THE COLLEGE OF EMERGENCY MEDICINE

Core (Level 1)
Ultrasound Curriculum

Contents

Ultrasound in Emergency Medicine
Level 1 Instruction
This document covers FAST, Assessment of the Abdominal Aorta and IVC, Vascular Access and Echocardiography in Life Support.

The classic Emergency Medicine scan is the Focussed Assessment using Sonography in Trauma (FAST). FAST involves assessment of the peritoneal cavity, pleural cavity and pericardial space. Learning that free fluid is present facilitates the most appropriate management plan.

Level 1 "core" skills also include Assessment of the Abdominal Aorta and IVC, Vascular Access, both peripheral and central, and Echocardiography in Life Support (ELS).

1. Curriculum for EMUS 2009

The curriculum and assessment system for ultrasound in EM should be delivered during HST. It is anticipated that some trainees will become familiar with the theoretical principles of ultrasounds during CT3 by attending a College approved course. However the formal assessment and examination of these skills and the theoretical principles will not be undertaken until the trainee is in HST. Most of the learning will be delivered by e-modules, before the trainee proceeds to practical training and evaluation.

Record of attainment in ultrasound skills will be demonstrated in this EMUS assessment handbook, and not in the e-portfolio. The objectives, together with the Knowledge, Skills and Attitudes are summarised below. The abbreviations used are as follows:

Assessment Method Glossary

AA	Audit Assessment
ACAT	Acute Care Assessment Tool
C	Case Based Discussion (CBD)
D	Direct observation of procedural skills (DOPS)
E	Examination
L	Life support course
Mi or A	Mini- clinical evaluation exercise or anaesthesia clinical evaluation exercise (Mini-CEX or Anaes-CEX)
M	Multi-source feedback (MSF)
PS	Patient Survey
S	Simulation
TO	Teaching Observation
W	Web based, ENLIGHTENme Hub and Knowledge Bank http://www.enlightenme.org/

GMP domain headings

GMP 1	Knowledge, skills and performance
GMP 2	Safety and quality
GMP 3	Communication, partnership and teamwork
GMP 4	Maintaining trust

Ultrasound physics	ST 4-7	Assessment methods	GMP
Knowledge	The basic components of an ultrasound system	C, AA, W	1
	Types of transducer and the production of ultrasound, with an emphasis on operator controlled variables.		
	Use of ultrasound controls		
	Know the frequencies used in medical ultrasound and the effect on image quality and penetration		
	The interaction of ultrasound with tissue including biological effects		
	Safety issues in ultrasound		
	The basic principles of real time and Doppler ultrasound including colour flow and power Doppler		
	The recognition and explanation of common artefacts		
	Image recording systems		
Skills	Can operate the key machine controls	D	1
	Transducer changing		
	Image manipulation and storage		
Behaviour	Safe practice	E, C	2, 3
	Limitations of own skills		

Sectional and ultrasonic anatomy			
Knowledge	Kidneys, Liver, Spleen Retro-peritoneal structures (aorta, IVC) Recto-vesical, vesico-uterine and recto-uterine pouches	E, C, W	1
	Heart and pericardium		
	Vessels: internal jugular veins, carotid arteries, femoral veins and arteries. Antecubital and basilic veins		
Skills	Describe and sketch key anatomy	D	1
Behaviour	Adheres to rule-in philosophy	E, C	2, 3

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Pathology in relation to ultrasound			
Knowledge	Kidneys: trauma/free fluid Liver and spleen: trauma/free fluid Retroperitoneal: presence or absence of abdominal aortic aneurysm (AAA) Vessels: vascular access Cardiac scan: trauma/pericardial tamponade, pericardial effusions, asystole	E, C, W	1
Skills	Describe and sketch key pathologies	C, D	1
Behaviour	Adheres to rule-in philosophy	E, C	2, 3

Administration and governance			
Knowledge	Image recording, storing and filing. Reporting medico-legal aspects – outlining the responsibility to practise within specific levels of competence and the requirements for training. Consent. The value and role of departmental protocols The resource implications of ultrasound use	C, AA	1
Skills	Integrate EMUS into departmental clinical governance system.	D	1
Behaviour	Adheres to rule-in philosophy	C	2, 3

Focused Assessment using Sonography in Trauma (FAST)			
Knowledge	Use focused ultrasound to assist in bedside emergency department decisions	E, C, AA, W	1
	Four areas to scan		
	How to position the patient		
	Key indications		
	Obtaining better views		
	Understands common aortic artefacts		
	Recognise the limitations of a scan and be able to explain these limitations to patients/carers		
	Recognise patients requiring formal specialist sonographic assessment		
	Incorporate ultrasound findings with the rest of the clinical assessment		
	Appearances of pleural and pericardial fluid		
	Appearances of fluid in Morison's pouch, spleno-renal recess, and pelvis		
Skills	Can obtain adequate images	D	1
	Can interpret accurately in the clinical setting		
Behaviours	Safe practice	E, C	2, 3
	Limitations of own skills		
	Adheres to rule-in philosophy		

Assessment of the Abdominal Aorta competency			
Knowledge	Use focused ultrasound to assist in bedside emergency department decisions	E, C, AA, W	1
	Recognise the limitations of a scan and be able to explain these limitations to patients/carers		
	How to position the patient		
	Key indications		
	Knows anatomy		
	Understands common aortic artefacts		
	Knows the views to obtain		
	Can measure diameter		
	Recognises different types of aneurysm		
	Understands when to use		
	Knows normal limits		
	Distinguishes Aorta from IVC		
	Can identify SMA and Coeliac Axis		
	Knows leaks /bleeding cannot be seen		
	Incorporate ultrasound findings with the rest of the clinical assessment		
Skills	Can obtain adequate images	D	1
	Can interpret accurately in the clinical setting		
Behaviours	Safe practice	E, C	2, 3
	Limitations of own skills		
	Adheres to rule-in philosophy		

Vascular access competency			
Knowledge	Knows vascular anatomy Can locate IJV, Femoral Vein and Basilic veins Can describe use of ultrasound to assist or to guide cannulation Understands parallelism and angle of approach	E, C, AA, W	1
Skills	Can obtain adequate images Can use sterile probe covers Can cannulate using ultrasound guidance Can avoid risk of air embolism Can avoid significant bleeding Can conduct without unnecessary discomfort to the patient	D	1
Behaviours	Safe practice Limitations of own skills Adheres to rule in philosophy	E, C	2, 3

Echo in Life Support (ELS)			
Knowledge	Limited echocardiogram in the setting of non-shockable cardiac arrest rhythms (PEA and asystole). Detecting wall motion Knows the treatable causes of PEA (cardiac tamponade, hypovolaemia, and pulmonary embolism). Views used - sub-xiphoid view first, augmented by a further view - the para-sternal long axis view. Visualisation of the inferior vena cava (IVC) for assessment of diameter and collapsibility.	E, C, AA, W	1
Skills	Can obtain adequate images Can interpret accurately in the clinical setting	D	1
Behaviours	Safe practice Limitations of own skills Adheres to rule-in philosophy	E, C	2, 3

2. Equipment - basics

Most ultrasound machines are fundamentally the same. Even the most apparently complex machine can be reduced to a simple series of functions. It is important that the following are understood and can be applied/manipulated as the scan progresses. Ensure you can always locate these functions on any machine you use.

> Patient Information
> Probe orientation
> Transducer Change
> Depth Button / Focus
> Time Gain Compensation
> Freeze
> Calipers
> Probe Choice
> Scanning Planes
> Label and pictogram
> Image storage

On /Off Button

There is nothing more embarrassing than not being able to find the on/off button. Most machines for near-patient scanning are designed to turn on quickly to a set **preset** so that image acquisition can commence rapidly. Some have a standby mode. Larger machines may have an on-board power supply which allows the machine to remain turned on for brief periods away from mains electricity. This, combined with the standby mode, enables a large machine to be moved from patient to patient.

Patient Information

It is essential to enter patient details so that images can be stored and reviewed later if needed. This not only ensures quality, but is valuable if images have been misinterpreted to correct mistakes. Most machines have a keyboard and mouse arrangement to facilitate this. A minimum data set should include surname, first name, patient identifier, date of scan and the identity of the person carrying out the scan. Some machines are linked to PACS enabling patient data to be directly drawn from the PACS system. It should only be in extreme time-limited applications that patient detail input is neglected. As you get to know your machine various preset labels are often available to make labelling of scans faster.

Gel Couplant

Air is the enemy of ultrasound! The idea of a gel couplant is to reduce air trapped – whenever you are struggling to get a picture the first thing you should do is to try more gel. A gel with enough adherence not to keep slipping off the skin is ideal – in an extreme emergency any gel will suffice though is not ideal - don't forget to warm it!
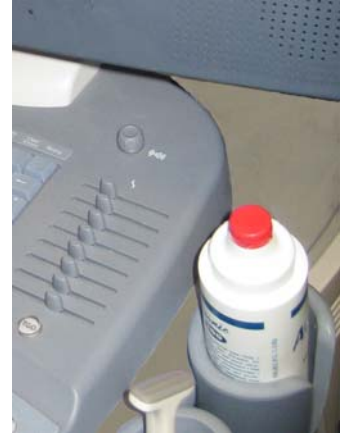
Probe orientation

A standard orientation is used when looking at images and when storing images so that anyone reviewing the images is able to identify the view. Most probes have a notch or light representing the orientation dot on the screen and it is good practice to identify this (tapping on the probe is a valuable way to check).

Standard orientation always has the head to the left so that the screen looks at head to feet from left to right. If a transverse image is then needed rotation anti-clockwise will maintain correct orientation because then the right side of the patient is towards the dot on the left of the screen.

Transducer Change

It is important to become familiar with how the machine changes transducers. Some machines need you to physically change the transducer; others are done from the console. Many machines also allow a change in frequency of individual transducers to enable more penetration (lower frequency) or more resolution (higher frequency).

Depth Button / Focus

Many basic machines will not allow a change in focus and in these machines it is generally set to the centre of the screen. If it can be altered, however, it should be moved to the area you wish to see and you will concentrate the processing power to that area.

The best area of focus of an image is in the middle of the screen. When one has acquired the desired image it is a good idea to remove the distal parts of the image that are not necessary to maximise the image and to place the area of most interest within the middle of the screen. There is often a depth measure on the side of the image that tells you what depth the image is at.
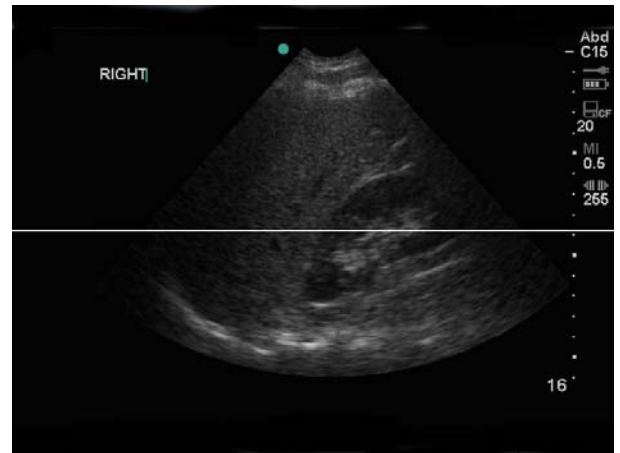
Calipers

Most machines allow calipers to be placed and then moved, usually via a mouse or roller ball. Usually a measure is given numerically on the screen. In general front to back measures of circular structures are better (e.g. vessels) as edge artefact can cause loss of definition at the edges.

Scanning Planes

There are 3 standard described scan planes, Coronal, Sagittal and Transverse. The beginner is generally advised to stay in these simple planes so as to be able to reliably obtain recognisable images repeatedly (which is what makes focused scanning possible). With experience, changes in the inclination of planes helps to obtain improved images.
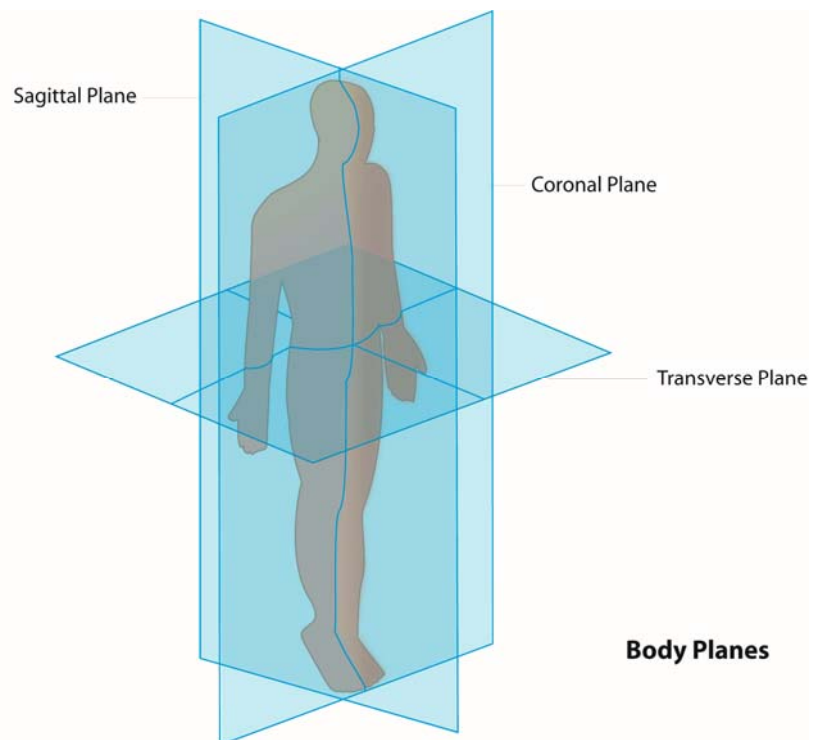
Label the image with appropriate patient details. These will usually appear at the top of the scan, but have not been included in this image for reasons of patient confidentiality.

Always add either a pictogram or a text description of what the image is intended to be. A pictogram is a small body picture (see bottom right of the image). Some operators prefer a simple text insert instead, such as 'RUQ'.

Pictogram showing right upper quadrant
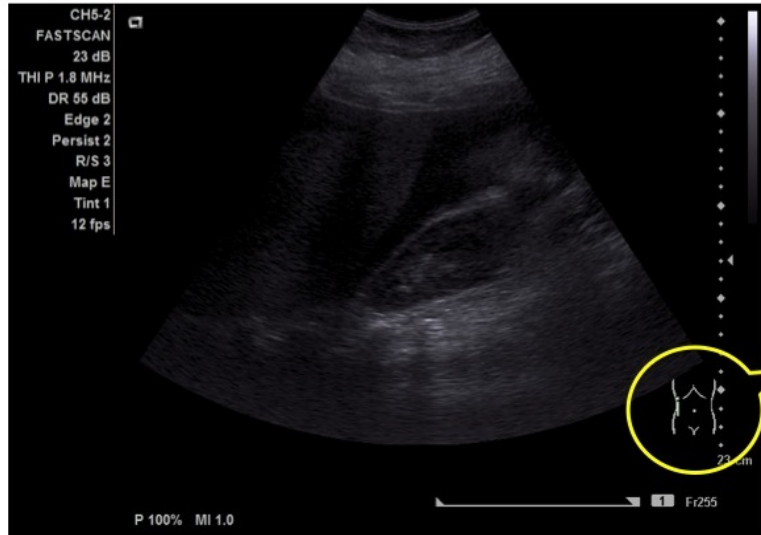
3. Core knowledge

3.1 Physics

In the hands of an expert, the production of an ultrasound image looks easy. However, both image acquisition and interpretation are hugely reliant on a reasonable depth of understanding of how ultrasound works. Where this is lacking, there is considerable scope for confusion and mis-diagnosis.

How Ultrasound works

Sound is simply the transfer of mechanical energy from a vibrating source through a medium. Ultrasound is defined as sound of a frequency above the human audible range, i.e. above 20 kHz. For most emergency medicine applications frequencies in the region of 1 to 10 MHz are used.

Medical ultrasound utilises the pulse-echo principle to construct a two-dimensional image of anatomical structures within a patient. This is essentially the same principle used by bats to catch insects through echo-location.

An ultrasound transducer converts electrical energy into a mechanical pulse of sound that is transmitted into the patient. Returning echoes are converted into an electrical signal from which the image is formed.

Ultrasound is not emitted continuously from the transducer, as there would be no way of knowing how long a wave had been travelling once it returned to the transducer. Instead, transducers oscillate between emitting a pulse of ultrasound, and then in the pause that follows, the time that elapses for the echoes to be detected is measured.   A pulse of sound leaving the transducer will travel into the patient until it encounters a change in acoustic impedance (Z).   At such an interface, a proportion of the sound energy is reflected back to the transducer and this return echo is detected. If the speed of sound is known and the time taken for the echo to return is measured, the depth of the reflecting interface can be calculated.

Distance = speed x time

Each pulse of sound transmitted into the patient will generate a stream of returning echoes from multiple reflecting interfaces at various depths within the tissue. Although all ultrasound is based on reflected sound, the means by which the echoes are analysed and displayed varies. This gives rise to several types, or modes, of ultrasound:
• A-Mode
• B-Mode
• M-Mode

A-mode is short for amplitude modulation. It displays as a graph on the screen with the x-axis as time, and the y-axis as amplitude. It is used in scanning the eye. The diagram shows an ultrasound of the abdomen with the A-mode display corresponding to each layer.

B-mode is short for brightness modulation. In its simplest form, it appears as bright spots with varying intensity depending on the amplitude, as in the diagram. The image becomes two-dimensional by virtue of the use of an array of multiple transducer elements, each of which forms a bright spot.

If performed fast enough, rapid update of frames can create a 'real time' image. Frame rate is limited by the depth to which the image is set. This is an operator control and should be set to display only the area of interest.

