>- I am going to do the following investigations; is there anything else you can suggest?<br>- If they do not improve; when would you like to be called?<br>- I don't think I can do any more; I would like you to see the patient urgently | • I am getting antibiotics ready and he is on IV fluids<br>• I need help - please can you come and see him straight away |

**Table 9.1 SBAR and RSVP communication tools**

## The importance of communication

Communication problems are a factor in up to 80% of adverse incidents or near-miss reports in hospitals. Such failures of communication may also be evident when a medical emergency occurs on a ward and a doctor or nurse summons senior help. The call for help is often suboptimal, with failure by the caller to communicate the seriousness of the situation or to convey information in a way that informs the recipient of the precise nature and urgency of the situation. The poor-quality information heightens the anxiety of the person responding to the call, who is then uncertain of the nature of the problem they are about to face. A well-structured process that is simple, reliable and dependable, will enable the caller to convey the important facts and urgency, and will help the recipient to plan ahead. It was for similar reasons that the ABCDE approach was developed as an aide-mémoire of the key assessments and interventions required to manage a critically ill patient safely and effectively.

The use of the SBAR (Situation-Background-Assessment-Recommendation) or RSVP (Reason, Story, Vital signs, Plan) tool enables effective, timely communication between individuals from different clinical backgrounds and hierarchies (Table 9.1).

## High-quality care

The Health Foundation defines quality in healthcare as a multifaceted concept that may be assessed in six key domains:

- Effectiveness
- Access and timeliness
- Capacity
- Safety
- Patient centredness
- Equity

(http://www.health.org.uk/public/cms/75/76/313/559/Quality%20of%20healthcare.pdf?realName=kHRt2D.pdf)

Hospitals, resuscitation teams and ALS providers should ensure that they deliver all these aspects of quality care to the deteriorating patient and to patients in cardiac arrest.

Two aspects of this are safety incident-reporting (also called adverse or critical incident reporting) and collecting good-quality data.

### *Safety incident-reporting*

In England and Wales, hospitals can report patient safety incidents to the National Patient Safety Agency (NPSA) National Reporting and Learning System (NRLS) (http://www.nrls.npsa.nhs.uk/report-a-patient-safety-incident/). A patient safety incident is defined as 'any unintended or unexpected incident that could have harmed or did lead to harm for one or more patients being cared for by the National Health Service (NHS). Previous reviews of the NRLS database have identified patient safety incidents associated with airway devices in critical care units and led to recommendations to improve safety. A review of NPSA safety incidents relating to cardiac arrest and patient deterioration by the Resuscitation Council (UK) shows that the commonest reported incidents are associated with equipment problems, communication, delays in arrival of the resuscitation team, and failure to escalate treatment. A report of a study on in-hospital cardiorespiratory arrests by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) (Time to Intervene: http://www.ncepod.org.uk/2012report1/downloads/CAP_fullreport.pdf) describes failures of non-technical skills relating to various aspects of the management of patients who suffered cardiorespiratory arrest. The report recommends that all CPR attempts should be reported through the Trust/Hospital critical incident reporting system.

### *Audit and outcome after cardiac arrest*

Measurement of processes and outcomes provides information about whether interventions and changes made to resuscitation guidelines improve patient care. Published survival rates from in-hospital cardiac arrest vary substantially and range from 13 to 59% at 24 h and 3 to 27% at discharge, with a median survival to discharge of about 15%. There are probably two main reasons for such variation:

Firstly, there are many confounders that influence outcome following cardiac arrest. These include:

- Differences in the type of EMS system (e.g. availability of defibrillators, differences in response times)
- Differences in the incidence of bystander CPR
- Different patient populations (e.g. a study may be confined to in-hospital cardiac arrests or may include pre-hospital arrests)
- The prevalence of co-morbid conditions
- The effectiveness of implementation of do-not-attempt-cardiopulmonary-resuscitation (DNACPR) policies
- The primary arrest rhythm
- The definition of “cardiac” arrest (e.g. inclusion of primary respiratory arrests)
- The availability of cardiac arrest teams and medical emergency teams

Secondly, there is lack of uniformity in reporting both the process and results of resuscitation attempts. For example, the definition of survival is reported variously as return of spontaneous circulation (ROSC), or survival at 5 min, 1 h, 24 h after ROSC, or survival to discharge from hospital. Many hospitals have no system for collecting data about cardiac arrests that were managed without a call to the resuscitation team. The lack of uniformity in cardiac arrest reporting makes it difficult to evaluate the impact on survival of individual factors, such as new drugs or techniques.

New interventions that improve survival rate only slightly are important because of the many victims of cardiac arrest each year. Individual local hospitals or healthcare systems are unlikely to have sufficient numbers of patients to identify these effects or eliminate confounders. One way around this dilemma is by adopting uniform definitions and collecting standardised data on both the process and outcome of resuscitation on many patients in multiple centres. Changes in the resuscitation process can then be introduced and evaluated using reliable measures of outcome. This methodology allows drugs and techniques developed in experimental studies to be evaluated reliably in the clinical setting.

