2.4 Scanning basics

Systematic approach

Ultrasound allows the acquisition of a variety of imaging planes. In fact, any plane whatsoever can be imaged as long as an acoustic window exists for the ultrasound beam to travel along the desired plane. The goal of ultrasound imaging is to represent three-dimensional anatomical structures in two-dimensional imaging. To reliably achieve this and accurately demonstrate the required anatomy, the ultrasound operator must be able to relate the displayed anatomy in a reproducible and standard fashion.

The general approach for ultrasound imaging is to follow a systematic method and image each organ or region individually as a focused exam. Particularly for inexperienced users, following a systematic approach is crucial. Starting in the same position and orientation each time for the same type of exam will allow users to become more comfortable with the standard manipulations required in order to optimally visualise the relevant anatomy.

Does it matter how I hold the transducer?

Most transducers have a marker or indicator (Figure 21) to guide the user. For most scanning techniques, except some cardiology exams, the transducer should be held lightly in your hand with the transducer marker (Figure 8) pointing towards the patient's right or towards the patient's head.

Figure 21: Transducer marker
A marker on the transducer corresponds to a dot displayed
on the ultrasound screen to guide the user.

> It is very important to hold and use the transducer
> in the correct standard positions, i.e. transverse and longitudinal.

Tip: If in doubt when orientating yourself on the screen, a user can simply place or tap a finger on one side of the transducer. This will confirm which side of the screen displays which part of the anatomy.

Transverse and longitudinal position

The two basic orientations with the transducer are the longitudinal and transverse position.

However, practically no organ in the body is actually oriented perfectly in these planes. Rather, the user must manipulate the location, angle and placement of the transducer on the skin in order to depict each organ along its transverse, i.e. cross-sectional, and longitudinal, i.e. lengthwise, axes.

Using a systematic approach, the standard positions are the starting point for all imaging, particularly for an inexperienced user.

Transverse position

In the transverse position the transducer has the marker pointing towards the patient's right, i.e. transducer orientated left to right across the body (Figure 22).

Figure 22: Transducer in transverse position with the marker (arrow) of the transducer pointing towards the patients' right.

In this transverse position the left side of the screen (as you see it) will be the patient's right, and the right side of the screen (as you see it) will be the patient's left (Figure 23).

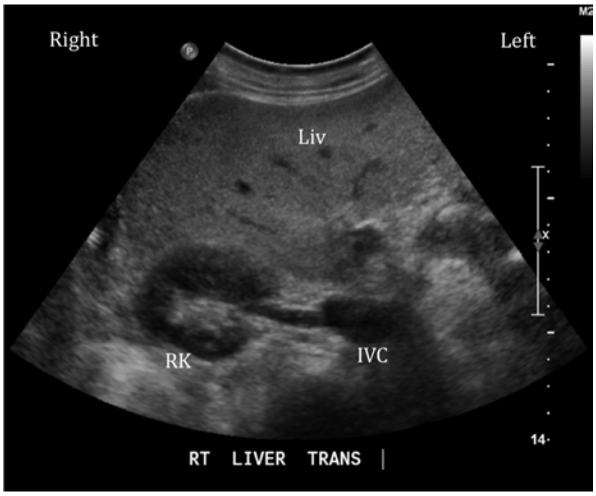

Figure 23: Transverse image through the right upper abdomen
This image to the right of the midline, shows the right lobe of the liver (Liv) and, deeper, the right kidney (RK), connected to the Inferior Vena Cava (IVC) by the right renal vein.
The patient's right (Right) displays on the left side of the image and the patient's left (Left) is on the right side of the image.

Longitudinal position

In the longitudinal position the transducer has the marker pointing towards the patient's head, i.e. transducer orientated head to toe along the body (Figure 24).

Figure 24: Transducer in longitudinal position with the marker (arrow) pointing towards the patient's head

In this longitudinal position the left side of the screen (as you see it) will be towards the patient's head and the right side of the screen will be toward the toes (Figure 25).

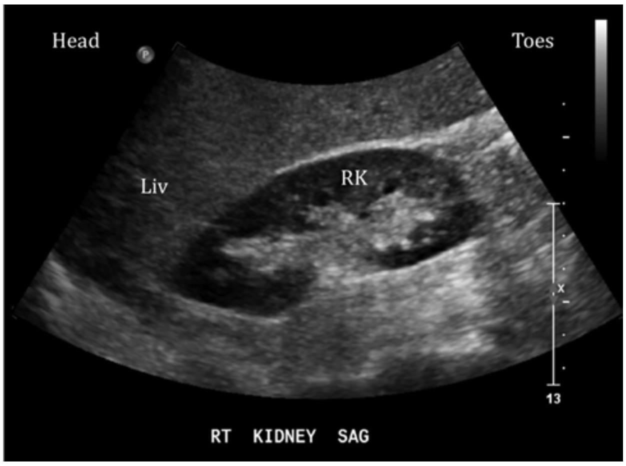

Figure 25: Longitudinal image through the right upper abdomen with the marker of the transducer pointing towards the patient's head.
This image to the right of midline shows the right lobe of the liver (Liv) towards the patient's head on the left side of the image, and below (inferior) to the liver, the right kidney (RK), towards the patient's toes on the right side of the image.

Near and far field

The anatomy that appears in the near field (closest to the transducer) is displayed at the top of the screen. The ultrasound beam passes through these tissues before reaching 'deeper' anatomy which is displayed at the bottom on the screen (far-field).

Moving the transducer, and orientation of the anatomy in the image

It is very important to ensure the anatomy of interest is centred on the ultrasound screen. For an inexperienced user this is not always straightforward as even small adjustments can result in big changes in positioning and the appearance of anatomy in an image.

Moving or angling / titling the transducer i.e. keeping the same position of contact on the patient, and tilting it from side to side or back and forth can dramatically change the appearance of a structure, and the ability to visualize it at all.