It is two-dimensional real time B-mode scanning which forms the basis for emergency medicine scans, such as Focused Assessment with Sonography in Trauma (FAST) and

Transducer

Z_1

Z_2

Z (acoustic impedance)
≈ density x compressibility
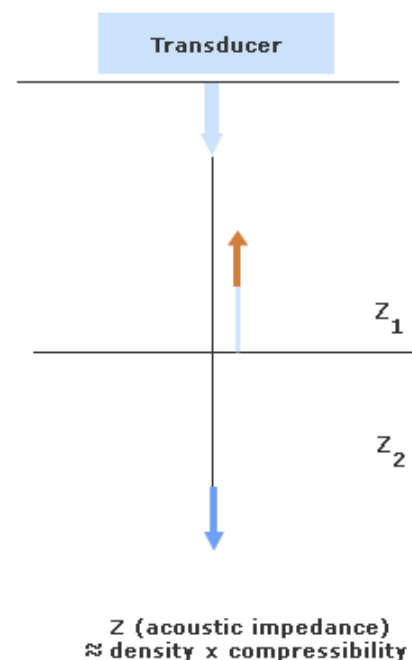
Abdominal Aortic Scanning.

M-mode stands for motion mode and this uses a stationary transducer with a moving recording device. M-mode detects all motion down a line drawn through the tissues. It is a useful modality to measure moving objects, classically the cardiac walls and valves. Essentially, M-mode takes a single line of the B-mode image and displays changes within this over time. Movement of reflectors along this line of sight generates a pattern across the monitor or a moving paper strip chart recorder.
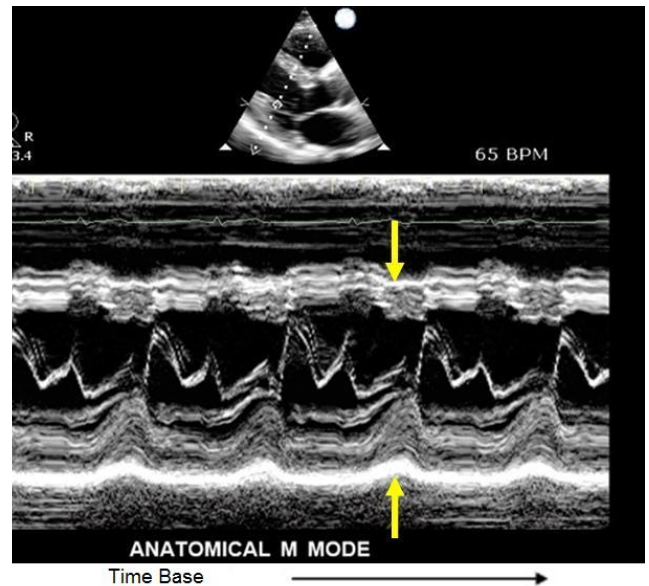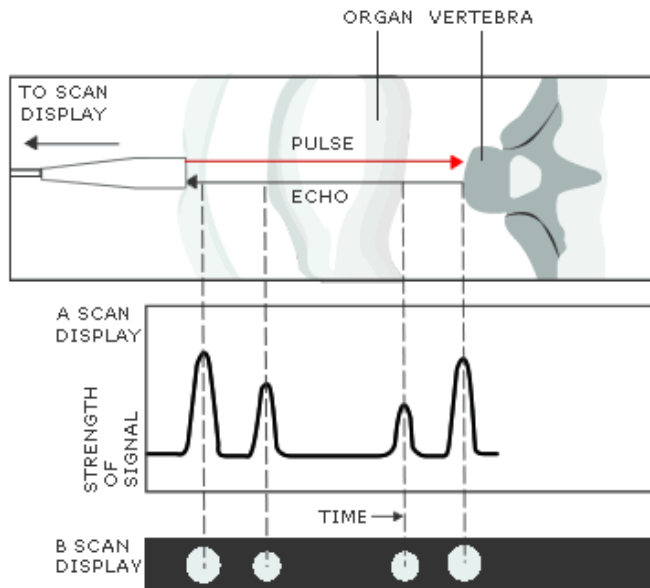
The image shows a B-mode view of the heart (left) with the M-mode view (right). B-mode data is collected from along a single line of sight (indicated by the dotted line) and displayed across a time base. Movement of the mitral valve leaflet and the left ventricular walls is demonstrated.

Most diagnostic conclusions about both normal and abnormal ultrasound appearances are based on four key observations:
• the spatial definition of tissue boundaries
• relative tissue reflectivity (brightness)
• echo-texture
• the effect of tissue on the through transmission of sound

All of these observations are based upon appearances that are the result of how sound waves interact with tissue. A great deal of potentially useful diagnostic

information can be inferred from these observations, but some understanding of how sound behaves is required to appreciate why the appearances arise.   In many ways, sound and light behave in a similar fashion. Concepts such as reflection, scattering and refraction are common to both. Reflection of the ultrasound pulse occurs when there is a change in acoustic impedance across a boundary between tissues. Specular reflection occurs when the sound pulse encounters a large smooth boundary, such as the diaphragm (see arrow) or an organ capsule. Sound is reflected from interfaces where there is a change in tissue density and compressibility.

In the graphic on the right, if the incident pulse (A) hits the surface at an angle, the reflected component (B) will be directed at an equal and opposite angle.

Z_1 Z_2

A

B

Transmitted pulse

Angle of incidence = Angle of reflection
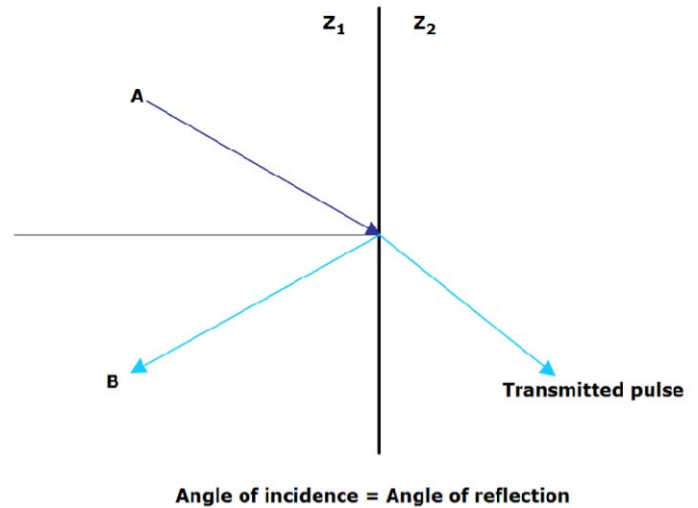
Structures insonated (i.e. struck by sound waves) at 90 degrees will generate an echo that is directed back to the transducer. This graphic shows a structure insonated at 90 degrees.
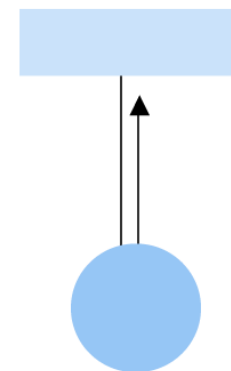
Reflective interfaces that are curved may not be demonstrated clearly, as the reflected pulse is directed away from the transducer. It may be necessary to scan from a different angle. The graphic shows a curved reflective interface.

15
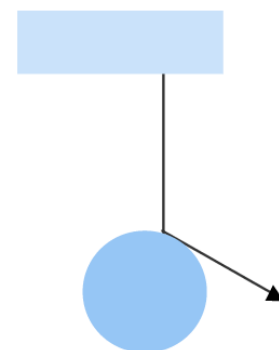
In the transverse views of the abdominal aorta below, the lateral borders are ill-defined, and shadowing is seen distal to the lateral walls of the aorta in the left image (arrow). For this reason the antero-posterior measurement is used, as calliper placement is more precise and the measurement reproducible. The image on the right shows the reflected pulse being directed deep into the patient. No useful information is gained from this region. Note the anechoic nature of the blood within the aorta

Reflective interfaces that lie at an angle may not be demonstrated clearly, as the reflected pulse is directed away from the transducer. It may be necessary to scan from a different angle. This graphic shows an angled reflective interface.
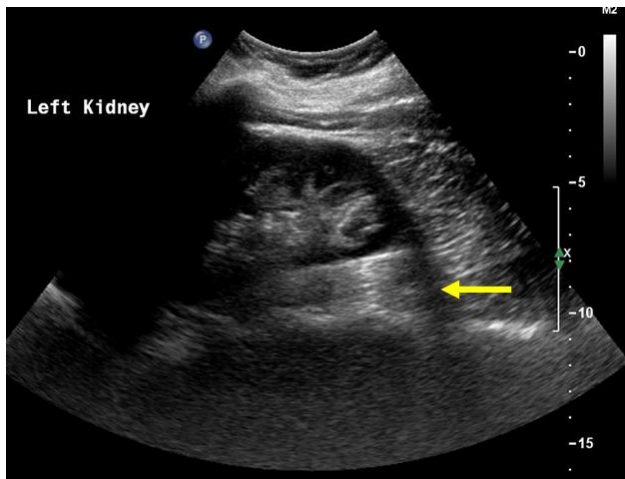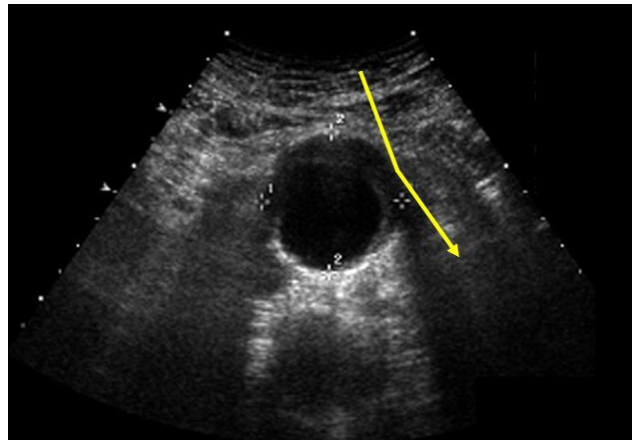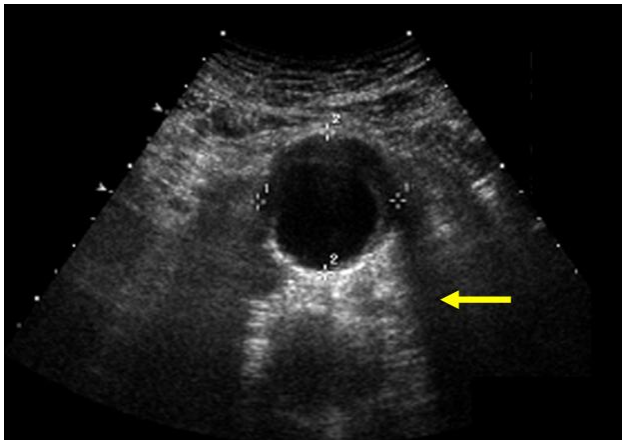
'Critical angle shadowing' is often generated by the edges of structures and is seen in this image distal to the lower pole of the kidney (see arrow).
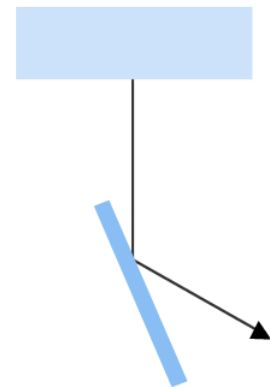
The cellular structure of soft tissue scatters *sound energy in all directions. This is similar to* the scattering of light seen when a car's headlights are raised on a foggy evening. Known as Rayleigh Scatter, this produces the characteristic grainy appearance of solid organs on ultrasound (see arrow within renal cortex).

The scattering of sound within a soft tissue structure determines the 'brightness' of the organ relative to adjacent tissues. Scattering also produces a characteristic speckle pattern or Echo Texture.

Absorption and scattering are both highly frequency dependent. High frequency sound produces better image resolution, but is attenuated by a smaller depth of tissue. This means that penetration to deeper tissues is limited when using a high frequency transducer.

There is always a compromise between resolution and penetration. In practice, use the highest frequency that allows adequate penetration to the depth of interest.

As sound travels through tissue, it will lose energy. A number of interactions contribute to this process of attenuation including reflection, scattering and absorption. This results in an exponential decrease in the energy of the pulse, therefore producing weaker echo signals, the deeper it travels into the patient.

LIVER / RIGHT KIDNEY
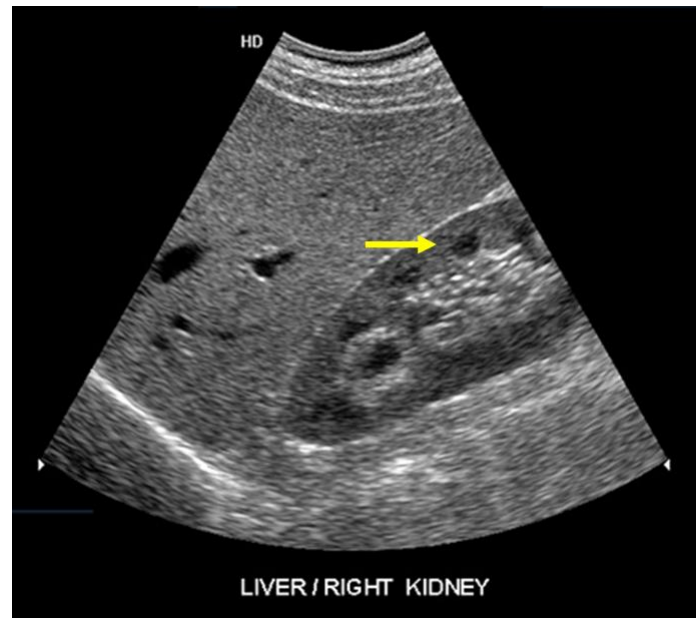
I= Intensity of transmitted pulse
X = distance from the transducer
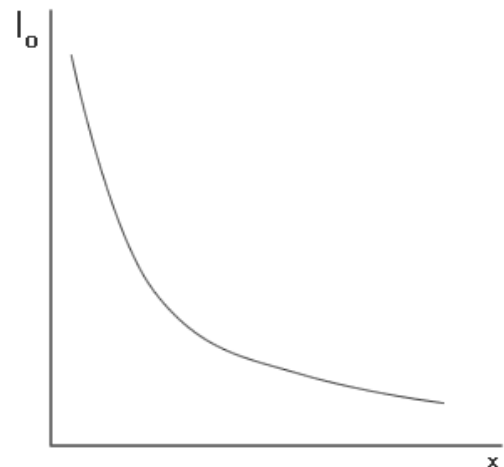
The acoustic impedance of the tissue being imaged determines attenuation. The variation between diverse tissues can be enormous, as shown in this table.

| Material	Speed of sound (m/s)	Density (kg/m^3)/10^3	Acoustic Imp Z (kg/m^2/s)/10^6
Air	330	1.2	0.0004
Water	1480	1000	1.48
Steel	5000	7800	39.0
Blood	1575	1057	1.62
Fat	1459	952	1.38
Muscle	1580	1080	1.70
Bone	4080	1912	7.8

Basic components of an ultrasound system

Any ultrasound machine is composed of a transducer to transmit and receive ultrasound, a computer for storage and manipulation of the acquired data and a monitor to display the image. Some form of image storage or hard copy device is needed to provide a permanent record of each examination.

The quality of the displayed data is determined by the skill of the operator and the inherent quality of the machine components.

The layout of the control panel will vary considerably between machines and manufacturers. Individual controls will also vary in appearance as well as location. Simple controls such as focus or depth may be a soft key, a dial, a paddle or on-screen. Individual tabs/keys may have multiple functions depending on the mode of operation selected.

It is for this reason that a 'co-pilot', who is familiar with the specific system, is a useful ally when using a machine for the first time. Manufacturers tend to group controls depending on function and to minimise operator movement and reach, such as callipers/measurement.

Freeze allows the operator to produce a static image for archiving and from which measurements can be taken. This is normally a soft key. Typically, it is situated towards the right hand side of the control panel to be reached easily with the left hand while scanning with the right. The key is normally labelled 'freeze' (some of the more imaginative manufacturers use a snowflake).
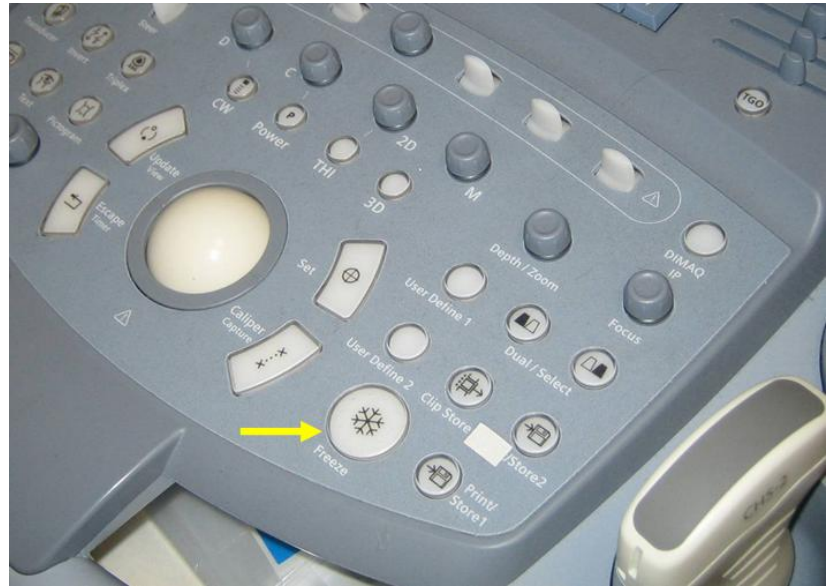

On most equipment, the track ball controls the cine-loop facility. The cine-loop feature allows the operator to scroll back through several seconds worth of captured frames once the image has been frozen. This is particularly useful when imaging non-cooperative patients. The tracker ball is probably the only control on an ultrasound keyboard that is common to virtually all manufacturers. This is the equivalent of the computer mouse and is used to move the cursor around the screen when entering patient. The laptop equivalent tracking pad has replaced the tracker ball on hand held systems.


