Bedside ultrasound has gained increasing prominence in emergency medicine over the last 2 decades. Its ready availability and portability can aid rapid diagnosis and assist in performing procedures more safely.

It is important throughout the course of your emergency training that you become familiar with utilising bedside ultrasound.

The purpose of these ultrasound modules is to introduce you to basic ultrasound imaging. The modules are meant to completed in order as follows:

- Introduction to Ultrasound
- Procedural Ultrasound
- FAST
- Abdominal Aorta Scanning

These modules are compulsory if you wish to gain accreditation for bedside ultrasound in the department. Until then all ultrasound performed must be supervised by a credentialed member of the department.

If there are any issues with the equipment or general concerns regarding bedside ultrasonography please contact Katherine Isoardi ext 3791 or katherine._isoardi@health.qld.gov.au
Basic Physics

Basic Terminology¹:

**Amplitude** is the peak pressure of a wave, in ultrasound it is akin to the strength or volume of the sound wave.

**Frequency** is the number of wavelength (cycles) per second and is measured in Hertz. One Hz is one cycle per second.

**Propagation Speed** is the speed of the wave through a medium (assumed to be constant). In soft tissue it is 1540 m/s.

**Attenuation** is the dampening of a sound wave as it travels through a medium.

**Resolution** refers to the ability to discriminate between two closely related points. Axial resolution is in the plane parallel to the emitted sound waves. Lateral resolution is in the plane perpendicular to emitted sound waves.

**Power** refers to the amount of energy leaving the transducer to form ultrasound waves.

**Reflection** is the redirection of an echo, on striking an interface, back to its source.

**Refraction** is the redirection of a pulse as it crosses the interface between two separate mediums.
**Basic Principles:**

The term ‘ultrasound’ refers to sound waves with a frequency which in excess of the upper limit of human hearing (20kHz). Medical ultrasound typically utilises frequencies in the range of 2 – 15 MHz.²

Ultrasound imaging comprises of mechanical waves that can transmit through different materials. It operates through the pulse-echo principle.³ Firstly, the transducer emits a short sound wave. This ‘pulse’ travels through and interacts with tissue giving rise to reflected echoes. Reflected echoes travel back to the transducer and are converted into electric signal which is then processed to form an image.

Sound waves are emitted from piezoelectric crystals within the transducer. Piezoelectric crystals can change electrical signals into mechanical vibrations and vice versa.²

Sound waves travel at a constant velocity through a given medium. At the interface of two differing media, sound undergoes reflection and refraction – the degree of which depends on the medium it is travelling through.

The amplitude of the returning wave correlates with the brightness of the received image. A high amplitude or strong signal wave is processed to form a bright or hyperechoic image. A low amplitude or weak signal forms a darker or hypoechoic image

The angle of incidence (x) of the sound wave is always equal to the angle of reflection (y). Following from this reflected sound waves are only received by the transducer and seen as a processed image if the angle of incidence is perpendicular to the surface being imaged.

If a material is very dense (eg bone) sonographic waves are readily reflected and the image appears hyperechoic. In contrast, fluid transmits sound very well so less is reflected resulting in an anechoic image.¹
If two separate materials have the same acoustic impedance their interface will not produce any echoes. If the difference is considerable a large proportion of incident waves are reflected. Bone or air interfaces can produce such large echoes that almost all of the sound is reflected and little imaging occurs beyond the interface.4

High frequency sound waves generate higher resolution pictures but are limited to more superficial imaging – that is the penetration is less. Transducers utilising lower frequencies are better for deeper imaging but have poorer resolution compared to higher frequency probes.

**B- Mode**

The conventional 2D ultrasound image we are most familiar with is referred to as Brightness mode or B mode imaging. It involves the conversion of waveforms into images by using a gray scale which corresponds to the amplitude of returning echoes.

**M-Mode**

Motion mode or M mode is used to better examine movement of structures such as lung pleura or heart valves. The image represents a single line of sight over time and is plotted as a waveform across the screen.

An example of M Mode imaging; normal lung window
Artifacts

Ultrasound machine process images based on multiple assumptions which do not always hold true. These assumptions include:

- Ultrasound travels in a straight line
- Ultrasound travels at a constant speed
- Ultrasound travels directly from the transducer to a reflector and back to the transducer
- All echoes detected by the transducer are due to the most recent transmitted pulse

Artifacts refer to errors in the processed image. They can be helpful at times in reaching a diagnosis and other times can prompt misdiagnosis. It is important that some common artifacts are understood.

Some common artifacts include:

Acoustic Shadowing
Acoustic shadowing occurs when a sound wave reaches a highly reflective surface (e.g., bones or gallstones). Almost all the sound is reflected and any image behind the structure is in shadow or hypoechoic. Ultrasound interacting with air produces a similar effect with sound scattering at the air interface. The presence of this artifact is important in the gallbladder imaging to aid the diagnosis of gallstones.
Reverberation
Reverberations are depicted as multiple equidistant lines which form along a line of sight in the image. It occurs when sound bounces between highly reflective structures such as the pleura.