Users must develop the skill and hand eye coordination to register the image on the screen with the transducer movements required to visualise the required anatomy.

When moving the transducer, use slow uniform movements

Moving and angling the transducer in the transverse position

In the transverse position:
– If the area of interest is on the left side of the screen, move and / or angle the transducer towards the patient's right.
– If the area of interest is on the right side of the screen, move and / or angle the transducer towards the patient's left.
– If the area of interest is towards the patient's left, move and / or angle the transducer in that direction.
– If the area of interest is towards the patient's right, move and / or angle the transducer in that direction.

In the following example, Figure 26 the right ovary is on the far left side of the screen and not well visualized.

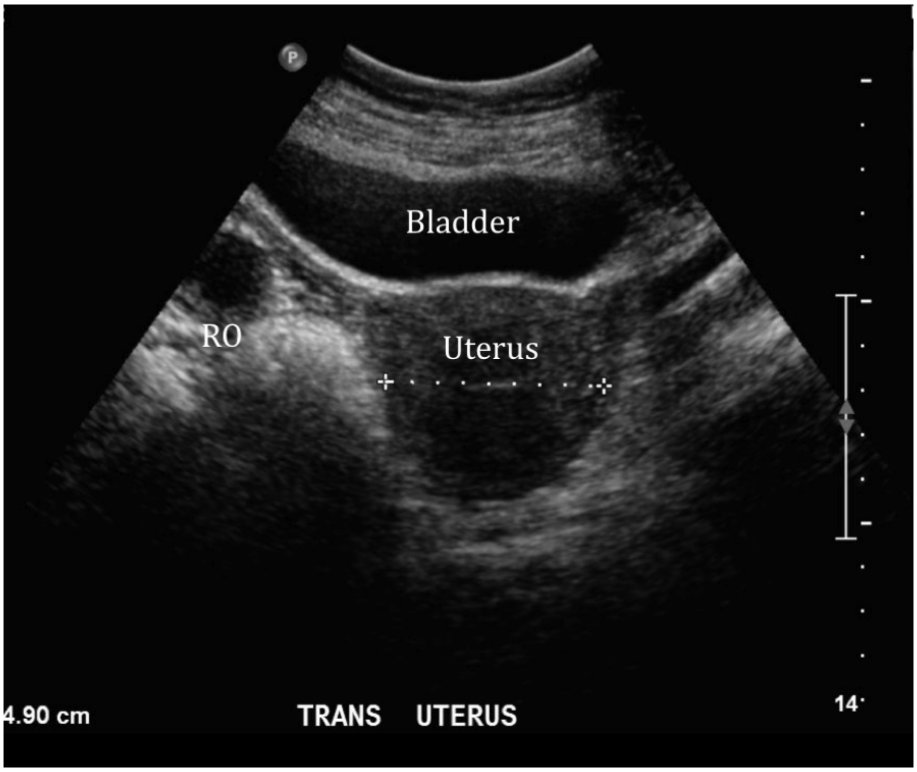

Figure 26: Same image as Figure 5, transverse imagine of the female pelvis
The right ovary (RO) on the left side of the screen is not well visualized.

By moving the transducer to the patient's right about 5 cm, or by simply angling the transducer towards the patients' right, it is possible to orientate the right ovary into the centre of the field of view (Figure 27).

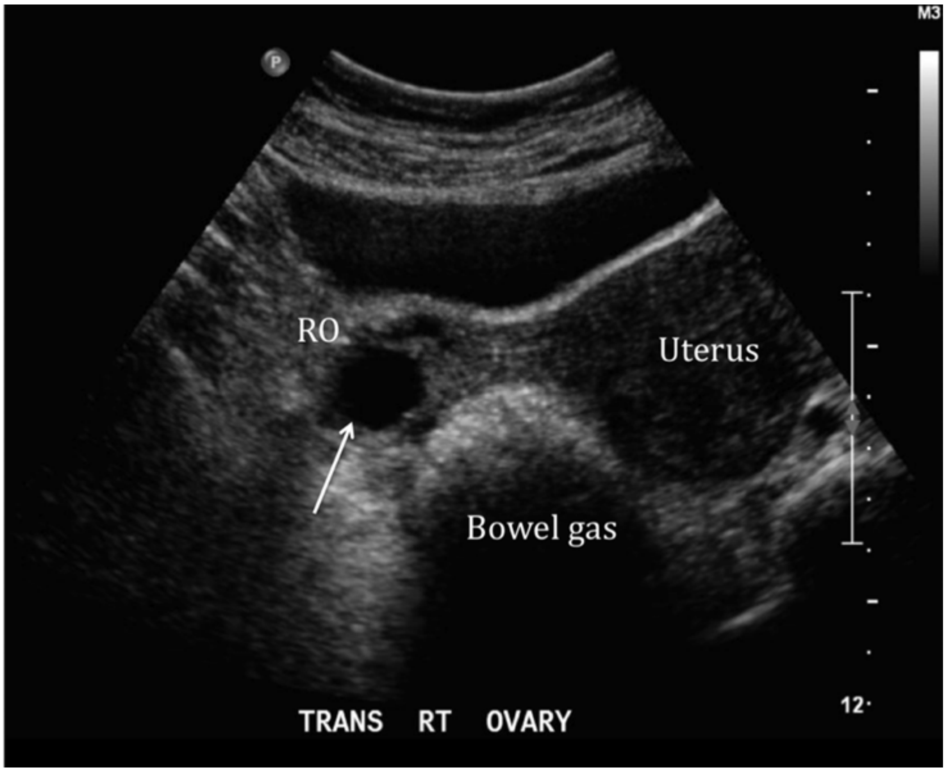

Figure 27: Similar image as Figure 26, transverse image of the female pelvis
Manipulation of the transducer as described above centres the right ovary (RO) so that the right ovary and simple cyst (arrow) are better visualized.