Depending on the scan mode that is operating, the tracker ball is used to move on-screen graphics such as callipers and to position the box location for high resolution zoom. The function of the track ball changes as each application is selected.

Consider the probe to be a torch with a very thin visible beam. Different probes create different acoustic 'beams', or fields of view, the shape of which varies. A high frequency linear array probe produces a flat beam with parallel sides, as in this image. A low frequency curvilinear probe produces a widening beam, as shown. The lower frequencies can give considerable depth. A phased array probe produces ultrasound beams with fractional time differences across the array. A sweeping beam results that gives a wide diverging field of view, but with a small footprint. This can be very useful when imaging between ribs, e.g. in cardiac applications.

On a higher specification ultrasound machine, once patient details are entered, an on-screen menu may appear giving options of transducer and application. Up to four transducers may be plugged in at any one time and the operator will need to select the correct transducer from the menu to match the area to be examined. Always use the highest transducer frequency that allows adequate penetration to the depth of interest. Some manufacturers offer high resolution or penetration settings for each transducer. This allows the operator to optimise the transmit frequency for slender or obese patients without changing transducers.

Once the correct transducer has been selected, the operator must select a specific body area pre-set.   When the relevant body area is selected, the machine will default to a range of settings that are optimised by the manufacturer for that target area. This will include settings affecting penetration, resolution, frame rate etc. It is important to choose the correct transducer/pre-set combination. It is not uncommon to observe inexperienced operators struggling to image deep into a large patient with these initial settings optimised for superficial structures. Inevitably, image quality will be poor and may be non-diagnostic.
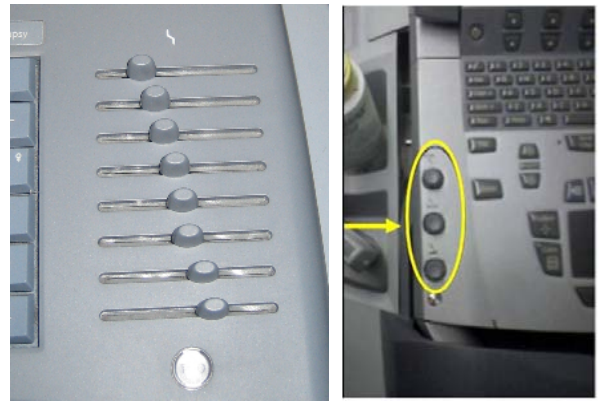
Time Gain Compensation (TGC) usually consists of a number of sliders/paddles that correspond to specific depths within the patient. TGC is used to compensate for increasing attenuation by increasing amplification of the return signal with depth.   On the smaller hand-held systems, TGC is often replaced by independent near and far gain controls. The operator should aim for an image where similar structures appear at the same brightness level, regardless of depth. Unlike TGC, overall gain alters the amount of amplification applied to signals from any depth. This is used to increase or decrease the overall brightness of the image. Overall gain amplifies the return signal and has no effect on the transmitted pulse. Therefore, gain cannot compensate for inadequate penetration. The only way to do this is to increase the output power of the equipment or change to a lower transmit frequency. If overall gain is set too high, the overall gain amplifies noise within the image and reduces both spatial and contrast resolution.
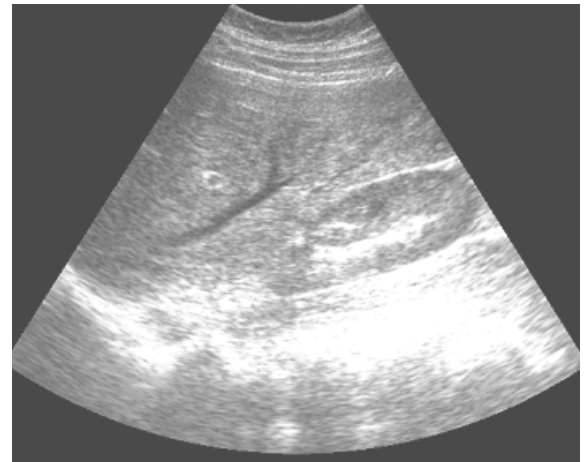

If overall gain is set too low, the result is too dark and image detail is lost (image on right)
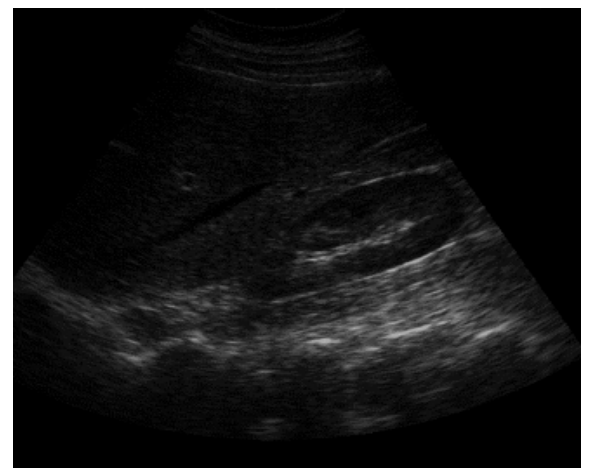
In this image, the overall gain is set so that the intra-hepatic veins appear black and the liver parenchyma is within the mid grey range. TGC is adjusted so that the liver is of a uniform brightness regardless of depth. No part of the image is saturated.

Depth is indicated on the monitor by a line of cm markers. The depth control should be set to demonstrate the whole region of interest during an initial survey of the area, as in this image.
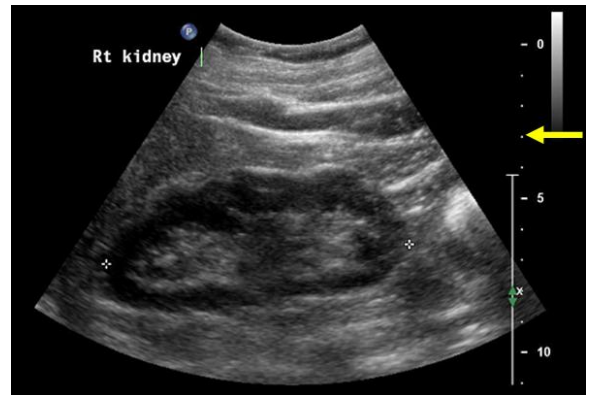
During interventions that may be guided by ultrasound, such as central line placement, it is often more important that the needle tip misses 'innocent bystanders', rather than the target structure being reached on first pass.

Setting the depth inappropriately deep loses temporal resolution, as in the left hand image. On the right, the correct depth setting enables optimal temporal resolution.

Initial depth settings should be set to demonstrate all of the relevant anatomy, not just the most superficial structures, but no deeper than the area of interest.
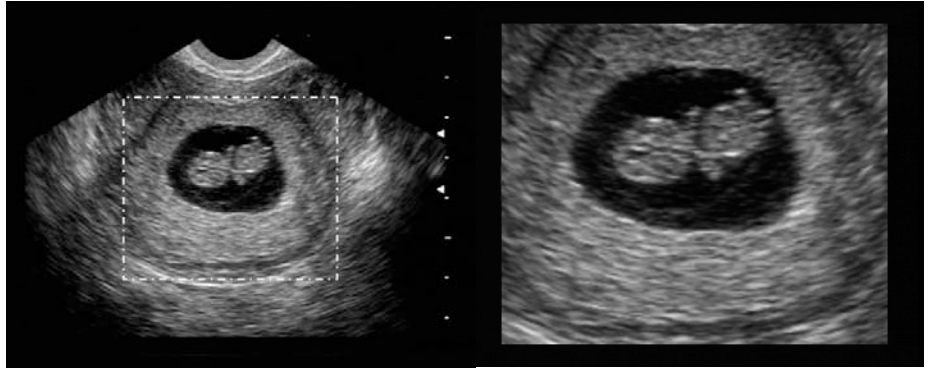
High resolution zoom may be used to provide an expanded view of small structures. A region is selected by placing an on-screen box over the structure of interest, as in the left hand image. The location of the box is, normally, controlled by the tracker ball. Zoom is then activated to provide a high resolution image of this small, defined area, as shown in the right image.

As the depth of interest changes from one structure to another, the depth to which the ultrasound beam is focused needs to be altered, as shown here. This will improve lateral resolution, making it easier to delineate small structures. This is particularly important when imaging structures such as nerves or foreign bodies that are small, and that may be similar in brightness level to surrounding tissues.
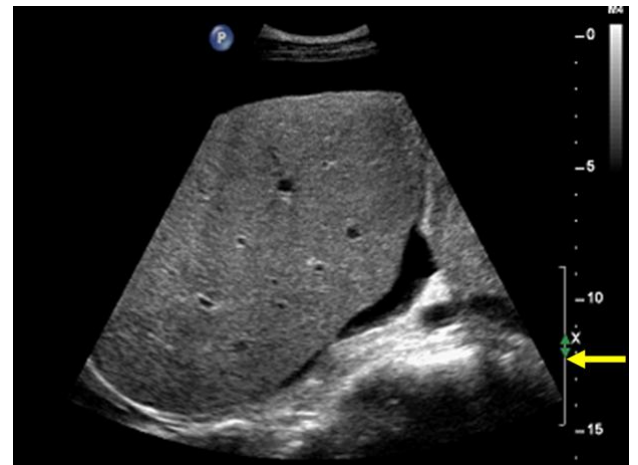
The homogeneous speckle pattern characteristic of many solid organs is, in part, a product of the effective beam width. As beam width is reduced, contrast resolution will improve and structures, such as nerves, will be better visualised. Focus may need to be adjusted throughout the examination.

On some hand-held systems, focus is optimised for the entire depth of view and is altered automatically, as the depth setting is changed. On these systems focus cannot be altered independently.

Image quality

The quality of the image depends on the spatial resolution, which is a function of:

•Axial resolution
•Lateral resolution
•Slice thickness
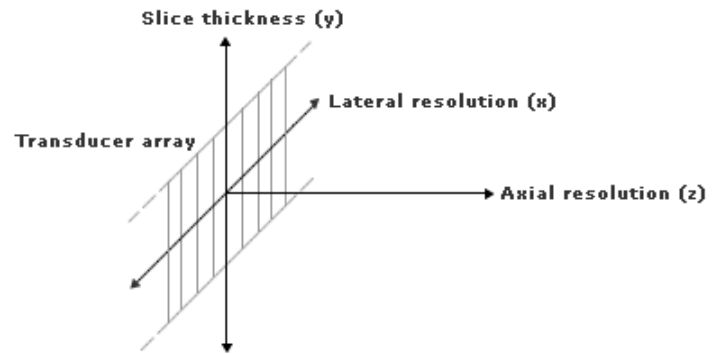
Limits of both spatial and contrast resolution are important in foreign body localisation. This table shows spatial resolution limits:

Axial	Wavelength limited	0.2-0.5 mm
Lateral	Array focusing	1-2 mm
Slice thickness	Lens focusing	≈ 5 mm

Is Ultrasound safe?

Ultrasound has been shown to be relatively safe, but no imaging method which deposits additional energy into the body should be considered entirely risk free. When the decision to make a diagnostic image is made, the physician should always make a conscious judgement about whether the potential benefits of the imaging procedure are greater than any potential risk. As kinetic energy is introduced into tissue, there is potential for both thermal and mechanical damage to cells.
Fractional increases in tissue temperature occur and varying degrees of cell damage have been observed.   While there is no evidence that ultrasound has resulted in actual harm, the fact that these effects may occur should be borne in mind.   For this reason, it is considered good practice to avoid extensive periods of scanning in one patient, unnecessary repeats, unwarranted foetal exposure etc. Anyone undertaking diagnostic ultrasound examinations should comply with the British Medical Ultrasound Society guidelines for the safe use of ultrasound equipment.

Particular care should be taken when scanning:
        -an embryo less than eight weeks after conception
        -the head, brain or spine of any foetus or neonate
        -an eye (in a subject of any age)
N.B. The use of Doppler is normally contraindicated in each of the above.

A further potential hazard of ultrasound is the risk of cross infection. Transducers should be cleaned after each patient with a non-alcohol based cleaning fluid or wipe. Alcohol-based cleaners should be avoided as, over time, these will dissolve the thin protective layer that covers the transducer crystals and will invalidate any warranty.

Key Points

•It is two-dimensional, real time B-mode scanning which forms the basis for Emergency Medicine scans, such as FAST and AAA
•In practice, use the highest frequency that allows adequate penetration to the depth of interest
•Initial depth settings should be set to demonstrate all of the relevant anatomy, not just the most superficial structures. Further, initial depth settings should be no deeper than the area of interest
•The cine-loop feature allows the operator to scroll back through several seconds worth of captured frames once the image has been frozen. This is particularly useful when imaging non-cooperative patients

3.2 FAST

Ultrasound has been used in the early assessment of abdominal trauma in countries outside the United Kingdom for the past 30 years. Over the last 15 years, increasing evidence of the utility of the technique has been published, and it is now widely practiced[1-5]. It has the advantage of being noninvasive, rapidly performed and readily repeatable. Although Chambers et al published a report in 1988 on use of ultrasound[6], there has been little other evidence published from the UK until 2000. There is growing interest in ultrasound use by non-radiologists in this country with increasing availability of affordable systems, and various authors having published recent evaluations of the technique by a small group of sonographers among the trauma staff[7,8].

The purpose of ultrasound in the initial assessment of abdominal trauma, is solely to document the presence of free intraperitoneal fluid. In the context of trauma this fluid is assumed to be blood but this may not actually be the case. There is no attempt to visualise specific organ injuries, as ultrasound is not accurate in the early assessment of solid organ or hollow viscus injury[9]. The absence of free fluid does not exclude serious intra-abdominal injury.

Further management is dictated by the clinical condition of the patient. Ultrasound is designed to complement other investigations such as Diagnostic Peritoneal Lavage (DPL), which is very sensitive but not without disadvantages. However, Computed Tomography (CT) remains the gold standard.

The fact that there is usually some delay in obtaining a CT scan, and transfer out of the department necessitates a haemodynamically stable patient, means that ultrasound in the resuscitation room becomes very useful in rapid diagnosis.
Key point: Ultrasound complements other investigations, and CT remains the gold standard to detect intra-abdominal injury.

Focused Assessment with Sonography in Trauma (FAST) has largely replaced DPL which, while sensitive, is regarded as invasive, compromising other investigations and time consuming. The advantage of FAST is that it can be repeated as many times as necessary. It can be carried out during clinical assessment, within minutes of the patient arriving and before any other investigation, such as CT, can be organized. It can also be carried out on an unstable patient where a CT requires the patient to be stable.

As in most aspects of non-radiologist ultrasound it should be operated on a 'rule in', not a rule out principle, i.e. there is no such thing as a normal FAST. This is important when communicating findings to colleagues. It is appropriate to say that free fluid has not been seen, but this should be qualified by the statement that this does not mean that bleeding is not occurring.

Review of published literature shows that there is no agreed training schedule, with programmes varying widely, from one hour lecture and one hour practical training, to over 500 supervised scans.[10-12] Shackford et al suggested that the error rate stabilised after ten scans.[13] Published data reveals that FAST carried out by emergency physicians, has a specificity between 95–100% and a sensitivity of 69–98%. It is clearly very operator dependant.

Branney et al[14] demonstrated that small quantities of fluid (as small as 225 ml) can be detected, but 85% of sonographers will be detecting 850 ml. Therefore, in regard to detecting free fluid, there was no difference between emergency physicians, surgeons or radiologists.

The Standard FAST Views

During the 1990's, six FAST views were described to include two paracolic views, but these paracolic views have generally been dropped. More recently, extended FAST (known as EFAST) is gaining popularity. This includes an upper thoracic view of the right and left lung fields, to look for signs of pneumothorax. EFAST is not part of Level 1 training, although the upper thoracic views are readily learned later. Furthermore, ACES (Abdominal and Cardiac Evaluation with Sonography in Shock) combines IVC visualisation and a view of the myocardium together with AAA and FAST, and this is also gaining a place in Critical Care Ultrasound.
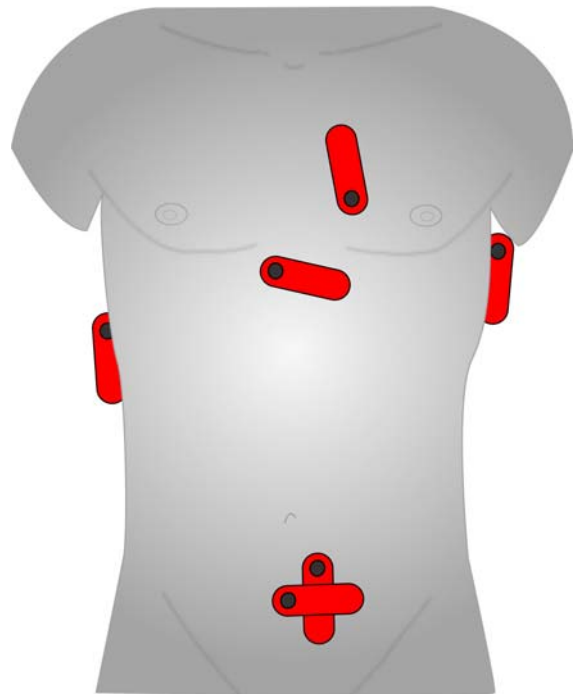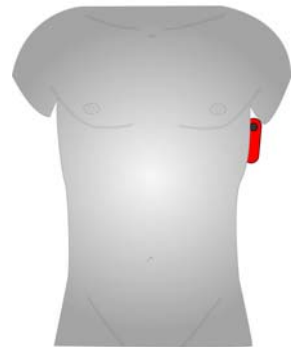
The standard FAST views are as listed below:

- The right upper quadrant (RUQ), to include Morison's pouch and the right costo-phrenic pleural recess
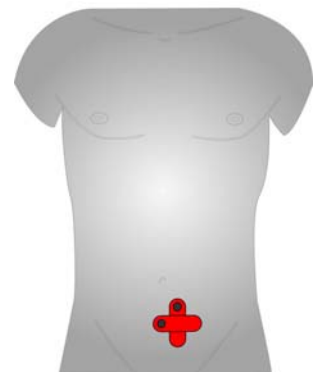
- The left upper quadrant (LUQ), to include the spleno-renal recess and the left costo-phrenic pleural recess

- The pericardial sac, from below or transthoracic

- The pelvic cavity, in two planes

Positioning the Probe – RUQ and LUQ Views

Imagine the probe is a torch and imagine shining it towards the internal area which you want to see. For the RUQ view, start on the right side and site the probe just anterior to the mid-axillary line, angled and slightly backwards, to look at the anterior aspect of the renal capsule.

