MEDECINS SANS FRONTIERES

Ultrasound manual

For trained practitioners

Internal document
2018 Edition

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Foreword

This manual is intended to inform on all aspects of ultrasound imaging for MSF projects. It is a collaborative effort of the Médecins Sans Frontières (MSF) Diagnostic Imaging Working Group (DIWG). It describes the use of ultrasound in MSF for field and headquarters staff and informs on topics such as selecting equipment, indications for use, scanning techniques, training, and teleradiology, among others. It is intended for use by health and specialist advisors, medical doctors, midwifes, nurses, medical coordinators, sonographers, radiographers, bio-medical engineers and logisticians amongst others for the planning and implementation of ultrasound services.

The DIWG is an intersectional working group aiming to set and improve the standards on quality of medical imaging in MSF projects.

For any questions on procuring or replacing equipment, installation, field visits, safety, staff training, image interpretation, and other issues relating to diagnostic imaging please contact your medical/health advisor from your OC, the MSF intersectional radiographer, or the biomedical engineer from your OC.

The DIWG would be grateful for any comments to ensure that this manual continues to evolve and remains relevant to the realities of the field.

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This manual is also available as a pdf document through diagnostic-network@msf.org.

Note: If no source is given to an image it has been obtained by the author(s) of the chapter, or the DIWG.

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Annexes

Abbreviations

AA	Abdominal Aorta
AAA	Abdominal Aorta Aneurysm
AC	Abdominal Circumference
AF	Amniotic Fluid
AFI	Amniotic Fluid Index
ANC	Antenatal Care
AP	Anterior-Posterior
APH	Antepartum Haemorrhage
AUA	Average Ultrasound Age
BEmONC	Basic Emergency Obstetric and Neonatal Care
BPD	Bi-parietal Diameter
CA	Celiac Axis
CCA	Common Carotid Artery
CEmONC	Comprehensive Emergency Obstetric and Neonatal Care
CFA	Common Femoral Artery
CFV	Common Femoral Vein
CI	Caval Index
CRL	Crown Lump Length
CT	Computed Tomography
CVC	Central Venous Catheter
CVP	Central Venous Pressure
DI	Diagnostic Imaging
DIWG	Diagnostic Imaging Working Group
DTA	Descending Thoracic Aorta
DVD	Digital Versatile Disc
DVT	Deep Vein Thrombosis
EDD	Estimated Due Date
EFW	Estimated Foetal Weight
EPTB	Extrapulmonary Tuberculosis
FASH	Focused Assessment with Sonography for HIV-associated tuberculosis
FAST	Focussed Assessment with Sonography in Trauma
FHR	Foetal Heart Rate

FL	Femur Length
FF	Free Fluid
GA	Gestational Age
GTD	Gestational Trophoblastic Disease
HC	Head Circumference
HCC	Hepatocellular Carcinoma
HIV	Human Immunodeficiency Virus
IE	Infective Endocarditis
IPH	Intraparenchymal Haemorrhage
IUD	Intrauterine Device
IUFD	Intrauterine Fetal Death
IUGR	Intrauterine Growth Restriction
IVC	Inferior Vena Cava
IVH	Intraventricular Haemorrhage
JPEG	Joint Photographic Experts Group
LBCV	Left Brachiocephalic Vein
LLD	Left Lateral Decubitus
LMP	Last Menstruation Period
LUQ	Left Upper Quadrant
LV	Left Ventricle
MD	Medical Doctor
MHz	Megahertz
MPEG	Moving Picture Experts Group
MRI	Magnetic Resonance Imaging
MSD	Mean Sac Diameter
MSF	Médecins Sans Frontières
OB	Obstetric
OC	Operational Centre
OCA	Operational Centre Amsterdam
OCB	Operational Centre Brussels
OCBA	Operational Centre Barcelona
OCG	Operational Centre Geneva
OCP	Operational Centre Paris
PA	Posterior-Anterior
PACS	Picture Archiving and Communication System
PICC	Peripherally Inserted Central Catheter

PID	Pelvic Inflammatory Disease
PCOS	Polycystic Ovary Syndrome
PE	Pulmonary Embolism
PPH	Postpartum Haemorrhage
QA	Quality Assurance
RBCV	Right Brachiocephalic Vein
RPOC	Retained Products of Conception
RV	Right Ventricle
RUQ	Right Upper Quadrant
SAH	Subarachnoid Haemorrhage
SEH	Subependyma Haemorrhage
SMA	Superior Mesenteric Artery
SMV	Superior Mesenteric Vein
SVC	Superior Vena Cava
TA	Transabdominal
TPR	Termination of Pregnancy
TOA	Tubo-ovarian Abscess
TB	Tuberculosis
TTE	Transthoracic Echocardiography
TV	Transvaginal
US	Ultrasound
USB	Universal Serial Bus
WHO	World Health Organization

1. Introduction to ultrasound

1.1 Ultrasound in patient management

Ultrasound imaging investigations can assist in the diagnosis and monitoring of disease and in guidance of invasive procedures. Trained clinician-performed, point-of-care ultrasonography is emerging as a useful diagnostic tool in resource-limited settings for a variety of indications. It has the advantage of being portable, safe (no ionising radiation incurred) and being relatively cheaper than other imaging options.