Moving and angling the transducer in the longitudinal plane

In the longitudinal plane:
- If the area of interest is on the left side of the screen, move and / or angle the transducer towards the patient's head.
- If the area of interest is on the right side of the screen, move and / or angle the transducer towards the patient's toes.
- If the area of interest is towards the patient's head, move and / or angle the transducer in that direction.
- If the area of interest is towards the patient's feet, move and / or angle the transducer in that direction.

The following example shows a longitudinal image of the left upper quadrant. The spleen and left kidney are not well seen due to the shadowing artefact created by the patient's ribs.

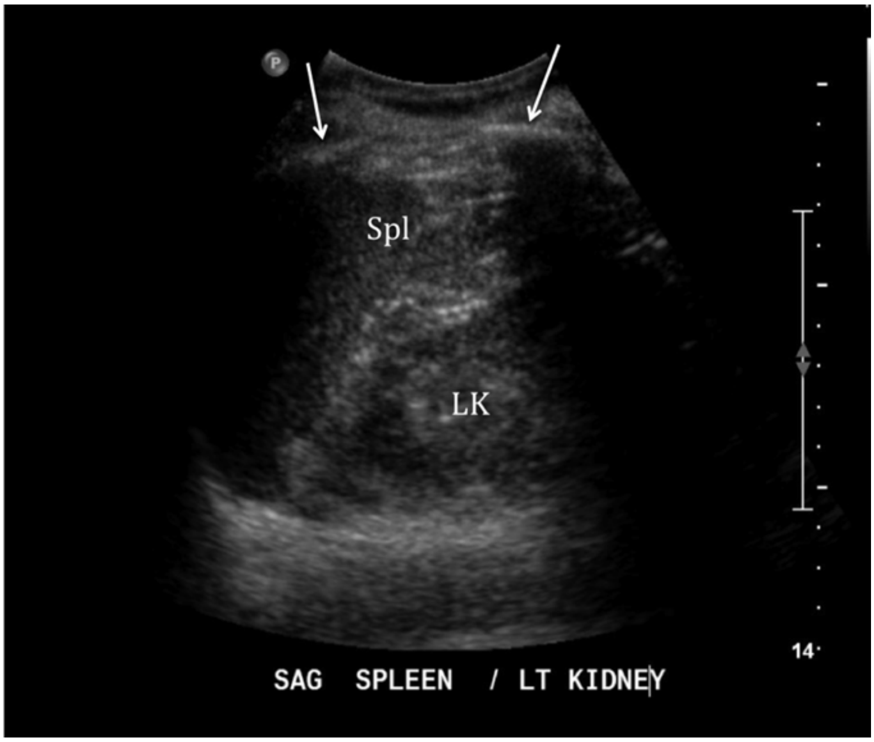

Figure 28: Longitudinal image of the left upper quadrant
with the patient in the right lateral decubitus position.
The spleen (Spl) and left kidney (LK) are obscured by shadowing from the left ribs (arrows).

By moving the transducer towards the patient's feet slightly and angling toward the head to avoid the ribs it is possible to avoid the artefact from the ribs. This adjustment allows a better visualization of the spleen (Figure 29).

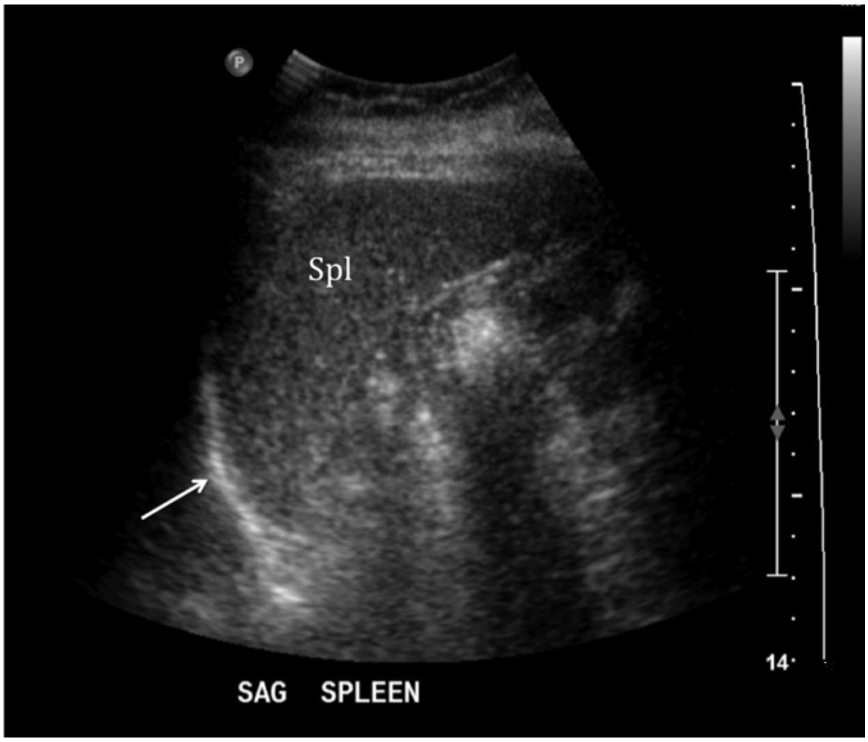

Figure 29: Longitudinal image of the left upper quadrant.
Manipulation of the transducer from the position of Figure 28 as described above
to avoid the ribs allowed visualization of the entire spleen, and the bright echogenic line
of the diaphragm (arrow).

Moving and angling the transducer in multiple planes

How to manipulate the transducer in the best way will vary for each particular situation. Moving or angling the transducer or using a combination of both may be required to improve the visualisation of the area of interest. With experience and using the different transducer positions as well as varying the angle of the transducer, the sonographer will gain expertise in slowly sweeping through each organ or structure of interest in its transverse and longitudinal orientations while avoiding interfering artefacts such as bone or bowel gas. Doing this in a systematic way forms a 3-dimensional mental image of the organs and structures of interest, in order to identify abnormalities.