The LUQ view is a little more difficult to obtain as the left kidney is higher than the right, and therefore the view through an intercostal window may need to be obtained. Site
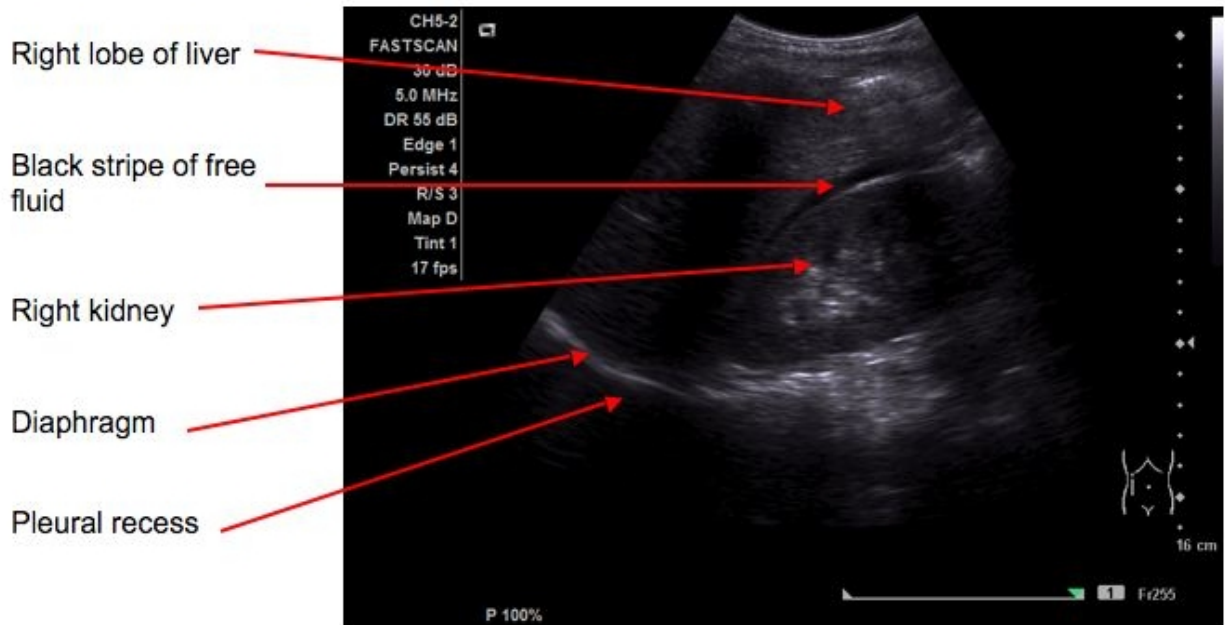
the probe just posterior to the mid-axillary line, angled and slightly backwards, to look at the anterior aspect of the renal capsule.

Key point: For RUQ and LUQ views, start at the mid-axillary line and angle the probe slightly backwards: the LUQ probe position is always slightly more towards the axilla.

For the pericardial view, try the sub-xyphoid approach first. Alternatively, the parasternal view may be better. In this instance, the marker should point down to the heart apex to gain a standard view.

For the pelvis sagittal view, position the probe as shown. A transverse view should also be obtained.

Key point: The marker on the probe should always be orientated towards the patient's head, or to their right (except in the long axis parasternal view).

One of the practical considerations in FAST image acquisition is moving the patient's arms, particularly when the cot sides are elevated. Obviously this can be difficult in a resuscitation setting.

Interpretation
Free fluid looks black, both in the peritoneal cavity and pleural recess. Early peritoneal collections are seen just anterior to the renal capsule and appear as a black stripe.

Small pleural collections begin to accumulate posteriorly, therefore may not be seen during a FAST scan. In the image shown the FAST appearances were normal but the CT revealed a small left haemothorax.

If no free fluid is seen consider a repeat scan, perhaps 10 minutes later. If at any stage a black line anterior to the renal capsule, or black area in the pleural recess is present, the interpretation should be that there is free fluid present. Be cautious in making the assumption that this is blood - as previously referred to.
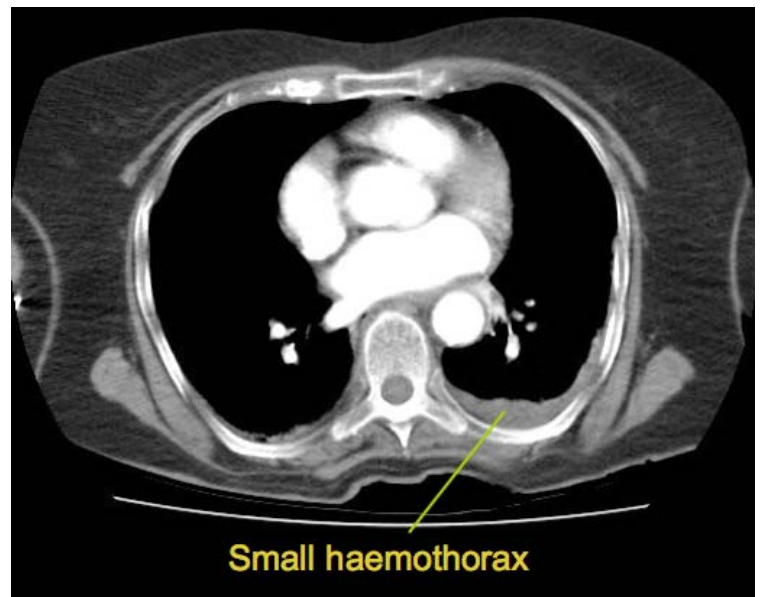

Small haemothorax

Image Appearances - Right Upper Quadrant
The RUQ is the area to scan first, as free fluid will often be seen in this area earlier than in other areas (as shown). In addition, this is probably the easiest area to scan and in which to gain confidence. Ensure the pleural recess is adequately seen.
Key point: The RUQ is the area where free fluid is likely to be detected first.
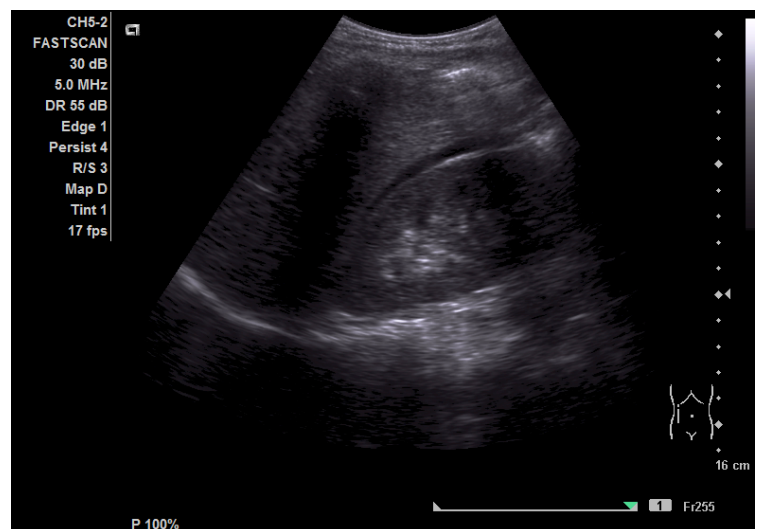

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Image Appearances - Left Upper Quadrant
The LUQ is the area to scan next. Position the probe as shown in the diagram, slightly closer to the axilla than for the RUQ view.
Key point: The LUQ view requires the probe to be slightly higher, i.e. toward the axilla, than the RUQ view.

Image Appearances - Pleura
The pleural space can be visualized in the RUQ and LUQ views. Pleural (and peritoneal) fluid is shown here in the RUQ view.
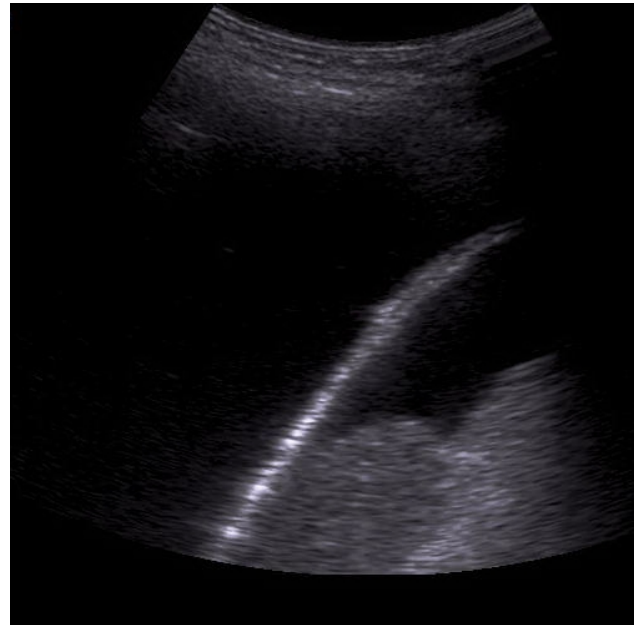
Image Appearances - Pericardium
The pericardium can be visualised sub-xiphisternally or parasternally. It is easier to carry this out using a parasternal view in the left parasternal area. The settings need to be changed to limit the view to the area being examined. With more advanced practice, the emergency sonographer will learn to look at the back of the posterior aspects of the pericardial sac and not at the anterior aspects, as in a supine patient this is where fluid will begin to pool earlier. In this apical view there is pericardial fluid present.
Key point: Pericardial collections will be seen posteriorly at first.
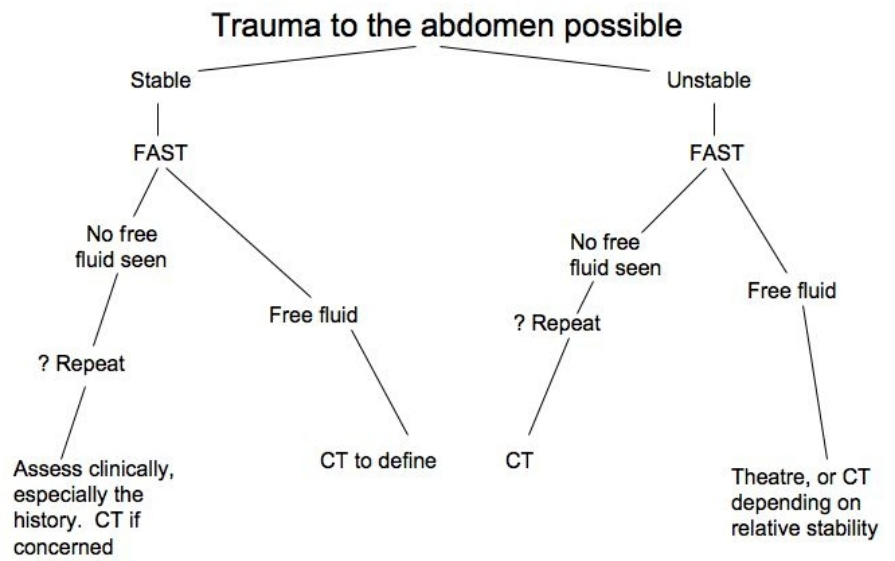
Image Appearances - Pelvic Cavity

The pelvic cavity is a more difficult area to scan and takes experience. The typical appearance of small bowel loops floating in fluid is shown, but much smaller volumes of fluid in the retrovesical pouch in the male, or the pouch of Douglas in the female, can be diagnostic. The technique for selecting these areas needs to be mastered in a practical session. A small amount of fluid in the pouch of Douglas, in the female pelvis, may be normal following ovulation.
Key point: Don't assume free fluid is blood.


Algorithm for FAST

FAST is no substitute for CT and a more definitive assessment of the patient is obtained with CT. Indeed a positive FAST scan in a stable patient should always lead to a CT scan. This defines with precision where the pathology is within the peritoneal cavity, and furnishes the surgeon with as much information as possible. A positive scan in an unstable patient may result in the surgeon feeling that immediate laparotomy is appropriate. This depends on the experience of the surgeon and a degree of confidence that the fluid is not due to pelvic venous bleeding.

Trauma to the abdomen possible

Stable — FAST
- No free fluid seen → ? Repeat → Assess clinically, especially the history. CT if concerned
- Free fluid → CT to define

Unstable — FAST
- No free fluid seen → ? Repeat → CT
- Free fluid → Theatre, or CT depending on relative stability

***Using FAST skills for Echocardiography in Life Support (ELS) –****see section 3.5*

Echocardiography in Life Support (ELS) is learned alongside FAST. It requires careful timing with the rhythm check. During this 10-second window the probe is often set to maximum depth and increased gain, to increase the likelihood of locating the heart rapidly. If the heart cannot be seen during the rhythm check, the probe should be removed at 10 seconds and CPR recommenced.
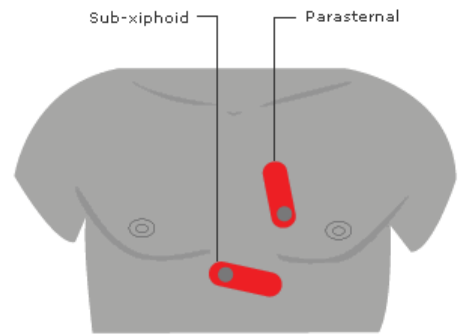
The technique of Echocardiography in Life Support (ELS), may be carried out with the probe in the sub-xiphoid position, but, in fact this view is often not satisfactory, and a switch to the parasternal long axis view can give better views, and is easier to carry out.

Key point: ELS has two priorities, to assess cardiac movement and to identify remediable pathology.
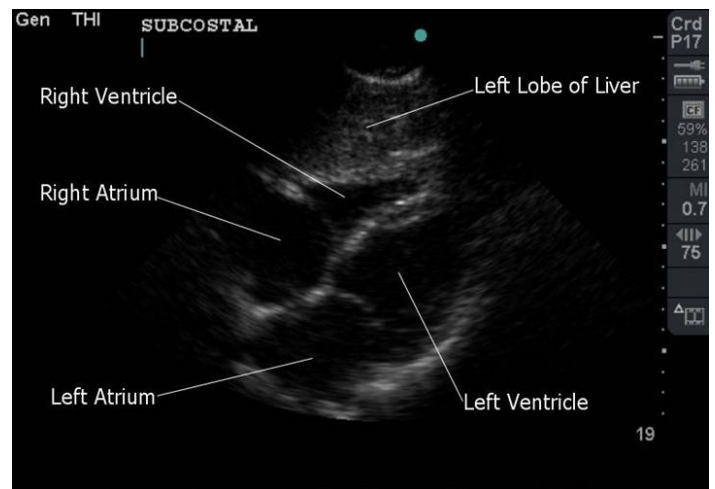
In ELS there are two priorities, namely:
(i) to assess cardiac movement and (ii) to identify remediable pathology

In assessing cardiac movement, three possibilities exist:

1. There is no cardiac movement. If the heart is seen to be motionless and this corresponds with asystole on the monitor, survival is highly unlikely. Identifying this clinical picture can aid the practitioner in decision making during a cardiac arrest.

2. There is cardiac movement with sinus rhythm on the monitor. If the carotid pulse is absent, the patient has a condition known as 'pseudo-PEA' in which there is mechanical action of the heart, but of insufficient magnitude to generate a pulse.[15] The importance of identifying this condition is that survival is much higher in these patients.[16]

3. There is visible ventricular fibrillation. Patients thought to be in asystole have been found to have VF on echocardiography.[17] Such patients obviously require cardioversion.

The two main conditions that may respond to immediate treatment are:

•Pericardial effusion sufficiently large to cause tamponade. Tamponade is a physiological diagnosis that is virtually impossible to make during cardiac arrest without the use of echo. If a large effusion is identified, this needs to be put into context with the overall clinical situation, but pericardiocentesis must be considered.

•Massive pulmonary emoblism (PE). Features of massive PE include presence of visible thrombus in the heart, a right ventricle diameter to left ventricle diameter ratio greater than one, and a dilated inferior vena cava (see the session Soft Tissue Musculoskeletal / Ultrasound / Skills of Carrying Out Assessment For Abdominal Aortic Aneurysm). If massive PE is strongly suspected, appropriate action should be taken (e.g. thrombolysis).

3.3 Assessment of the Abdominal Aorta and IVC

Ultrasound is routinely used for the screening and monitoring of aortic diameter, and a limited ultrasound scan can reliably record the presence of an AAA.   Approximately 90-95 % of abdominal aortic aneurysms (AAA) are confined to the infrarenal aorta. The risk of rupture within 5 years is 25 % at 5 cm diameter. AAA smaller than 5 cm have a 3 % risk of rupture over 10 years. In the acute setting an AAA is defined as a transverse aortic diameter greater than 3 cm.

Aorta = 92.8mm

The role of ultrasound is to detect an enlarged abdominal aorta at the earliest clinical opportunity. If a normal aorta is clearly seen along its full extent then an aortic aneurysm can be excluded. However, it must always be borne in mind that there are other, more rare aneurysms, e.g. splenic artery. The use of ultrasound by emergency physicians is becoming increasingly popular in the UK. The immediacy and availability of bedside ultrasound in the Emergency Department means that critical management decisions can be made earlier.