Mirror Imaging
Mirror imaging occurs when a sound wave strikes a very bright reflector (e.g., diaphragm) which behaves as a mirror. The ultrasound machine assumes sound travels in a straight line and is confused, depicting the mirror image of the object behind the reflector.
**Enhancement**  
Enhancement is seen as an abnormally high brightness. The sound through this area is attenuated less than in surrounding tissue. Often this is due to a window through fluid – which conducts sound readily. Enhancement is often helpful to imaging – a good example is a full bladder greatly aids pelvic ultrasonography.

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**References**

Getting Started: Equipment

- Depth dial
- Gain dial
- Freeze button
- Saving controls
- Patient details key
- Preset key
- End exam key
- Callipers
- Mouse ball
- Depth dial
- Gain dial
Patient details key
Almost all machines require registration of unique patient details to allow saving of images. It is a good habit to fill this in first each time you use the machine.

Preset key
The preset key allows you to switch between the different transducers.

Freeze button
The freeze button will freeze a moving image to enable measurements and saving. It will also switch the machine to the scanning screen if you are in any administrative pages on the laptop (such as patient details etc).

Gain
The received ultrasound signal can be amplified by increasing the gain. The effect is to increase the overall brightness of the image. When you first begin scanning there is a tendency to overuse gain and have a very bright image. A good gain setting is a balance between optimising brightness but ensuring blood within vessels still appears black.

Depth
The depth knob increases or decreases the depth of the image. Optimise the depth for all your images such that the far field contains the limit of what you want to see. A good example is with Abdominal Aorta Scanning the depth should be set so that the vertebrae is at the back of your image to optimise resolution of the aorta.

Callipers
Can be used to measure the width or height of structures.

End Exam key
The End Exam key does exactly that. You are taken to a screen which shows a summary of your series. You can choose which images you wish to save permanently to the hard drive by choosing the Permanent Store option.

Saving controls
The saving controls are designated to the numbered P buttons. P1 saves the image to the laptop. P2 prints the image. P3 saves the image to a USB stick.
Transducers: Linear Array (Vascular Probe)

- contain small rectangular crystals arranged in a straight line
- usually high frequency (7.0-1.0 MHz).
- scan image is rectangular
- better resolution in superficial tissue but has a smaller acoustic window

Transducers: Curved Array (Abdominal Probe)

- contains crystals arranged in a convex arc
- lower frequency (3.5-5.0 MHz)
- scan image diverges at increased depth
- produces better resolution of deeper structures because of lower frequency

Transducers: Phased Array (Cardiac Probe)

- small footprint with a diverging field
- good for areas with limited access (e.g., between ribs)
- has sequential firing of the elements from one end to the other, resulting in steering of the beam
**Probe Marker**

All probes have a marker on them which correlates with a certain side of the screen. An easy way to confirm if you are not familiar with the equipment is to gently touch one end of a probe with overlying gel. You will be able to see on the image which side this correlates to and orient your probe accordingly.

**Holding the probe**

It is easiest to hold the probe close to the transducer surface using the back of your hand resting gently on the patient to stabilise the image. Probe convention is that the left of the screen correlates with the patient’s right hand side (your left hand side if you are facing the patient) in the transverse position or the patient’s head in the longitudinal position.

**Ultrasound Gel**

A generous amount of ultrasound gel is required between the transducer and the tissue to optimise the image.

**IMPORTANT REMINDER**

It is very important that you clean the ultrasound machine with soap and water after every use, ensuring there is no blood, gel or fluids remaining on the probe, cords or machine. Take particular care to maintain the probes, which if dropped, punctured or run over with the wheels of the machine can be very costly to repair.
Improving your image

- Use the right probe for the right purpose. A higher frequency linear probe is best for superficial structures like veins and nerves. The curvilinear probe uses lower frequencies and is better to image deeper structures like abdominal organs.
- Optimising depth and gain is the simplest way of improving your image. The optimal depth will ensure better resolution of your imaging field. Try to make the limit of what you want to see in the far field of your picture. Gain adjusts the intensity of the processed image (not the quality).
- Using generous amounts of ultrasound gel improves conduction between the transducer and the patient.
- Certain patient manoeuvres – particularly breathing in when imaging the heart or solid organs or performing a Valsalva when imaging vessels – can greatly enhance the image and need to be remembered.

Documentation

It is very important that you complete comprehensive documentation for each clinical bedside ultrasound study. At a minimum documentation should include your name, your proctor's name if applicable, study performed, adequacy of views and results. It is good practice to make a copy of any clinically relevant images for the patient's notes.

Accreditation

Practitioners of emergency department ultrasonography should meet accreditation requirements as set out by the ACEM.

In essence the requirement is to attend an accredited course, perform and record the required number of proctored scans and to complete an exit examination. Ongoing requirements must be met to maintain credentialing.

While acquiring accreditation, all ultrasound examination should be proctored and documented – preferably in a logbook.

Once completed, these images are reviewed by the supervisor of emergency ultrasound in your department, following which a successful practical assessment should then lead to gaining accreditation in that module.

To maintain credentialing, it is suggested that 3 hours of ultrasound training per year as well as maintaining a logbook is necessary. Bimonthly auditing of departmental ultrasounds should be undertaken as a quality improvement process.