Angling the transducer

Angling the transducer towards the head or toes can also have a large impact on a transverse image, the same as angling a transducer left or right in a longitudinal image.

This is a very important consideration, especially if a user is performing measurements or evaluating the size of a structure. For example, starting from the transverse position (Figure 30 A) then angling the transducer towards the patients' toes centres the ovarian cyst (Figure 30 B). The size and shape of the image of the cyst changes significantly.

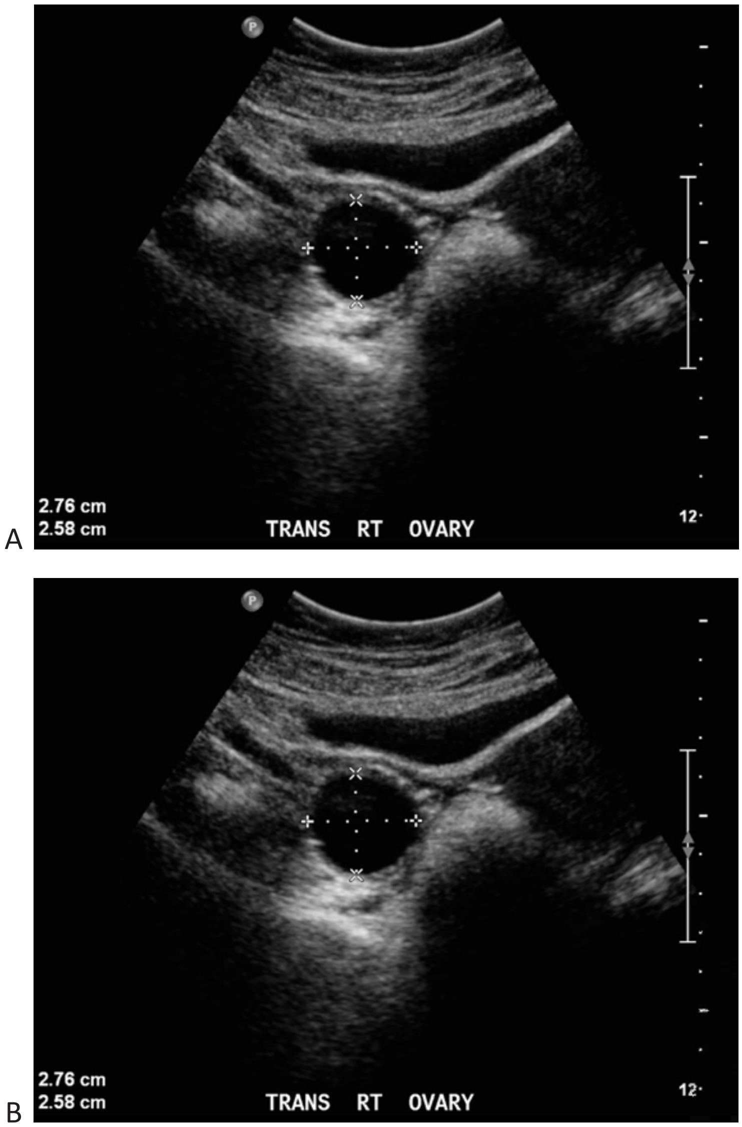

Figure 30A and B: Transverse images of the female pelvis.
Compare the view of the right ovarian cyst (arrow) in A with its appearance in B (between cursors). In Figure B the cyst is now centred and the image plane is through its midpoint for the most accurate size measurement.

Compare the different transverse images through the aorta (Figure 31 A-C). As the transducer is moved in different directions it can drastically change the appearance of the aorta. In this case the diameter is almost twice as large as the true cross sectional diameter when the image plane is oblique to the plane of the aorta.