As the clinical assessment of the abdominal aorta for AAA has shown to be unreliable[15], one of the key roles, identified internationally for emergency physician performed ultrasound, is early identification of abdominal aortic aneurysms (AAA). Internationally, studies have demonstrated that emergency physicians can accurately perform aortic ultrasound scans with relatively little training.[16–19]

In the emergency setting it is usually difficult to define the limits or relations of the aneurysm, so we would usually concentrate on the single issue of whether it is aneurysmal or not. Similarly, ultrasound is not accurate in determining the presence of a leak from the
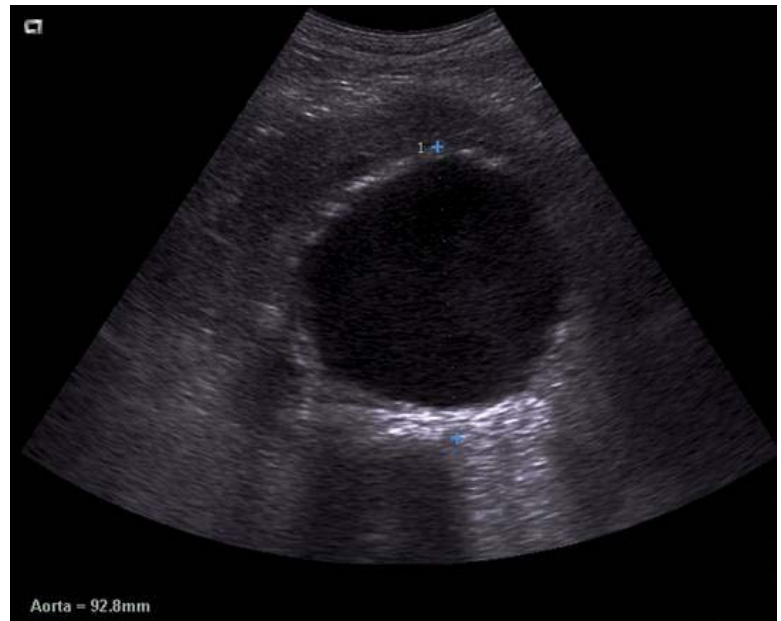
aneurysm. Again we concentrate on whether aneurysmal change is present or not. The current evidence for the diagnostic ability of emergency physician ultrasound, for detection of AAA, is based on a number of international small cohort studies.[16-19] These series report high sensitivities (94–100 %) and specificities (98–100 %).

UK emergency physicians can accurately and usefully undertake emergency ultrasound scans to detect AAA, with a sensitivity comparable to that obtained internationally. Emergency ultrasound, performed by UK emergency physicians, has been reported as having the following accuracy profile for the detection of AAA[20]:

D1 = 34.1mm

•Sensitivity of 96.3 % (95 % confidence interval (CI), 81.0 % to 99.9 %)
•Specificity of 100 % (95 % CI, 91.8 % to 100 %)
•Negative predictive value of 98.6 % (95 % CI, 88.0 % to 99.9 %)
•Positive predictive value of 100 % (95 % CI, 86.8 % to 100 %)
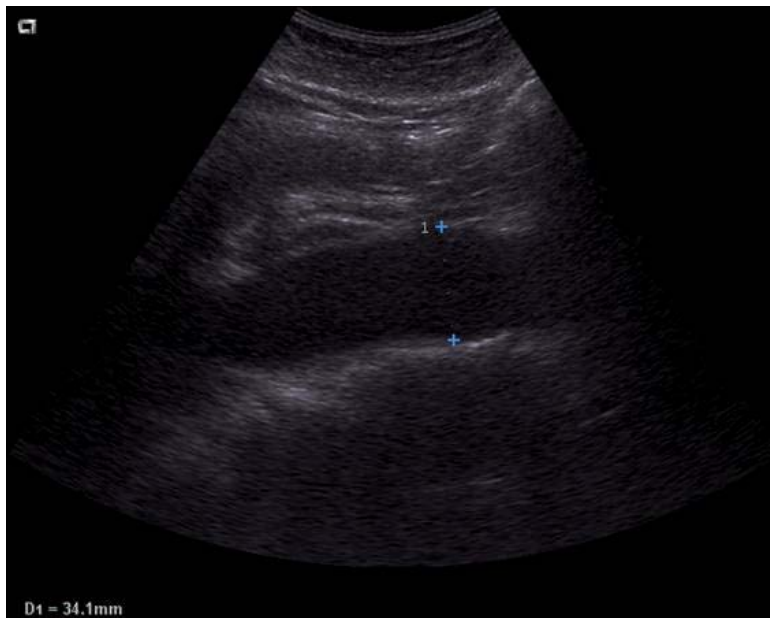
Benefits appear considerable. Sierzenski's work[22] indicates that emergency physician ultrasound decreases the time to diagnosis in ruptured AAA. The mean time of 180 minutes was reduced to 80 minutes. In addition, the time to CT scan is also reduced, as is the time to operative repair.

Emergency Medicine AAA assessment is a focused examination to answer a single clinical question, i.e. **"Is an abdominal aortic aneurysm (with a diameter greater than 3cm) present?"**

As in all areas of Emergency Medicine ultrasound we 'rule in' pathology rather than rule it out. Having said this, if the entire aorta is confidently seen, an AAA will not be present. The combination of an aneurysm on ultrasound, and an unstable or symptomatic patient, is enough to warrant an emergency vascular surgery opinion.

Aortic aneurysm is more prevalent in elderly men (male:female ratio is 4:1), and the incidence has been estimated at 11 % in men over 65.[23] It is related to, and therefore may co-exist with, other atheromatous diseases, such as myocardial infarction, stroke and mesenteric ischaemia. It has been estimated that, of those who suffer a ruptured aortic aneurysm in the community, only about 50 % will reach hospital alive. Furthermore, the 30-day mortality rate of those with a ruptured aneurysm who reach surgery, is also approximately 50 %. As a result, short-term survival after a ruptured AAA is 1 in 4, whereas mortality following elective surgery is less than 5 %. Detecting a quiescent aortic aneurysm in the emergency department may therefore be lifesaving.
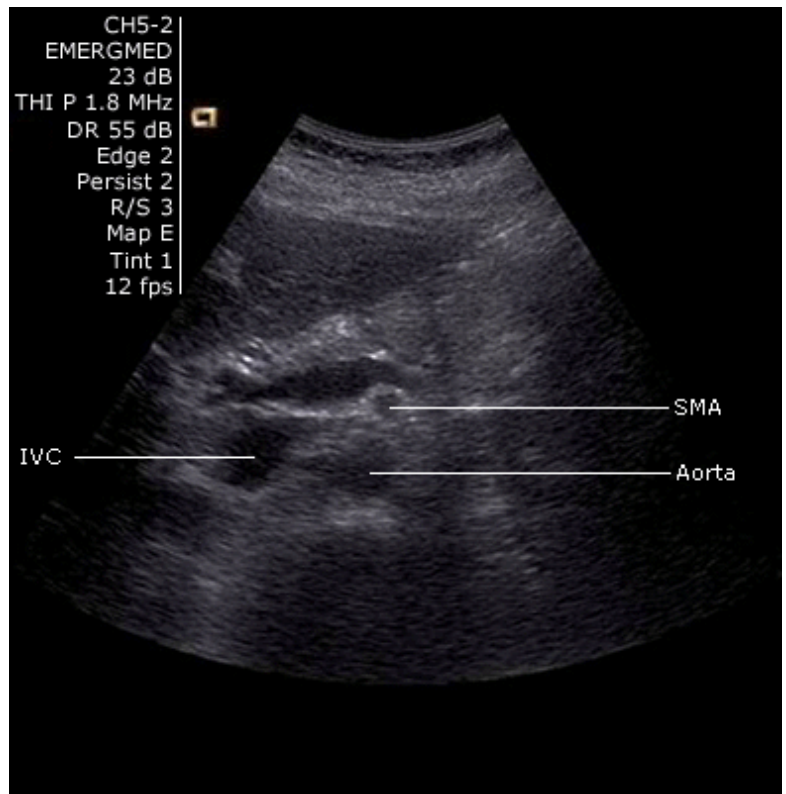
The inferior vena cava (IVC) and aorta are both seen in most cases, as in this ultrasound scan. It is possible for a novice to confuse the two.

The aorta is situated anterior to the vertebral bodies and left of midline, whereas the IVC lies to the right of midline. The aorta tapers and tends to be tortuous and move to the left. It can be calcified anteriorly which can make the ultrasound view more difficult.

The main features of the IVC are:
•Right side
•Thin walled
•Compressible
•Transmitted pulse ('double bounce')
•Almond shaped (Shape varies)

The main features of the aorta are:
•Left side
•Thick walled
•Will not compress
•Pulsatile
•Round in shape
•Constant shape
•Superior mesenteric artery (SMA) demonstrated

Before starting to scan the aorta, it is helpful to understand the anatomy, which is shown in the image. Note the branches of the coeliac axis and its relationship to the superior mesenteric artery (SMA).

The coeliac axis is 1-2 cm below the diaphragm, the superior mesenteric artery is 2 cm below the coeliac axis, the inferior mesenteric artery is 4 cm above the bifurcation, the aorta bifurcates at, or immediately below, the umbilicus (L4), the maximum external diameter (measured from outer wall to outer wall) at different levels will vary, ie 3cm at the epigastrium, 1.5cm at the bifurcation

Fusiform aneurysms are the type most commonly seen in the abdominal aorta. Most fusiform aneurysms are true aneurysms. The weakness is often along an extended section of the aorta and involves the aorta's entire circumference. The weakened portion appears as a roughly symmetrical bulge, as shown in the image.

Saccular aneurysms appear like a small blister or bleb on the side of the aorta and are asymmetrical. They may be pseudoaneurysms caused by trauma, such as a car accident, or by a penetrating aortic ulcer.

Dissecting aneurysms occur when a tear begins within the wall of the aorta causing the wall layers to separate. Dissections can cause aneurysms, but an existing aneurysm can also dissect. This is more commonly seen in the thoracic aorta.

Traditional screening for suspected AAA has been physical examination plus further imaging for high risk cases. At best this method is only 68 % sensitive for AAA. Computed tomography is the gold standard investigation, but can lead to a delay in definitive diagnosis and treatment. An early ultrasound scan is the primary investigation of choice. This is helpful for those patients who are requiring resuscitation, and also for those patients in whom one wants to identify an aneurysm early, so as to ensure an optimal clinical management plan.
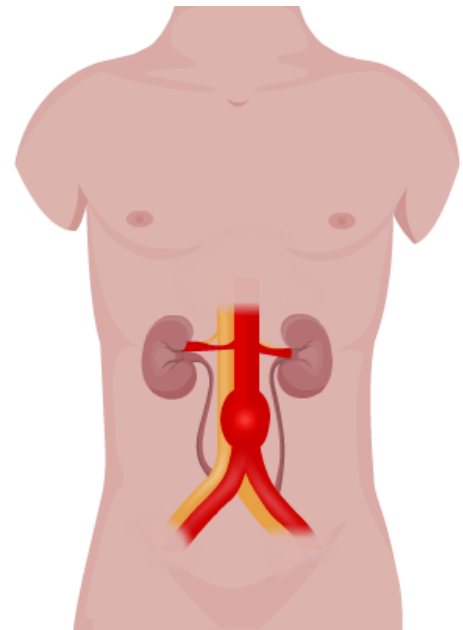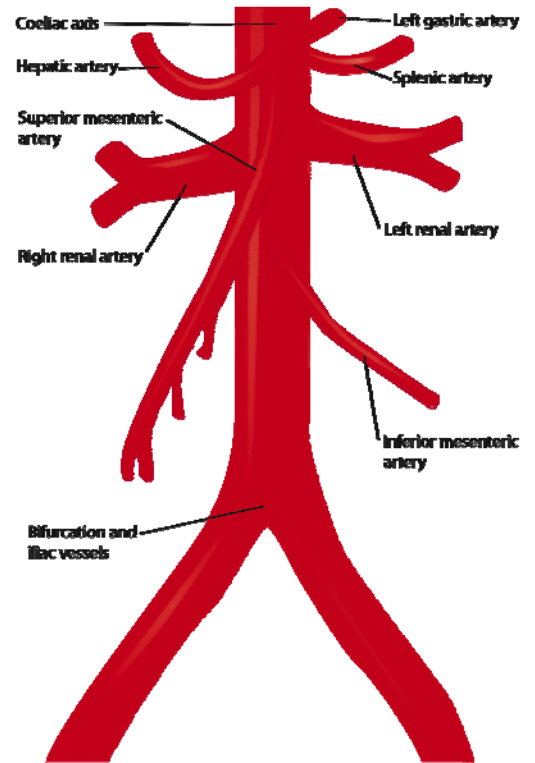
*Key point: As abdominal pain and collapse are common, a low threshold should exist for scanning the abdominal aorta in Emergency Department patients.*

A scan should always be carried out when an AAA is suspected. Features of a suspected abdominal aortic aneurysm include:

- Unexplained back or abdominal pain in an older patient
- Renal colic in an older patient
- Syncopal episode in an older patient
- Clinical examination
- Risk factors - Ischaemic heart disease (IHD)/ Peripheral vascular disease (PVD)/ age
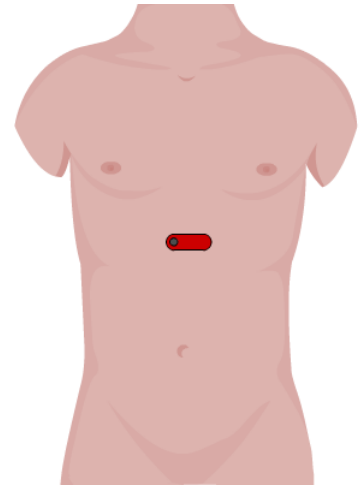
Imagine <u>the probe is a torch</u>, and imagine shining it towards the internal area which you want to see. Start at **the epigastrium**. Aim to get as high as you can for the first view. If the patient has eaten recently it may not be possible to view beyond the stomach/duodenum. Firstly, begin with the patient in the supine position. Start with a transverse section. Identify the vertebral body (pre-vertebral stripe and acoustic shadow). The aorta lies anterior to the echo-bright pre-vertebral stripe. Use the left lobe of the liver as the initial acoustic window.
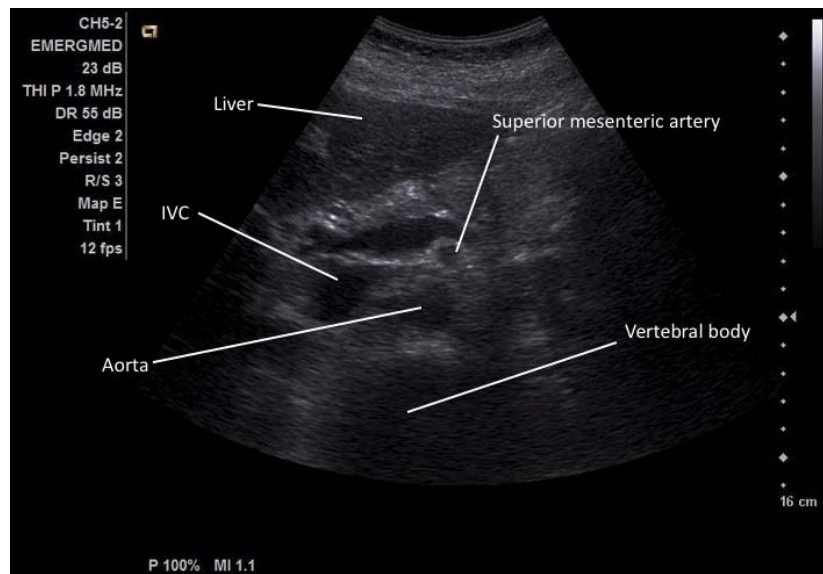

You should image, as shown, the coeliac axis, then the superior mesenteric artery (SMA). Lower you will find the renal vessels, and around the umbilicus the bifurcation and origin of the iliac arteries.

*Key point: Start in transverse section before moving on to a longitudinal section.*

37
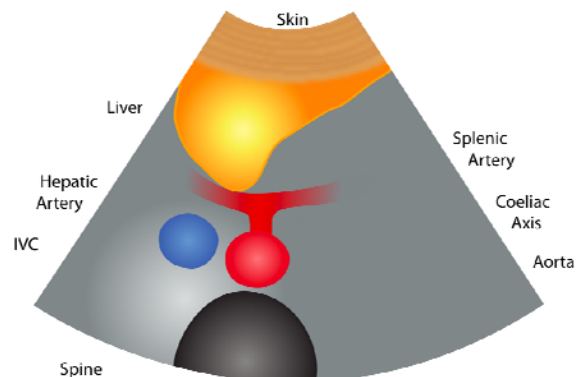
The coeliac axis is seen high in the epigastrium. The division into splenic artery and hepatic artery is said to resemble the wings of a seagull, with each division appearing as a wing. Often bowel gas obscures the coeliac axis, and this view may be difficult to obtain.
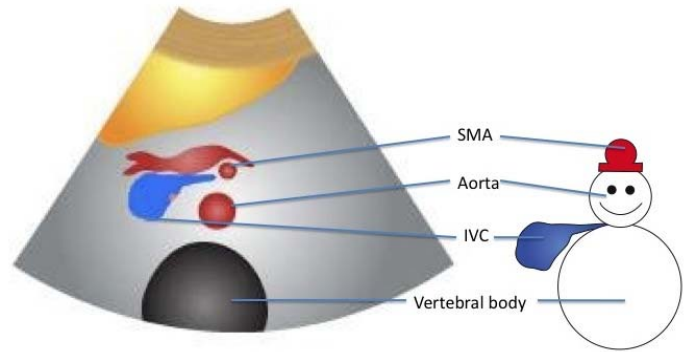
Lower down is the superior mesenteric artery (SMA), which has a characteristic appearance. When seen in transverse section, it is important that the 'snowman' be recognised.