In the UK, the National Cardiac Arrest Audit (NCAA) is an on-going, national, comparative outcome audit of in-hospital cardiac arrests. It is a joint initiative between the Resuscitation Council (UK) and the Intensive Care National Audit & Research Centre (ICNARC) and is open to all acute hospitals in the UK and Ireland. The audit monitors and reports on the incidence of and outcome from in-hospital cardiac arrest in order to inform practice and policy. It aims to identify and foster improvements in the prevention of, care delivery in, and outcomes from cardiac arrest. The initial scope of data collection is patients who meet all of the following criteria:

- Adults or children over 28 days of age
- Patients who receive chest compressions and/or defibrillation
- Events attended by the hospital-based resuscitation team (or equivalent) in response to a cardiac arrest (2222) call

Data are collected according to standardised definitions and entered onto the NCAA secure, web-based system. Once data are validated, hospitals are provided with activity reports and comparative reports, allowing a comparison to be made within and between, hospitals locally, nationally and internationally. Furthermore the database allows monitoring of the effects of introducing changes to guidelines, new drugs and new techniques in a way that would not be possible on a hospital-by-hospital basis.

## Further reading

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## Acknowledgment

The Resuscitation Council (UK) would like to express its thanks to Professor Rhona Flin, University of Aberdeen, for permission to use the Anaesthetists Non-Technical Skills (ANTS) system.

# Appendices

## Appendix 1

## Focused Echocardiography Training Log

**For training purposes only. NOT FOR ADDITION TO PATIENT NOTES**
**When reporting echo studies you must report in line with local governance**

| | | | | |
|---|---|---|---|---|
| **Patient Details** | | | | |
| **Age** | years | **Sex** | **M** ☐ | **F** ☐ |
| **Clinical indication:** | | | | |
| **Cardiac arrest with CPR** ☐ | **Peri-Arrest** ☐ | **Other** ☐ | | |
| **Study details** | | | | |
| **Date performed** | | **Performed by** | | |
| **Quality of images** | | **(2-optimal, 1-suboptimal, 0-inadequate)** | | |
| **Windows used** | **Subcostal** ☐ | **PLAX** ☐ | **PSAX** ☐ | **Apical 4 chamber** ☐ |

| | | |
|---|---|---|
| **Findings / Results** | | |
| **Rhythm** | | |
| ECG complexes with cardiac motion on echo | **Yes** ☐ | **No** ☐ |
| ECG complexes with no cardiac motion on echo | **Yes** ☐ | **No** ☐ |
| Cardiac standstill | **Yes** ☐ | **No** ☐ |
| VF? | **Yes** ☐ | **No** ☐ |
| **Left Heart** | | |
| LV severely dilated | **Yes** ☐ | **No** ☐ |
| LV severely impaired | **Yes** ☐ | **No** ☐ |
| LV severely underfilled | **Yes** ☐ | **No** ☐ |
| **Right Heart** | | |
| RV severely dilated | **Yes** ☐ | **No** ☐ |
| RV severely impaired | **Yes** ☐ | **No** ☐ |
| Paradoxical septal motion? | **Yes** ☐ | **No** ☐ |
| **Pericardium** | | |
| Large pericardial collection? | **Yes** ☐ | **No** ☐ |

| | |
|---|---|
| **Free text /additional comments** | |
| **Outcome/management** | |
| **Signatures** | |
| **Echocardiographer** | |
| **Supervisor** | |
| **Supervisor comments:** | |

## Appendix 2

# Front page of logbook

| | |
|---|---|
| **Name** | |
| **Institution(s)** | |
| | |
| **Date of your course** | |
| **Venue** | |
| **Course Director** | |
| | |
| **Mentor's name** | |
| **Echo qualification** | |
| **Institution** | |
| | |
| **Mentor's name** | |
| **Echo qualification** | |
| **Institution** | |
| | |
| **Mentor's name** | |
| **Echo qualification** | |
| **Institution** | |

**FEEL-UK competency statement**

I/We confirm that I/we have mentored and reviewed the focused echo studies performed by the above-named candidate and that they are of an adequate standard.

| | |
|---|---|
| ______________________ | ______________________ |
| **Candidate** | **Mentor** |

**Notes:**

- Studies should be recorded and reported on the standard reporting sheet, and copies of these reports should be included in the trainee's personal logbook.
- Each echocardiographic study completed by the trainee should be reviewed with the mentor, who will countersign the report. If the study and interpretation are satisfactory, the mentor should countersign the logbook summary.
- Once the mentor considers the trainee has achieved competency in peri-resuscitation echocardiography, this summary should be signed and dated (by both the supervisor and the trainee) and returned to the course director.
- The total number of studies performed at the time of achieving competency should also be recorded, and must be a **minimum of 50.**

## Appendix 3

# Logbook

| Study Number | Date of echo | Comment | Trainee signature | Supervisor signature |
|---|---|---|---|---|
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## Logbook (continued)

| Study Number | Date of echo | Comment | Trainee signature | Supervisor signature |
|---|---|---|---|---|
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6. Jones AE, Tayal VS, Sullivan DM, Kline JA. Randomized controlled trial of immediate *versus* delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. Crit Care Med 2004;32:1703-8.

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8. Joseph MX, Disney PJ, Da Costa R, Hutchison SJ. Transthoracic echocardiography to identify or exclude cardiac cause of shock. Chest 2004;126:1592-7.

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## Useful websites

1. Resuscitation Council (UK). www.resus.org.uk
2. Yale atlas of anatomy. www.med.yale.edu/intmed/cardio/echo_atlas/views/index.html
3. P Barbier. Echobyweb http://www.echobyweb.com
4. Eric Sloth. www.fate-protocol.com
5. Schallware. www.schallware.de
6. WINFOCUS: World Interactive network focused on critical care ultrasound. www.winfoucs.org
7. Principles of Ultrasound. www.folk.ntnu.no/stoylen/strainrate/Ultrasound/