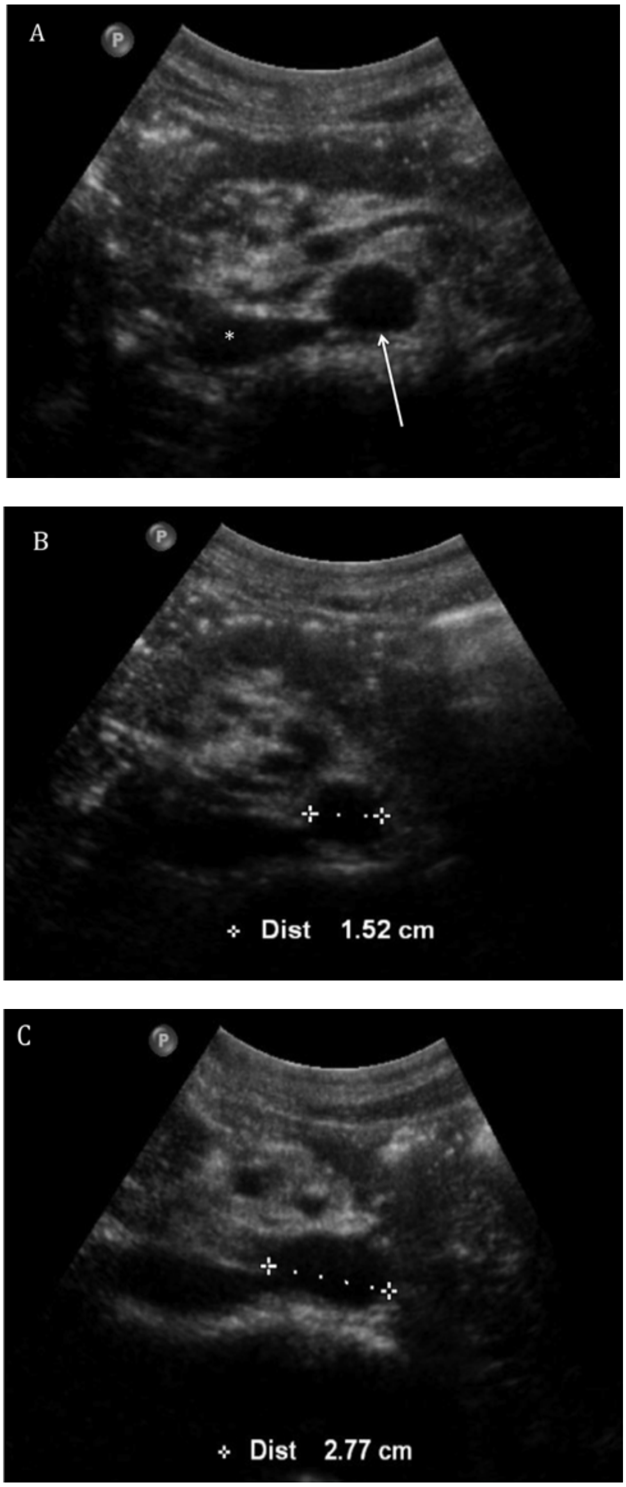

Figure 31: A-C: Transverse midline images through aorta
Image A - the aorta (arrow) and IVC (*).
Image B - correct orientation of the imaging plane with the aorta in true cross-section, with accurate measurements (between cursors).
Image C - incorrect orientation of the imaging plane in relation to the aorta with the resulting measured diameter nearly twice the true diameter.

> Anatomy rarely lies perfectly in the 'standard' transverse or longitudinal scanning planes. It is an operator skill to identify the anatomy and image the structure in its own anatomical plane.

Artefacts

Artefacts are misrepresentations of the internal structures of the body as they appear on the ultrasound image. There are a number of different specific ultrasound artefacts that can affect how an image is acquired and interpreted. Understanding the basic principles of ultrasound can help identify the most common of these. This is very important, as in certain cases these can be beneficial in making a diagnosis, but can lead to misdiagnosis if not well understood.

Shadowing

Shadowing is a common and sometimes useful artefact. It is caused when certain tissues, such as dense bone absorbs the ultrasound beam preventing its transmission into deeper tissues. As none of the ultrasound beam penetrates that tissue, no echoes (or images) are formed by anything beyond that structure.

Structures that cause this dense shadowing artefact by blocking sound wave transmission include cortical bone, gallstones, kidney stones, uterine fibroids, intrauterine devices, surgical clips and calcifications in organs like the thyroid gland.

Shadowing from calcified structures like stones cause a hard black shadow or band that descends in a straight path deep to the structure causing it. Shadowing produced by stones, aids in stone detection and diagnosis. This 'clean' shadowing is distinguished from the 'dirty' shadowing often seen from bowel gas (see gas artefacts).

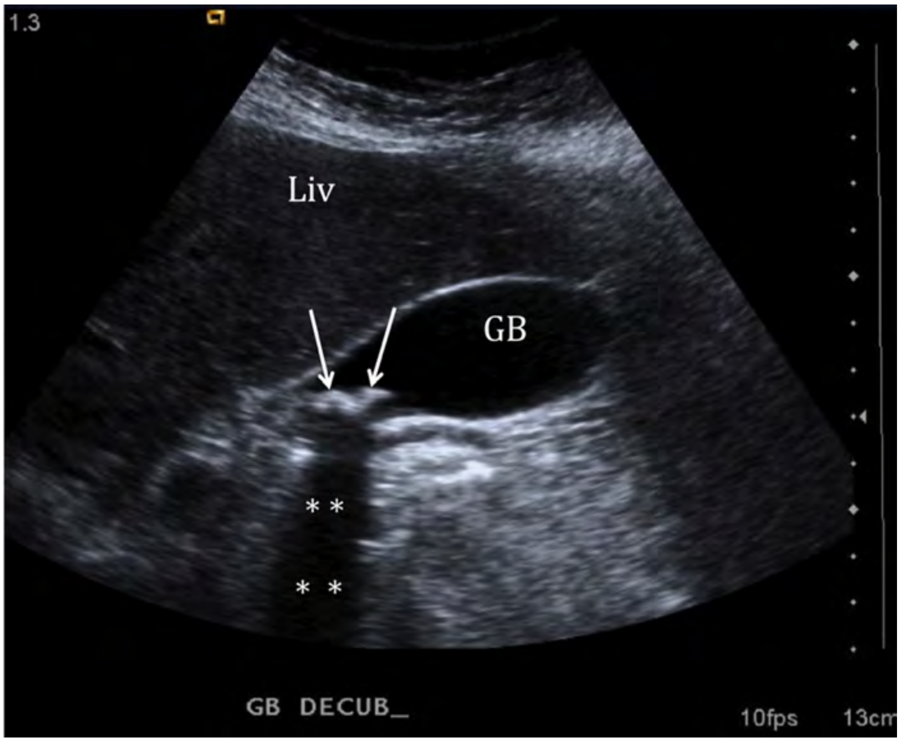

Figure 32: Left decubitus view of the gallbladder (GB)
A collection of small stones (arrows) is seen in the proximal gallbladder (GB), with dense shadowing (*) deep to the stones.