Secondly, obtain **longitudinal images** of the entire abdominal aorta. Notice how in the image the aorta moves from quite deep at the diaphragm, to much more shallow at the umbilicus. This is due to the normal lumbar lordosis.
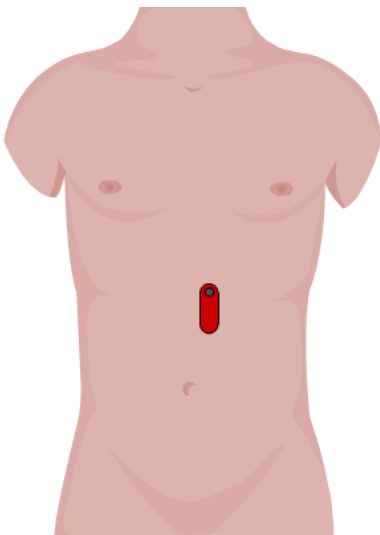
The SMA is readily seen, together with the lumbar vertebral bodies and discs in the background.
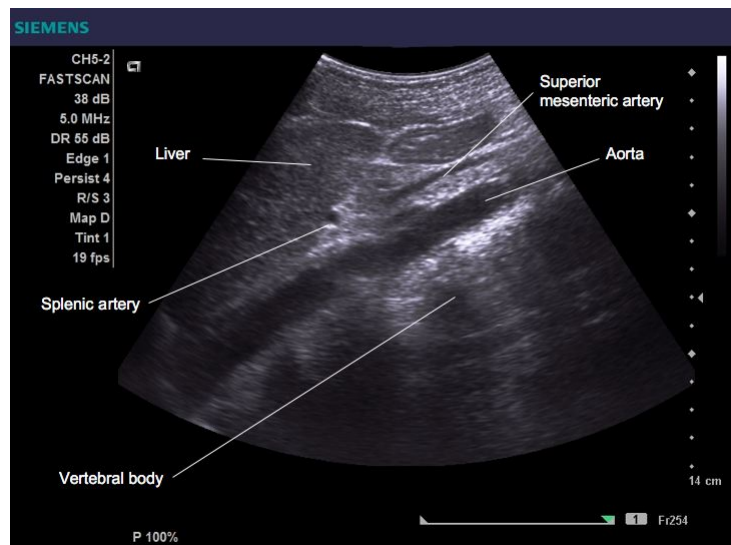
Thirdly, move the **probe** slightly over to the right to view the inferior vena cava (IVC) in longitudinal section. Viewing the IVC as it passes through the diaphragm can give an indication of the load on the right side of the heart.

In unventilated patients, if the IVC diameter (IVCD) is >25 mm with minimal collapse, this is indicative of increased right atrial pressure (RAP) e.g. cor pulmonale, fluid overload. A diameter of <15 mm with complete collapse is indicative of being under filled[24].
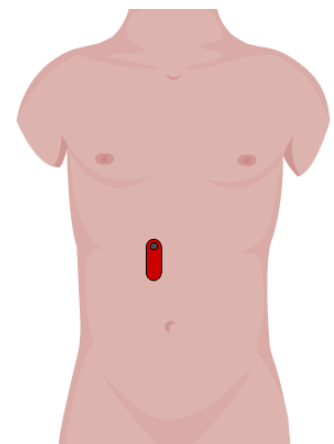
In ventilated patients, the correlation between the IVCD and RAP is less reliable. Research suggests that assessment at end-expiration using ECG synchronisation improves correlation. Furthermore, diameters over 12 mm appear to have no predictive value of RAP, whereas diameters below 12mm may. An IVCD that is seen to vary throughout the respiratory cycle has been associated with fluid responsiveness, whereas minimally varying IVCD has been associated with less fluid responsiveness.

Key point: IVC assessment can give an indication of hydration.

Finally, measure the antero-posterior diameter of the aorta. The measurements should be from outer wall to outer wall of the vessel. Any clot or false lumen should be ignored when measuring.

Be careful to avoid two pitfalls. One is taking a non-perpendicular view of the vessel, thereby creating a 'salami slice' with over-estimation of the diameter. As the aorta is angled against the lumbar lordosis, the probe often needs to point slightly caudally to overcome this. The other is failing to appreciate a tortuous aorta, though this only creates significant problems if transverse measurements are taken.
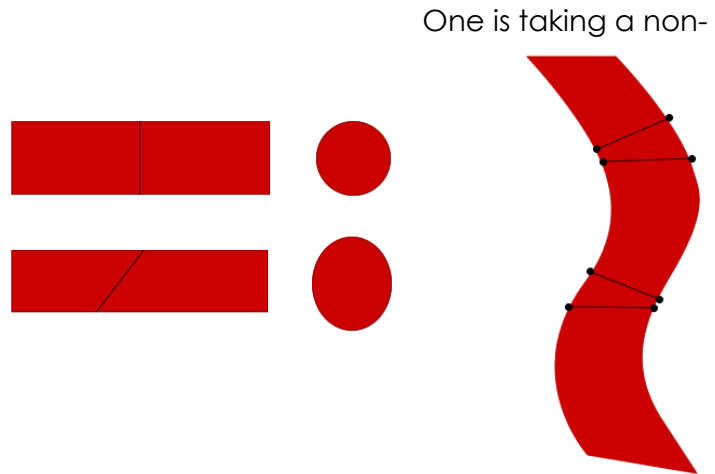
Abnormal appearances can vary immensely, but one common appearance, besides a fusiform aneurysm, is the presence of clot within the lumen. This can easily lead to errors in measurement. In the case shown here, the antero-posterior measurement has been incorrectly assessed at 37.1 mm, whereas the aneurysm is actually around 60 mm in diameter. This is a serious error, as the risk of rupture at 37 mm is considerably less than at 60 mm.

There are many pitfalls in AAA scanning, predominantly by not assessing the patient clinically.   Be wary of diagnosing 'renal colic' or musculoskeletal back pain in any patient over 60 years of age without first excluding AAA. Any patient, presenting with renal colic in this age group, should have an ultrasound scan to ensure that the aorta is non-aneurysmal.

Do not exclude an AAA unless the whole abdominal aorta and proximal iliac arteries have been visualised. At all times think about the history and context, and ensure you are attempting to answer a legitimate question.

3.4 Ultrasound Guided Vascular Access

Context

In routine Emergency Medicine practice we use peripheral venous, central venous and arterial catheters in adults and children. Ultrasound has been used to assist line placement for over 20 years. We know that Ultrasound aids placement of central lines as well as peripheral lines, both in terms of speed of access and reduction of complications[25,26]. The National Institute for Clinical Excellence (NICE)[27] has highlighted the need for the use of ultrasound to guide central venous access cannulation, and it has been this recommendation that has partly driven the wider use of ultrasound in Emergency Medicine[28]. This learning session will cover the indications and techniques for jugular, femoral and peripheral cannulation.

Indications

The indications for the use of ultrasound in vascular access vary. In central access, ultrasound should be used at all times[29] unless time-critical intervention mandates otherwise (e.g. in cardiac arrest)[27]. In femoral access, it is a very useful adjunct. In peripheral access it has a use when conventional access fails. This may be in an ill patient who is shut-down, or in an

intravenous drug user whose veins are damaged. In both instances the basilic vein medial to the biceps above the elbow is usually accessible and patent. Peripheral cannulation, whilst invasive, does not carry the risks of air embolism, bleeding and damage to other structures that jugular and femoral cannulation carries.

The use of a central cannula is immensely helpful when assessing filling pressures in cases where there is significant potential for misjudging intra-venous fluid resuscitation. This is particularly the case in the elderly whose physiology allows much less margin of error.

Other sources of information however, are urinary output, and ultrasound assessment of the inferior vena cava (IVC). Viewing the IVC as it passes through the diaphragm can give an indication of the load on the right side of the heart.   If the diameter is >2.5 cm with minimal collapse this is indicative of increased right atrial pressure (e.g. cor pulmonale, fluid overload). A diameter of <1.5cm with complete collapse is indicative of being under filled, and a useful indicator of hypovolaemic shock[30].

Definition
For the purposes of this training document the following terms have these meanings:
- Central venous cannulation means internal jugular cannulation
- Femoral cannulation means the common femoral vein (and not the great saphenous vein sometimes cannulated in error). This may be damaged in intravenous drug users (IVDU)
- Peripheral cannulation refers to basilic vein cannulation

Basic science, anatomy and technical considerations

Ultrasound in Emergency Medicine has become a point-of-care tool, often referred to a "bed-side ultrasound". Its use enables interventions to be made, which, in the case of vascular access, facilitates identification of vascular anatomy and direct visualisation and cannulation of vessels.

The aim is therefore twofold:
- to identify relevant anatomy and pathology prior to cannulation
- to use ultrasound to actually guide the process of cannulation

<u>Identification of structures</u>
The difference between veins and arteries can be determined by compressibility i.e. veins compress and arteries do not. Here is the normal internal jugular vein (IJV) and carotid.
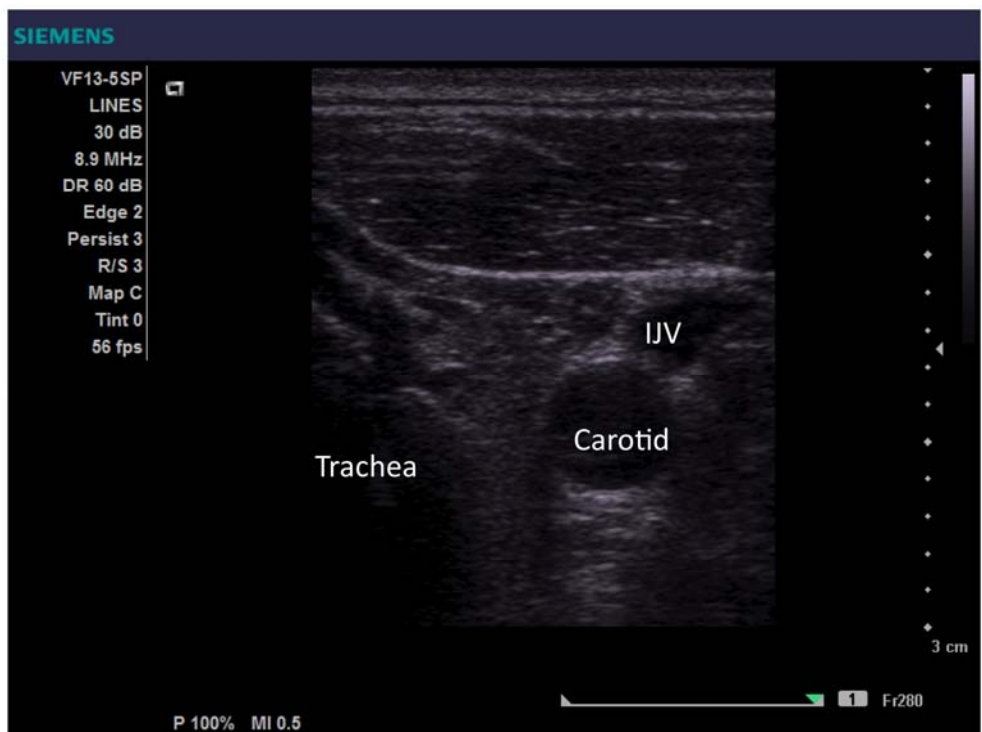
When the probe is pressed into the neck to compress the structures, the vein is obliterated while the artery remains.
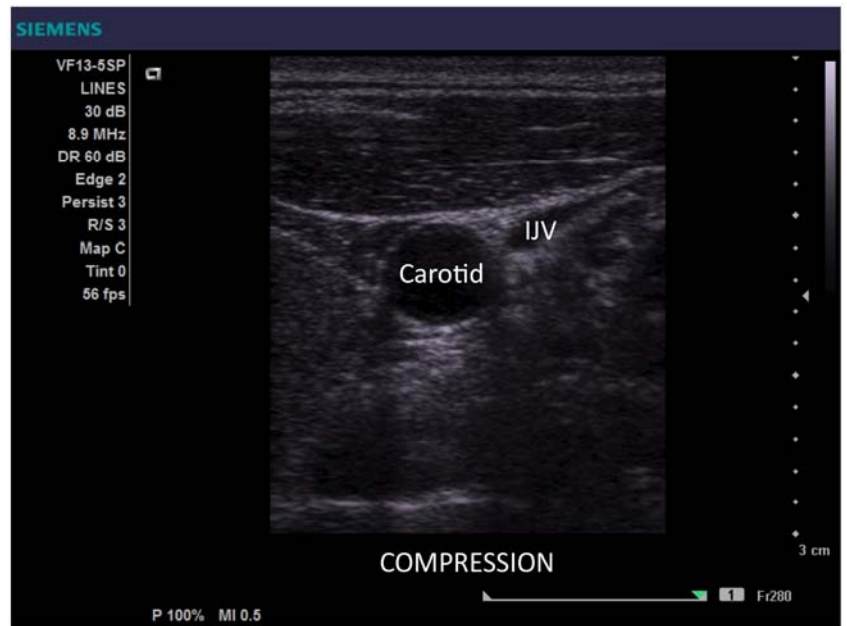
Meanwhile, if the patient carries out a Valsalva manoeuvre, the IJV dilates.

Furthermore, the shape of the vessels is different. Arteries tend to be circular in transverse view, with muscular walls, whereas veins are often oval.
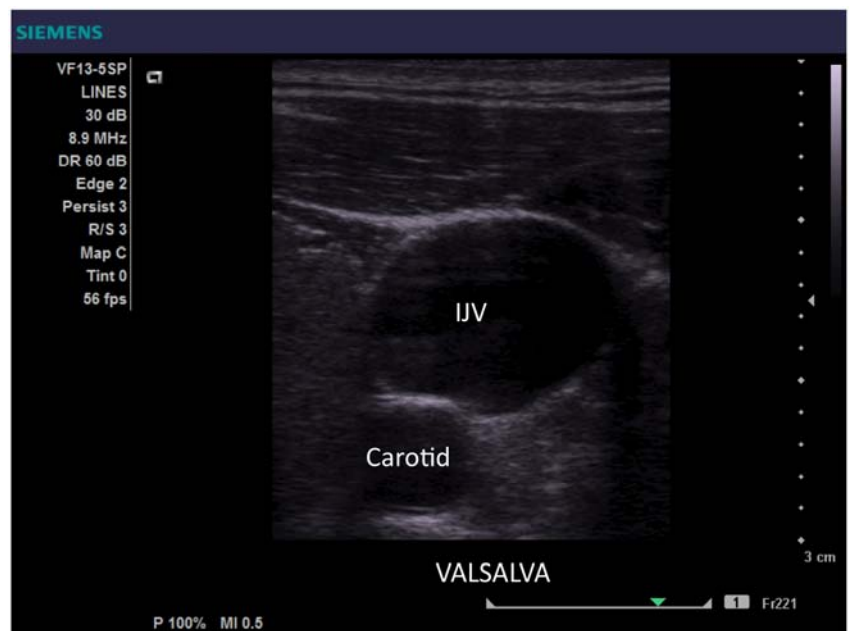
Their flow dynamics differs, and if colour flow is available it can be utilised to determine this. With the probe angled so that flow is marginally towards, or away from the probe, the colour flow convention is:
Blue = Away
Red = Towards
This is easily remembered by the acronym B.A.R.T. This image of a groin A-V fistula shows the value of colour flow.
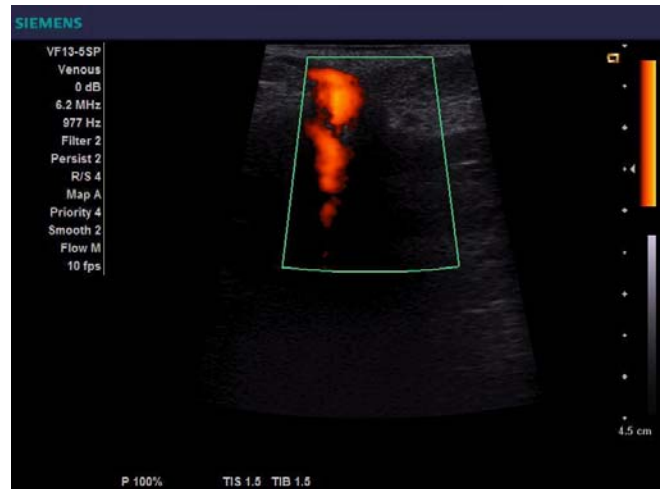
Neck anatomy

The right side of the neck is usually selected to avoid theoretical risk of damage to thoracic duct, which lies on the left. The thoracic duct ascends through the mediastinum and enters to left internal jugular vein. While injury to the thoracic duct is unlikely, it can produce a chylothorax, which is a significant problem[31].

Traditionally the approach was defined by finding the apex of the triangle formed by the confluence of the sternal and clavicular parts of the sterno-cleido-mastoid muscle. Note that excess head rotation can begin to reduce the IJV diameter and is best avoided. With ultrasound guided CVC, the exact approach can be determined by direct visualisation of the anatomy. The approach is still within the triangle, but an optimal site can readily be selected. It is important to palpate the location of the two parts of the sterno-cleido-mastoid muscle, and to recognise them by ultrasound imaging, as a needle should not be introduced through their muscle bulk.