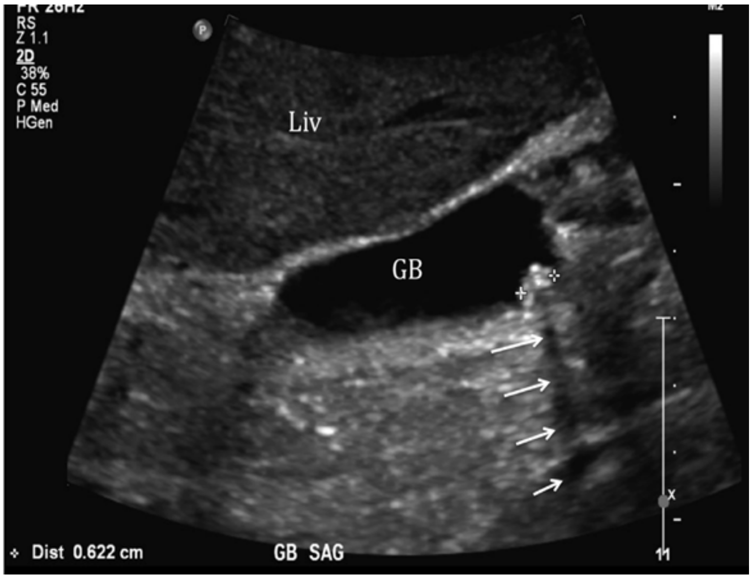

Figure 33: Longitudinal image of the gallbladder in the left decubitus position
A 6 mm gallstone (between cursors) demonstrating dense shadowing (arrows) deep to the stone.

Posterior enhancement (increased through-transmission)

Posterior enhancement, also known as increased through-transmission, is a phenomenon related to the relative absence of ultrasound beam reflectors in some structures. It happens when the ultrasound beam penetrates fluid more easily than surrounding tissues.

This occurs when few echoes are formed within the fluid and it appears black or almost black. The tissue adjacent to the fluid-filled structure progressively attenuates the sound beam. There are more sound waves available to form echoes deep to the fluid-filled structure and therefore the tissue deep to the fluid-filled structure appear brighter than the tissue to either side.

Common examples of this phenomenon are the gallbladder filled with bile (Figure 34), renal, ovarian and other simple cysts, and pathologic fluid collections, including abscesses filled with liquid pus contents.

Figure 34: Decubitus view of the gallbladder (GB) with posterior enhancement
Posterior enhancement / increased through-transmission) is evident by the broad band of more echogenic (whiter) tissue indicated by asterisks (*), always located deeper to the tissue (liquid bile in the gallbladder in this case) that causes the artefact.

The through-transmission effect is typical for some pathology such as haemangiomas (Figure 35), a very common solid lesion found in the liver. Therefore, demonstrating the phenomenon can have great impact on diagnostic accuracy of ultrasound.

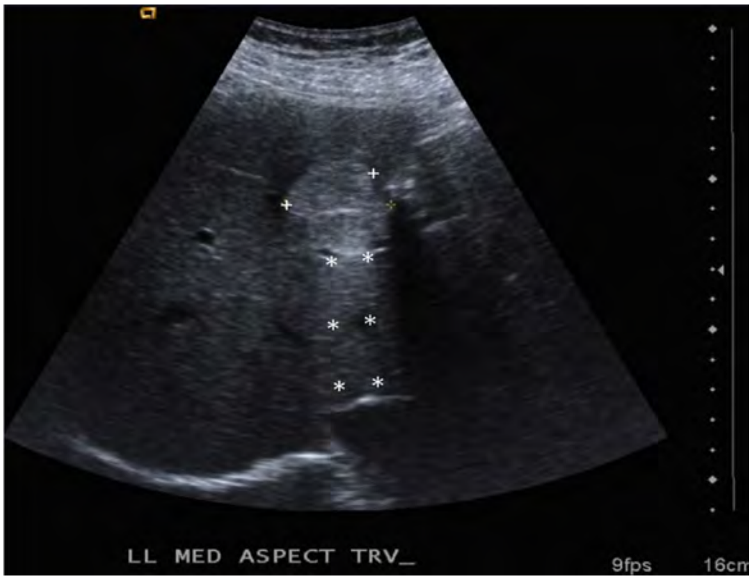

Figure 35: Transverse scan through left lobe of liver, showing an echogenic (bright) haemangioma (between the cursors), and obvious posterior enhancement / increased through-transmission (*) deep to the haemangioma.

Reverberation

Reverberation artefact occurs when the ultrasound beam encounters very strong reflectors, and the sound beam bounces back and forth between them before returning to the transducer. As a result of those waves bouncing back and forth more often than others, they appear to have travelled further. The computer generates a series of echoes from the reflectors.

Common examples of reverberation artefact include reverberation from the diaphragm (Figure 36), mirror-image (Figure 37) and comet tail (Figure 38 and Figure 39) artefacts.

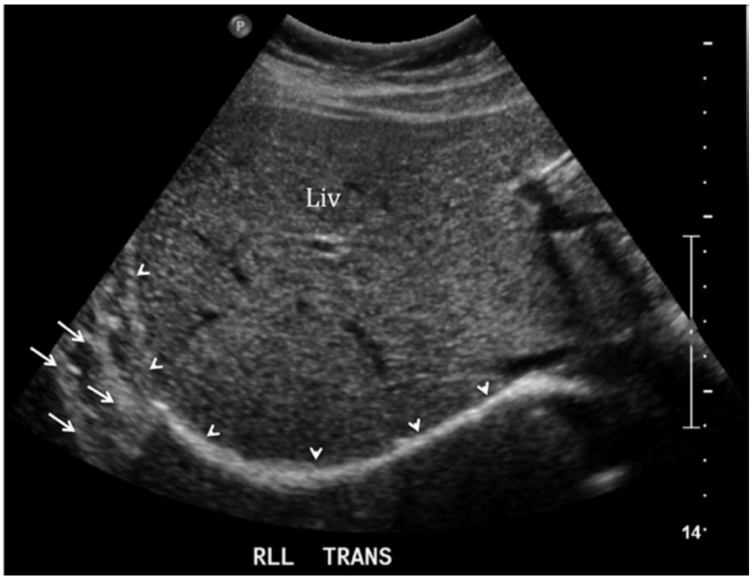

Figure 36: Reverberation artefact caused by the interface of the liver (Liv) and diaphragm (arrowheads), a strong acoustic reflector, with a series of copies of the liver / diaphragm interface (arrows).

Mirror image artefact is a kind of reverberation artefact in which a mirror image of a structure is reproduced deep to a strong acoustic reflector. The interface between the diaphragm and the air-filled lung above totally reflects (like a mirror) the sound beams coming through the liver. The strong sound beams reflected back through the liver toward the transducer are repeatedly re-reflected back and forth between the liver tissue and the lung surface. Delayed return of echoes to the transducer results in creation of an artefactual image of the liver above the diaphragm (Figure 37).

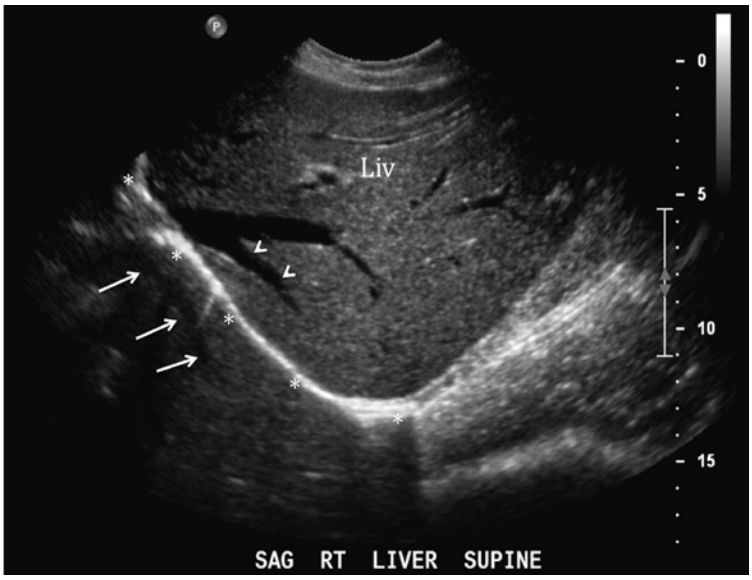

Figure 37: Mirror image artefact of hepatic vein across the diaphragm
Longitudinal image of the right upper quadrant and shows a mirror image artefact of the hepatic vein across the right diaphragm (*). A right hepatic vein branch (arrowheads) is projected as a mirror image (arrows) on the other side of the diaphragm (*).

Comet tail artefacts are caused by reverberations of echoes from small, yet strong reflectors which typically create a triangular shaped effect deep to the structure (Figure 38). Common examples include foreign bodies, needles, air lung interface, minute calcifications in the wall of cysts or adenomyomatosis in the gallbladder wall.

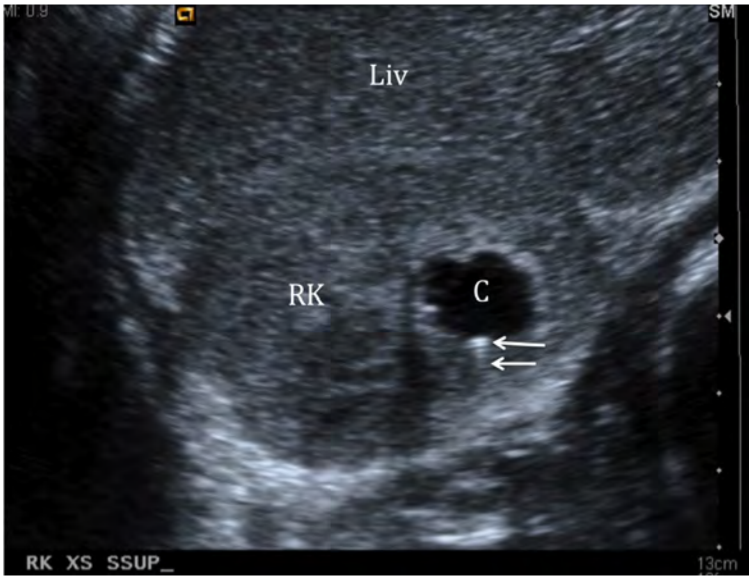

Figure 38: Comet tail artefact in a cyst wall
Transverse scan through the right upper quadrant showing the right kidney (RK) deep to the liver (Liv). There is a bright echogenic focus (arrows) in the wall of a cyst (C) of the kidney caused by a small calcification in the cyst wall. There is a triangular echogenic (bright) artefact extending deep to the bright reflector, with the apex of the triangle pointing deep to the reflector in a straight line.

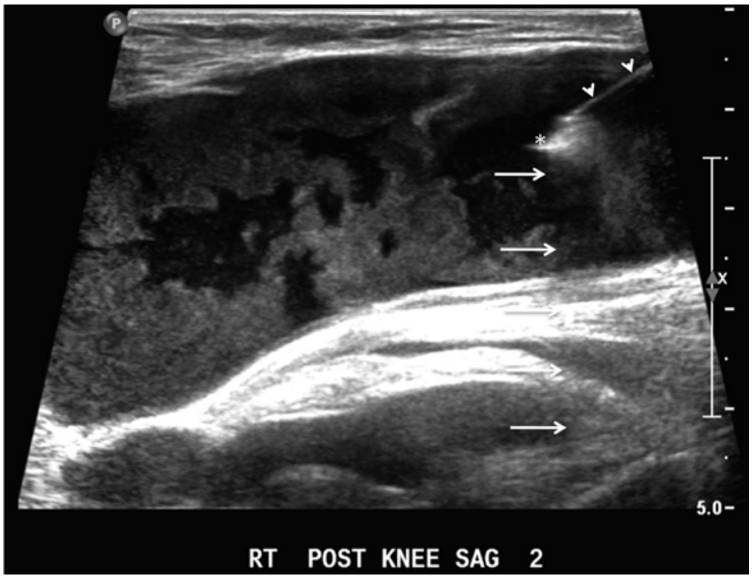

Figure 39: Aspiration biopsy needle reverberation artefact
There is a large thick walled cavity in the right knee, and a needle aspiration under direct sonographic guidance shows the echogenic needle (arrowheads), reverberation artefact from the needle with the edge of the artefact marked by arrows, indicating the location of the very tip of the needle (*).