Internal jugular vein
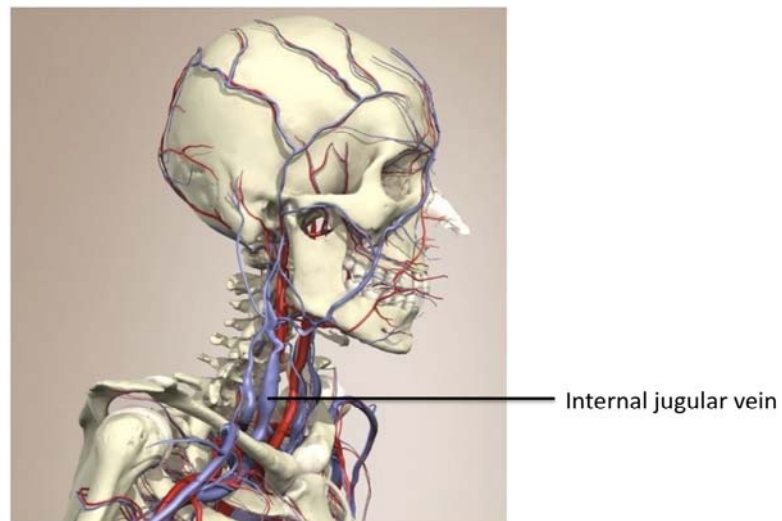
Groin anatomy

In the groin the location of the femoral vein is straightforward – i.e. medial to the artery.

Its depth varies, and ultrasound location aids speed and efficacy of cannulation.

The inguinal ligament is an important landmark, as keeping immediately below it will avoid attempts at cannulating the great saphenous vein.
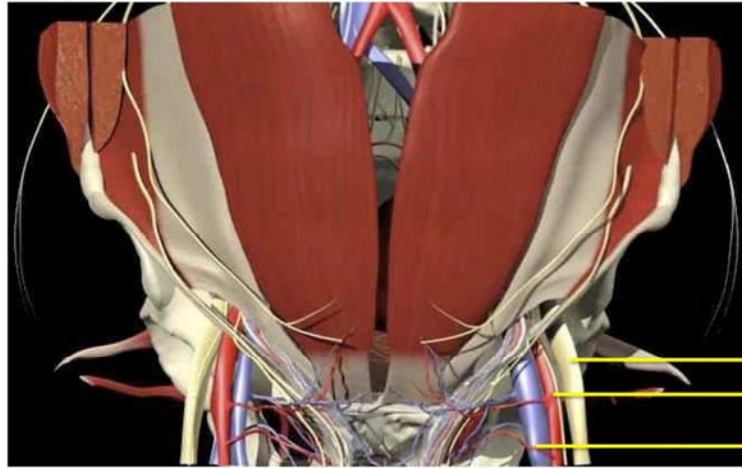
Femoral nerve
Femoral artery
Femoral vein

Basilic vein anatomy

Peripheral cannulation can be attempted at any site, but technical expertise in cannulation of the basilic vein is extremely valuable in Emergency Medicine, as this vein is almost always patent.

It tends to lie at least 5 mm below the skin, and may be deeper. It is found in the recess created by the medial border of the biceps muscle.
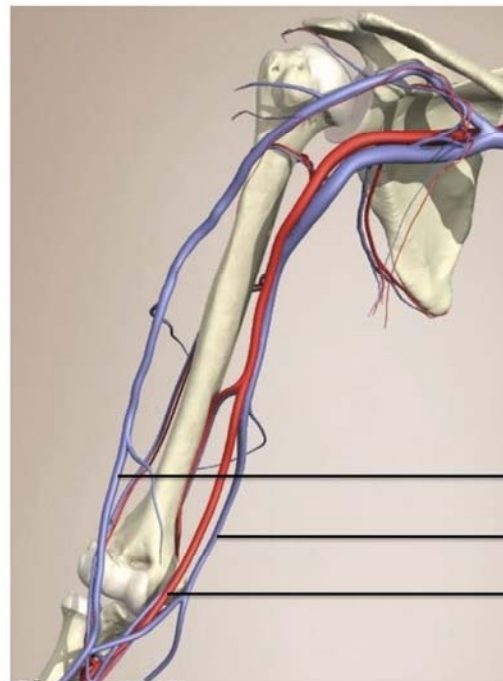
Cephalic vein
Basilic vein
Brachial artery

Technical application of ultrasound when cannulating

In all cases, a linear, high frequency probe should be selected. The machine should be set to a depth of around 5 cm for central access, 4 cm for femoral and 3 cm for basilic cannulation. The TGC should be flat. In all cases avoid zoom or the skin surface will not be seen.

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For a Level 1 trainee, this may be the first use of ultrasound in order to carry out an intervention. There are new skills sets to learn, and two key technical issues when introducing a needle into tissue with the hope of seeing it on the screen. These are:

1. Parallelism
2. Angle of approach

Parallelism is a function of the physical characteristics of a linear probe. The transducer array will effectively "see" a needle only if it sits within the tolerances of the lateral and slice thickness resolution.
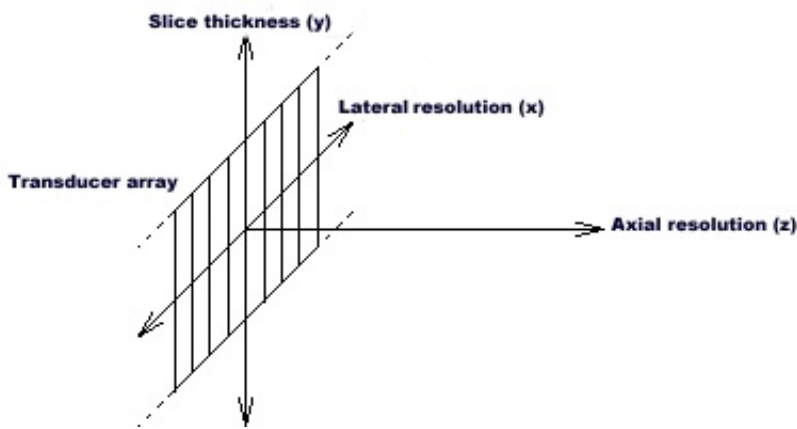
Axial	0.2-0.5 mm
Lateral	1-2 mm
Slice thickness	≈ 5 mm

This is illustrated above, and the typical tolerances are shown in the table. This means that the operator needs to keep the needle within the very narrow slice thickness of the probe, typically 5 mm or less.

The angle of approach of the needle into the tissue is critical. If this is too steep, the reflected sound does not return to the probe, and consequently no image is seen.

Needle introduced too steeply

Skin surface

No reflected sound reaches transducer
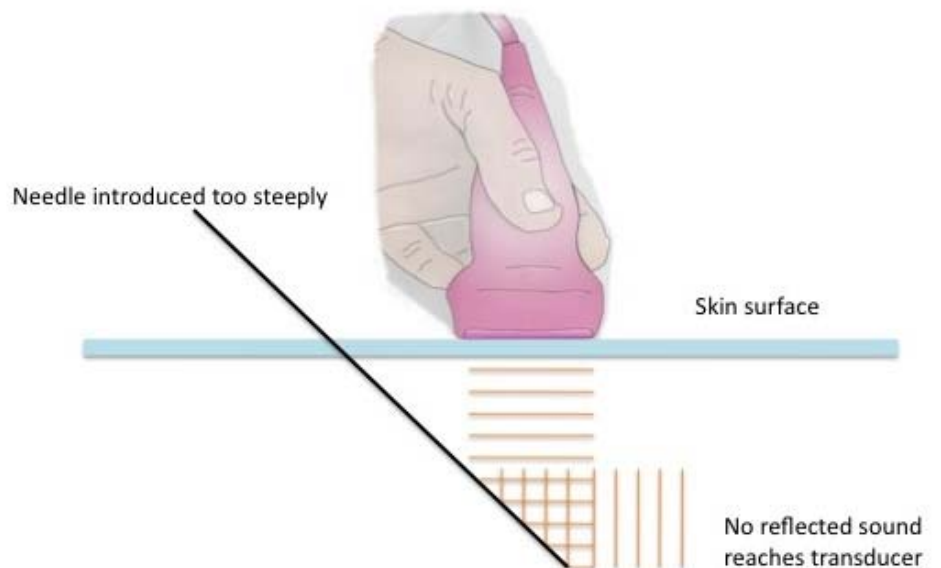
Angles less than 35 degrees to the skin are needed to see the needle, and the smaller the angle, the better the image, as shown here.

Needle introduced as parallel as possible

Skin surface

Reflected sound now reaches transducer
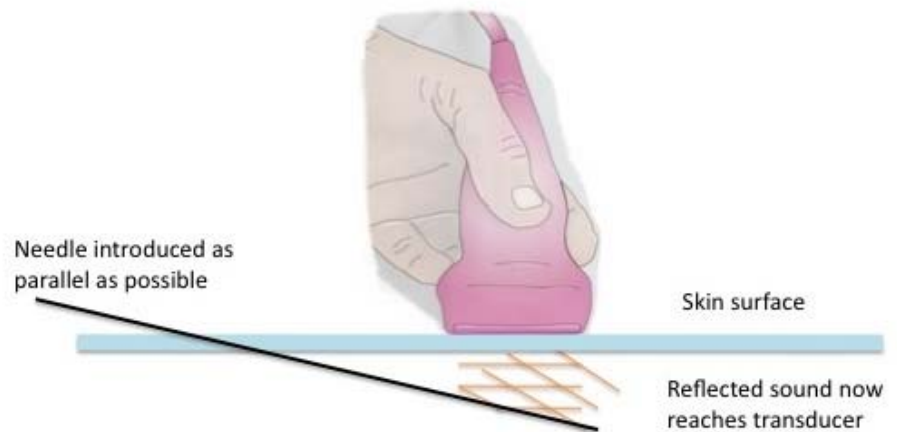
Ultrasound can be used in one of two ways when carrying out invasive procedures:
- Static ultrasound assisted. Anatomic structures are identified and an insertion position is identified with ultrasound. This may be marked on the skin. The cannulation then proceeds as it would without ultrasound and is not performed with the transducer imaging the needle being introduced or entering the vessel. Its use is merely to demonstrate the position of the vessel. In most instances this is sub-optimal, and not recommended.
- Real-time ultrasound guided. The ultrasound transducer is placed in a sterile covering and the procedure is performed with simultaneous ultrasound visualisation of the cannulation. This is recommended.

Clinical assessment & risk stratification
All cannulations, ultrasound guided or otherwise, are obviously undertaken in the light of the clinical setting. The indications have been covered in "Context"; however, it is important to repeat that internal jugular and femoral cannulation are invasive techniques, not without risk of harm, and should have adequate justification.

These techniques can be used in children[32,33], and ultrasound guided femoral cannulation can be rapid and extremely helpful in the very sick child. The groin is often readily available while the neck is not due to airway manoeuvres.

Consent should always be undertaken, which in the relatively critical context of the Emergency Department, will usually be verbal. It is wise to document "Verbal consent obtained" in the notes before starting.

The competent use of ultrasound will always make internal jugular and femoral cannulation safer. We have already stated that its use decreases complications, increases the first-time success of line placement, decreases the number of efforts required and decreases the overall time spent carrying out the technique. In addition, it results in a successful cannulation in otherwise difficult cases.

In other EM ultrasound applications it is acceptable to learn on humans, either volunteers or patients. However in vascular access, the invasive nature requires a certain amount of training on simulators. The most basic of these is a thin tube in a block of soft gel, and these can be made readily. This type of simulator helps the trainee to gain the hand-eye co-ordination required, together with the angle of approach.

Several central venous simulators exist, and these aim to provide a life-like image of the anatomy, while allowing a simulation vessel to be cannulated. Internal jugular cannulation should be learned in this way if possible. The trainee who already has experience in central venous cannulation will be able to migrate to ultrasound-guided cannulation without a great deal of training compared to the trainee who has never carried out the technique.

In all instances there is the need for sufficient one to one supervision by the trainer.

Precautions
Be cautious in significantly hypovolaemic patients as negative pressures result in flat veins, with increased technical difficultly. Treatment of hypovolaemic shock has always been viewed as technically challenging through a central line as the principal iv route. However, using ultrasound, CVC is not difficult in the hypovolaemic patient using 30° head down[34].

Technique
Select the correct probe and machine settings as previously described. All invasive procedures should employ standard sterile techniques to diminish the risk of infection.
For venous access using real time ultrasound, a sterile probe cover should always be used. Whilst it is reasonable to attempt peripheral and femoral access by skin marking and no real time ultrasound, (especially in cardiac arrest[11]) this is not acceptable for internal jugular cannulation.

Basic tips
Some linear probes have their surfaces at right angles to the skin, while others are angled. In the case of the latter, it may be easier to hold the probe in the most natural way, and switch the marker from left to right on the screen.

You will soon discover the need to stabilise the probe with the little finger touching the skin.   Unless you do this, the slippery nature of the gel will inevitably mean that your probe slowly drifts and you lose the screen image. In all invasive procedures it is important to learn to watch the screen, not your hands. This involves an appreciation of which way to move the cannula to achieve the desired result.

The first skill to acquire is to be able to recognize the vein in transverse section, and to distinguish it from the artery by virtue of its compressibility. Then learn to rotate the probe to view the vein in longitudinal section.   This entails knowing which part of the probe corresponds to the marker on the screen.

Venous cannulation can be carried out using a single or dual operator technique. It is recommended that initially the trainee works with the trainer in a dual operator technique, with the ultrasound carried out by the trainer, and the cannulation by the trainee. Besides the obvious training benefit, this also frees up both hands for the trainee. It also significantly reduces the risks of the probe sliding off the area of work and onto the floor.   The consequences of dropping a probe are more than inconvenience and loss of sterility – crystals may be broken in the probe resulting in permanent damage.

The final tip is to be aware that soon after a vessel is entered, if successful cannulation does not occur, a small clot may form in the lumen of the cannula. This can result in subsequent failure to get any flash-back, even when the cannula is correctly placed.   Priming the cannula with heparinised saline can minimise this, but will not prevent it.

Real time guided cannulation is described in the following slides for each of the three areas (internal jugular, femoral and basilic).   In real time cannulation there are two accepted approaches:

- The short axis, transverse approach allows only a cross section of the needle to be visualised by the ultrasound beam and may lead to errors in depth perception of the needle.   The acoustic shadow can lead to confusion.   The potential of the scan is not optimised by this approach.
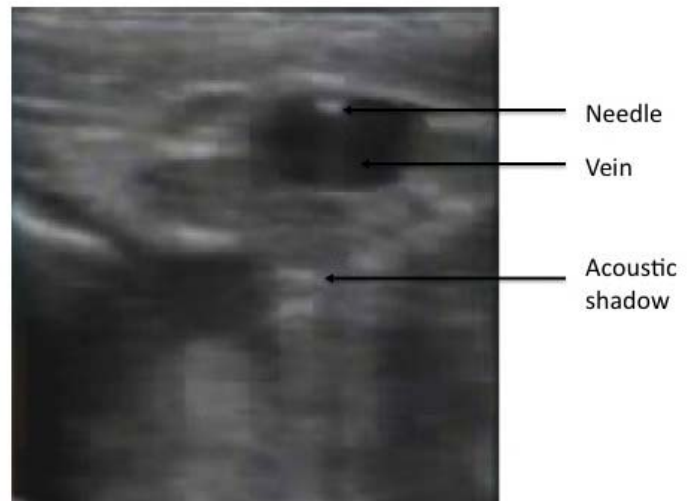
- The long axis orientation allows the operator to trace the entire path and angle of the needle from the entry site at the skin and into the vessel. The long axis orientation is the preferred approach.
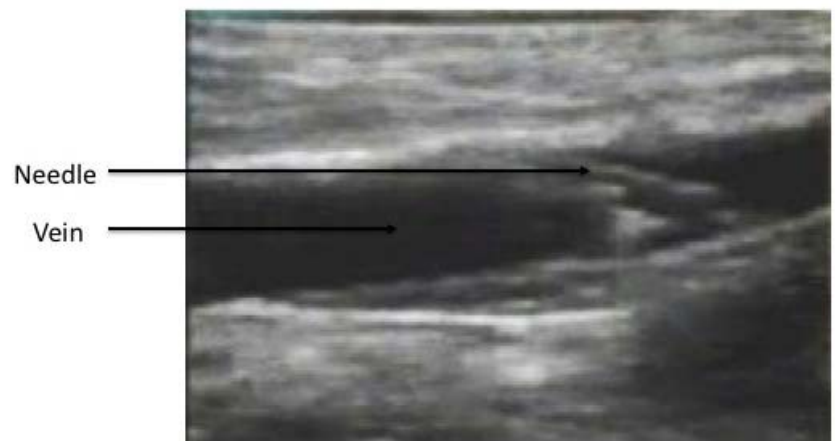
Specific techniques

A Jugular
Preparation
Sterile setting, drapes, gloves etc
Seldinger cannula of choice
Sterile sheath for ultrasound probe. Standard gel within sheath and sterile gel outside – can use catheterization lignocaine. Secure with a sterile band
Set ultrasound to 10MHz linear probe, should default to approx 4 cm depth
Use local anaesthetic.

Positioning
Patient 30° head-down,[10] little neck rotation and no extension[12]. This maximises venous filling, and reduces the risk of air embolism.

30 degrees

Procedural technique
In cross section, find vein (80% over or lateral to artery and compressible)
Rotate probe to see vein in longitudinal section. Check it is still compressible
Introduce needle through the skin bevel upwards
Watch it enter the vein

When blood obtained feed in wire
Check it is being fed caudally
Observe progress on screen
Check it remains in the lumen
Beware of acoustic shadow as it can be very off-putting! Feed the cannula over the wire
Secure the line. Check the line position with a CXR

Needle introduced bevel upwards

Feed cannula over wire

guide wire

acoustic shadow
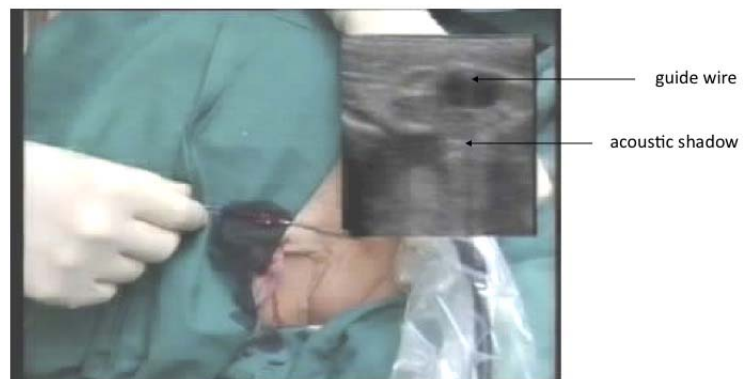
B Femoral

Preparation
As for CVC

Positioning
Patient 5º head-up. This ensures filling of the vein without undue pressure.

5 degrees

Procedural technique

In cross section, find vein (medial or med/ant to artery)
Rotate probe to see vein in longitudinal section. Check it is still compressible
Introduce needle through the skin bevel upwards
Watch it enter the vein
When blood obtained feed in wire OR, if cannula over needle, thread cannula into the vein
Observe the progress on screen
Check it remains in the lumen
Beware of the acoustic shadow – it can be very off-putting!
Secure the line

SIEMENS

VF13-5SP
Small Parts
30 dB
THI P 5.7 MHz
DR 65 dB
Edge 1
Persist 3
R/S 3
Map D
Tint 0
25 fps

FEM NERVE   FEM ARTERY   FEM VEIN

3.5 cm

P 100%   MI 0.9

C Peripheral[37]

<u>Preparation</u>
As before

<u>Positioning</u>
The technique is most facilitated by the upper limb being help extended and externally rotated, or by the hands being beneath the patients head.

<u>Procedural technique</u>
In cross section, find the basilic vein (in the recess medial to the biceps muscle)
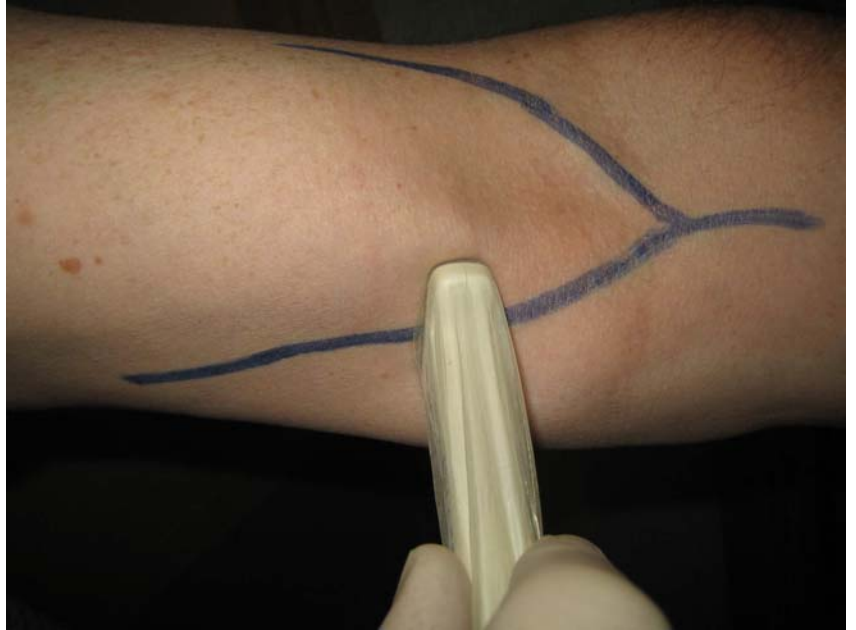
Rotate the probe to see the vein in longitudinal section. Check it is still compressible

Introduce needle through the skin bevel upwards
Watch it enter the vein
When blood obtained feed in wire
OR, if cannula over needle, thread cannula into vein
Observe progress on screen
Check it remains in the lumen
Beware of the acoustic shadow
If Seldinger, feed the cannula over the wire. Secure the line
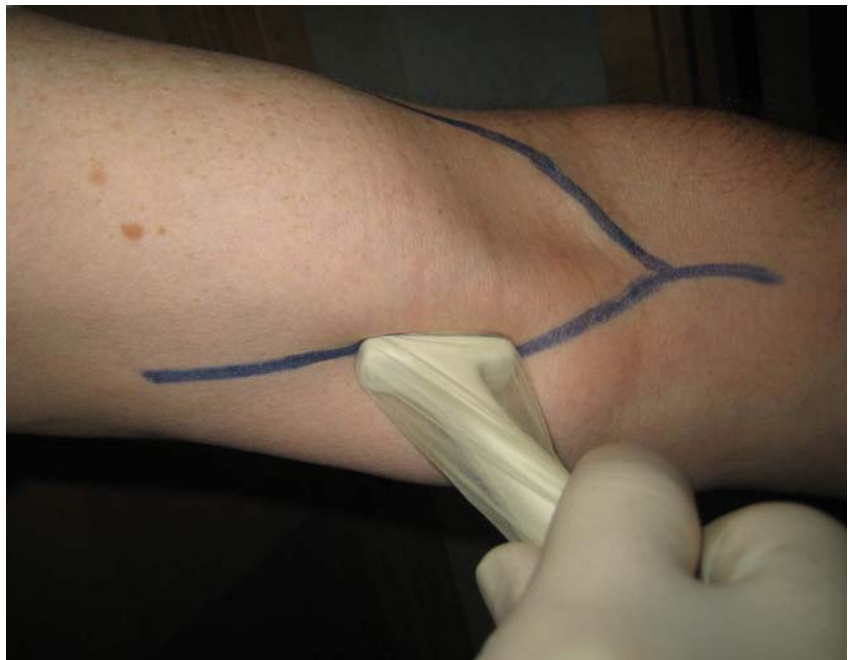
Further management (general and specific)
Always maintain sterility
Always maintain line security. Apart from having your precious lines pulled out by accident, significant bleeding or air embolism may occur through careless line care.
In patients who are hypovolaemic, once some fluid is introduced, the venous system becomes more accessible to conventional cannulation.

Pitfalls - all
Air embolism
Loss of sterility
Breakage of probe
Dropping the probe (so use a second operator/helper while you gain experience[14])
L - R disorientation on screen
> **CVC**
> Not filling the vein by using head down
> Vein compression by probe or too much neck rotation
> **Femoral**
> Haemorrhage
> **Peripheral**
> Damage to the brachial artery which is compressible if sufficient pressure is applied.

3.5 Echocardiography in Life Support (ELS)
(see also under FAST, section 3.2)

This is a limited echocardiogram used in the setting of non-shockable cardiac arrest rhythms (PEA and asystole). The heart is examined during a rhythm check for wall motion and the treatable causes of PEA (cardiac tamponade, hypovolaemia, and pulmonary embolism). Assess the pericardial space for fluid, look for the presence/absence and character of ventricular wall motion, and look for gross abnormalities of right and left ventricular size. The subxiphoid view is primarily used, augmented by a further view; most commonly the parasternal long axis view (other appropriate views include the parasternal short axis view and the apical four chamber view). In addition, the longtidudinal subxiphoid view allows visualisation of the inferior vena cava (IVC) for assessment of diameter and collapsibility.

Acquisition of the best possible image:
Demonstrates subxiphoid view and the long axis parasternal view
Identifies pericardial space and any fluid that is present
Identifies presence/absence of ventricular wall motion
Comments appropriately on right and left ventricular size
Identifies IVC in LS. Measures IVC diameter and collapsibility

4. Competences required for EMUS

Competences are threefold and require theoretical and practical training to achieve.
1. Theory – covered in this chapter.
2. Knowing how to interpret a scan – partly covered but hands-on required
3. Practical ability- can only be achieved by hands-on

OVERALL ASSESSMENT	BASED UPON		
	KNOWING	DOING	THINKING
(a) Competent to scan and interpret findings	Able to research and critique that knowledge and use it wisely	Learner doing: teacher available by phone	Excellent professional judgments
(b) Needs supervision and if scanning alone cannot rely on findings	Able to understand and use that knowledge	Learner doing: teacher within EM environs	Clinical reasoning and deliberation
(c) Not competent at this stage	Having to ask or be told	Teacher showing: Learner assisting	Clinical reasoning

5. Training

The training program is the same for both established practitioners and residents. This can be either done "in house" or on external approved courses. As an example, the College of Emergency Medicine has a national network of suitable courses published on their website.

Level 1 training is seen as the standard of knowledge and practice that Critical Care doctors should have in the future. Practice at this level would usually require the following abilities:

- To perform common examinations safely and accurately
- To recognise and differentiate normal anatomy and pathology
- To diagnose common abnormalities within certain organ systems
- To recognise when a referral for a second opinion is indicated
- To understand the relationship between ultrasound imaging and other diagnostic imaging techniques

Theoretical training
Preliminary theoretical training should cover relevant anatomy, the physics of ultrasound, levels and sophistication of equipment, image recording, reporting, artefacts and the relevance of other imaging modalities to ultrasound. This element of training may be best delivered by use of the CEM e-learning modules.

Practical training
Practical experience should be gained under the guidance of a named supervisor trained in ultrasound within a training department. The syllabus set out includes a competency assessment sheet for training. This should be completed during the course of training, as it will help to determine in which area(s) the trainee can practise independently.

- Practical training should include regular examinations, ideally supervised initially. If a trainee is unable to access local scanning opportunities, the CEM regional ultrasound co-ordinator may be able to facilitate arrangements for further practice within the region.

- The goal of training is competency, and this must be demonstrated rather than rigid adherence to a fixed number of training scans.

- Examinations should concentrate on the core clinical indications of trauma, aortic aneurysm and IVC assessment and peri-arrest assessment where there are benefits of an early focused ultrasound scan.

- A logbook listing the types of examination undertaken should be kept. All training scans must be logged, and a pictorial record containing an illustrated description of 10 cases in which the trainee has been personally involved should be collected and is a useful confirmation of experience when moving between departments.

- ♦ EMUS users who have achieved level 1 competency (or invoke the grandfather clause) should register their status with the CEM via the regional co-ordinator.

- ♦ The learning and practice outlined in this document refers to adults and children.

6. Trainers

Training should be supervised by a Level 2 practitioner or a Level 1 practitioner with at least 6 months experience of Level 1 practice.

"Grandfather clause"
Practitioners who have used Ultrasound in Level 1 practice for some time, but have never been through an assessment process may be deemed to be "Level 1 competent" for the purposes of appraisal if they have a letter from a Consultant Radiologist or a Consultant practicing in FAST/EFAST/ACES with extensive ultrasound experience confirming their competence. This letter should be held within their appraisal folder. This "grandfather clause" is very likely to be withdrawn in the future when robust training capacity exists.

7. Assessment tool

This is a Work-based DOPS known as a Triggered Assessment – see Appendix 2

8. Maintenance of Skills

Having been assessed as competent to practice there will be a need for CPD and maintenance of practical skills. A trainee will need to continue to perform ultrasound scans throughout the remainder of the training programme and into his/her consultant appointment. Such further ultrasound practice may be intermittent, but no more than 3 months should elapse without the trainee using his scanning skills. If more than 3 months elapses there must be a brief re-assessment using a DOPS by a trainer, and a portfolio note made.

All practitioners should have regular meetings within the department to ensure appropriate focused emergency ultrasound use. The department lead for ultrasound practice will have regular contact with radiological colleagues and should have a named radiologist as an 'ultrasound mentor'.

Practitioners should:
- Include ultrasound in their ongoing CME/CPD
- Audit their practice

- Participate in multidisciplinary meetings
- Keep up to date with relevant literature

The minimum amount of on-going experience in ultrasound as outlined in each syllabus should be maintained. CME/CPD should be undertaken which incorporates elements of ultrasound practice.

Regular audit of the individual's ultrasound practice should be undertaken to demonstrate that the indications, performance and diagnostic quality of the service are all satisfactory. Employing Trusts should ensure that an adequate governance framework exists.

9. Further Reading
Refer to the following texts for additional information:
- Bowra J & McLaughlin R "*Emergency Ultrasound Made Easy*" Churchill Livingstone, 2006
- Gaspari RJ, Fox JC & Sierzenski PR "*Emergency Ultrasound – Principles and Practice*" Mosby, 2006

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Appendix 1 – Scanning log, summary of cases and reflective learning

(Three blank pages follow for scanning records, personal notes and reflective

practice)

The College of Emergency Medicine

Emergency Medicine Ultrasound

Core (Level 1) competency

Workplace Based Triggered Assessment - 2010

Before using this document, a trainee should have completed a suitable theory course or series of modules, and received hands-on instruction. They should then have carried out supervised practice with maintenance of a log.

This document covers all workplace based assessments in level 1 (ie Focussed Assessment of the Abdominal Aorta, FAST, Ultrasound assisted Vascular Access, and Echo in Life Support) and is to be used alongside a training log.

When trainees are confident that they are ready for a formal assessment, the relevant section of the document is completed by an assessor who watches an actual patient scan.   When each section is successfully completed, the whole document forms proof of achieving competency.

Trainee information, theory training and log summary

Trainee's Name:	**Year EMUS training started:**	**Trainer:**
CT / HST / Non-training / Post CCT (circle)	**School or Deanery:**	**Regional EMUS Co-ordinator:**

Theoretical and hands-on training

To cover basic theory

- o All 6 Enlightenme sessions completed (Indications, Physics, Image acquisition, FAST, Aortic assessment and Vascular access)

And/Or to cover basic practice

- o CEM approved course, **OR** local modular training

Certified as complete by _____ (signed by above named Trainer)

Date completed _____

Logged Experience

Evidence provided of scans carried out. Follow up notes and reflective writing on 10 case studies.

Certified as complete by _____ (signed by above named Trainer)

Date completed _____

Section A –Triggered Assessment in Focused Assessment of the Aorta

Date

Location

Within each of the following three sections, the learner must:	Medical assessor's comments recorded during the assessment	Competent?
1. Preparation for the scan Greets the patient appropriately and identifies the patient with the notes		
Confirms that the indication for the procedure is within own competency		
Positions the patient correctly		
Demonstrates appropriate attitude and professional manner		

2. The scan
Sets up the equipment acceptably
   o   Patient details
   o Body marker insertion		

Probe selection, handling and scanning technique		
Acquisition of the best possible image Identifies IVC and Aorta in LS and TS Identifies SMA Measures AP diameter of aorta accurately		

Timelines
   o   Knows when to scan
   o Speed of scan		

Saves/prints		
3. Post scan Informs the patient appropriately		
Makes a record of the findings		
Knows if a repeat scan would be useful		

Section B –Triggered Assessment in FAST

Date

Location

Within each of the following three sections, the learner must:	Medical assessor's comments recorded during the assessment	Competent?
1. Preparation for the scan Greets the patient appropriately and identifies the patient with the notes		
Confirms that the indication for the procedure is within own competency		
Positions the patient correctly		
Demonstrates appropriate attitude and professional manner		

2. The scan
Sets up the equipment acceptably
  o   Patient details
  o Body marker insertion		

Probe selection, handling and scanning technique		
Acquisition of the best possible image: Demonstrates Morison's pouch Demonstrates the spleno-renal interface Demonstrates potential fluid in the pelvis Demonstrates pericardial views Demonstrates the pleural space and can identify fluid		

Timelines
  o   Knows when to scan
  o Speed of scan		

Saves/prints		
3. Post scan Informs the patient appropriately		
Makes a record of the findings		
Interprets and reports findings appropriately		
Knows if a repeat scan would be useful		

Section C –Triggered Assessment in Vascular Access

Date

Location

Within each of the following three sections, the learner must:	Medical assessor's comments recorded during the assessment	Competent?
1. Preparation for the scan Greets the patient appropriately and identifies the patient with the notes		
Confirms that the indication for the procedure is within own competency		
Positions the patient correctly		
Demonstrates appropriate attitude and professional manner		

2. The scan
Sets up the equipment acceptably
   o   Patient details
   o Body marker insertion		

Probe selection, handling and scanning technique		
Acquisition of the best possible image Demonstrates the internal jugular vein Demonstrates a peripheral vein Indicates the technique to cannulate (may be ultrasound assisted or guided if peripheral)		
Timelines o Speed of scan		
Saves/prints		
3. Post scan Informs the patient appropriately		
Makes a record of the findings		
Interprets and reports findings appropriately		
Indicates if a CXR is needed (ie in CV access)		

Section D – Echo in Life Support

Date

Location

Within each of the following three sections, the learner must:	Medical assessors' comments recorded during the assessment	Competent?
1. Preparation for the scan Greets the patient appropriately and identifies the patient with the notes		
Confirms that the indication for the procedure is within own competency		
Positions the patient correctly		
Demonstrates appropriate attitude and professional manner		

2. The scan
Sets up the equipment acceptably
   o   Patient details
   o Body marker insertion		

Probe selection, handling and scanning technique		
Acquisition of the best possible image: Demonstrates subxiphoid view plus one other cardiac view (eg long axis parasternal) Identifies pericardial space and any fluid that is present. Identifies presence / absence of ventricular wall motion, globally and focal. Comments appropriately on right and left ventricular size and can decide if RV dilated. Identifies IVC in LS. Assesses IVC diameter and collapsibility.		
Timelines o Speed of scan		
Saves/prints		
3. Post scan Informs the patient appropriately		
Makes a record of the findings		
Interprets and reports findings appropriately		
Indicates if a CXR is needed (ie in CV access)		

Summary

	(a) Competent to scan and interpret findings independently	(b) Needs Supervision. If scanning alone cannot rely on findings	(c) Not competent at this stage	Signed and dated
Assessment of the abdominal aorta				
FAST				
Vascular access				
Echo in Life Support				

Once (a) has been achieved in all four areas, final sign –off can occur. If not, advice from trainer:

_____

__FINAL SIGN-OFF__

Trainee name in print _____

This doctor is certified as competent in Level 1 Emergency Medicine Ultrasound, as defined by the College of Emergency Medicine, having undergone theoretical and practical training and demonstrated competency in all required areas.

Signed by:

Regional Ultrasound Co-ordinator (print name/ sign) _____

Date _____   **Further advice** _____

_____

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