Gas artefact

Gas causes several kinds of artefacts. The general problem with gas is that it reflects the entire ultrasound beam, such that structures deep to the gas are obscured. Because of this powerful reflection, there are no ultrasound waves remaining to penetrate the tissue deep to the gas and thereby form images of that deeper tissue.

A common appearance of gas artefact is 'dirty shadowing' (Figure 40) in which there is a diffuse low-to-moderate echogenicity throughout the tissue deep to the superficial soft tissue-gas interface. Another pattern is a type of reverberation artefact caused by gas bubbles admixed with fluid (Figure 41).

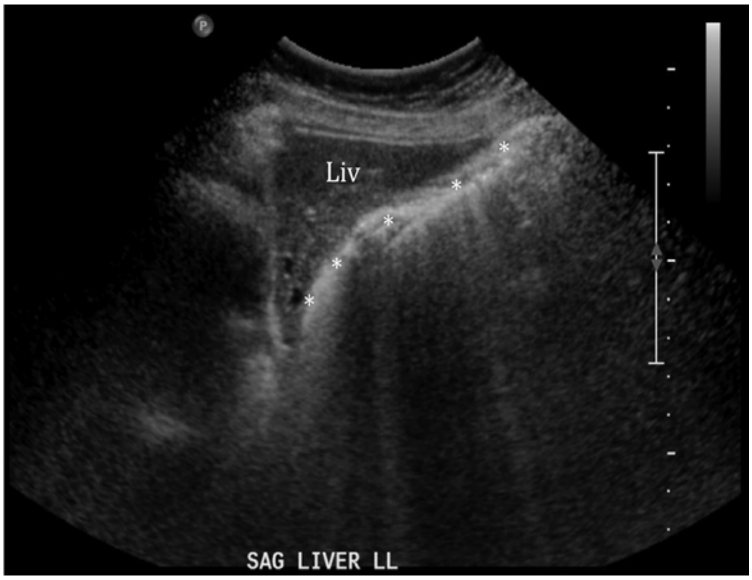

Figure 40: Dirty shadowing pattern of artefact from gas in the stomach
Longitudinal image through the left lobe of the liver (Liv), with a gaseous distended stomach just beneath the liver causing complete non-visualization of tissue deep to the anterior wall of the stomach, marked by the anterior margin of the brightly echogenic (white) interface (*) between the gas in the stomach and the liver margin.

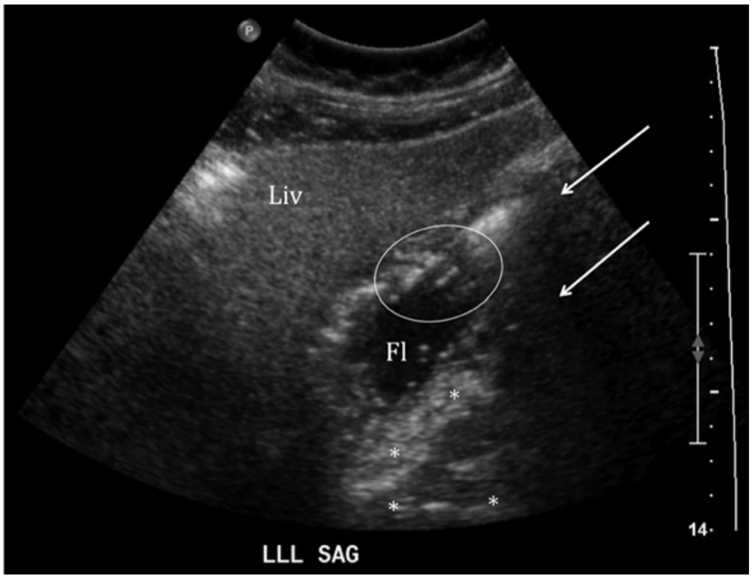

Figure 41: Longitudinal image through the left lobe of the liver (Liv) and stomach demonstrating three typical artefacts from gas and fluid in one image.
Fluid (Fl) in the stomach just inferior to the liver, with dirty shadowing from gas in the stomach (arrows). Reverberation artefact (circled) where gas bubbles are admixed with fluid. Posterior enhancement / increased through-transmission (*) deep to the fluid in the deepest most gravity dependant portion of the stomach, which contains the fluid.

2.5 Other considerations

What advantage does ultrasound have over other imaging techniques?

Ultrasound imaging differs from other modalities because of the great variety of imaging planes, and the real-time nature of the procedure that allows a variety of approaches, e.g. the position of the transducer on the body, and manoeuvres such as real-time imaging during compression and suspended respirations in different respiratory phases. It demonstrates fluid well so it's very useful for looking at the gallbladder, the urinary bladder, free fluid in the abdomen, pleural and pericardial fluid, and pregnancy when there is sufficient amniotic fluid. It also does not use radiation and therefore it is attractive for use especially in children and in pregnancy.

Are there any safety concerns with ultrasound imaging?

There are few safety concerns with the sound frequencies used in ultrasound and it is generally safe for use in children and for foetal imaging. However, the sound energies used for spectral and colour Doppler are substantially (10-15 times) higher than the energy used for routine ultrasound imaging. In the first trimester of pregnancy Doppler ultrasound should be used with caution as there is potential for chromosome damage because of heat deposition in tissues when Doppler ultrasound is aimed at the embryo. There is no evidence that the much lower energy levels used for routine imaging ultrasound can harm the foetus even in the first trimester.

Except for the most experienced examiners in highly specific situations, Doppler ultrasound should not be utilized in first trimester obstetric ultrasound examinations. Foetal cardiac motion should be documented by use of M-mode ultrasound, which is safe and of the same low sound energy as imaging ultrasound. There is no limitation in number of procedures per patient, but care must be taken not to hurt patients with pain by compressing vigorously. Care must be taken with transducers in regards to cleanliness and sensitivity to patients.