Ultrasound can provide accurate information when other imaging modalities are not available. It can not only indicate a diagnosis but can also be used to guide a biopsy or an aspiration that may lead to more accurate treatment. It is a safe, effective and highly flexible imaging modality.

Ultrasound supports the following clinical areas in MSF:
- Obstetrics: routine and emergency obstetrics
- Gynaecology
- Surgery, e.g. abdominal
- Infectious diseases e.g. FASH (Focused Assessment with Sonography for HIV-associated tuberculosis) scan in extrapulmonary tuberculosis
- Paediatrics
- General medicine
- Emergency medicine e.g. FAST (Focussed Assessment with Sonography in Trauma)
- Anaesthesia e.g. line placement

1.2 Can anyone perform an ultrasound procedure?

Ultrasound is operator dependent and the usefulness of an ultrasound examination depends on the experience and the capability of the ultrasound examiner. Ultrasound technique can be taught but is solidified by experience. In the hands of an untrained or poorly trained person, ultrasound may be misleading and even be dangerous because misinterpretation will lead to an erroneous diagnosis.

Various medical persons use ultrasound and can be trained in its use. This includes doctors, health practitioners, nurses, midwives, radiographers and sonographers. Sonographers train for several years to develop wide professional expertise. Some medical specialties perform specialised ultrasound scans as part of their training e.g. gynaecologists and cardiologists. Training for diagnostic ultrasound examinations and procedures is varied and the level, duration and intensity depend on the desired uses.

When using an ultrasound machine, application training is essential to be able to find and select the appropriate functions. This is additional to basic anatomic knowledge for ultrasound imaging.

Interpretation of findings also requires knowledge of anatomy and pathology but specific questions must be posed and answered. It is also important to understand when an ultrasound examination is actually inconclusive.

Teleradiology can be used to send clips and images for specialist consultation. For more information on teleradiology, see Chapter 4.2.

Field trainings can be coordinated by the diagnostic imaging advisors. Workshop training is also available on request. For more information on ultrasound training, see Chapter 5.

In the hands of an untrained or poorly trained person,
making a diagnosis based on ultrasound images may be misleading and even dangerous.

1.3 Procurement

Ultrasound machines and accessory equipment that are recommended in this manual are available under the section 'Diagnostic Imaging' in the current Medical Catalogue, Volume 2, Part B.

Consumable items such as ultrasound gel can be found in the 'Diagnostic Imaging Supplies' section, Volume 2, Part A.

1.4 Ultrasound definition of terms

Patient positioning

Supine	Lying on the back, face up.
Prone	Lying on the front, face down.
Semi-Supine	Lying on the back, face up, with the upper body titled forward (to varying degrees).
Right lateral decubitus	Lying on the right side.
Left lateral decubitus	Lying on the left side.

Anatomical planes

Transverse (axial) plane	Horizontal line dividing the body into upper and lower (superior and inferior) sections.
Sagittal (longitudinal) plane	Vertical line dividing the body into left and right sections.
Coronal (frontal) plane	Vertical line dividing the body into front and back (anterior and posterior) sections.

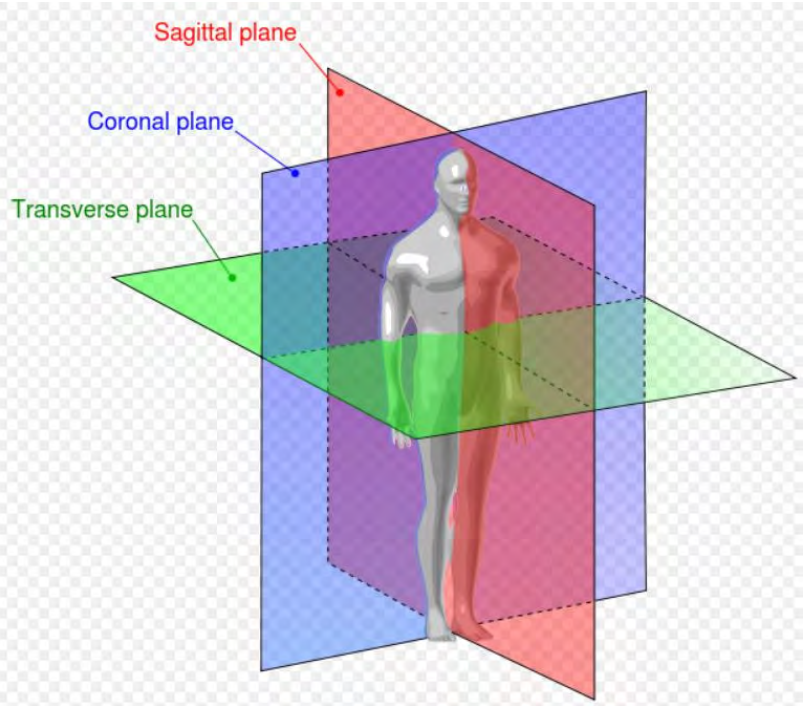


Figure 1: Human anatomical planes
Image sourced from: https://en.wikipedia.org/wiki/File:Human_anatomy_planes.svg

Transducer positions

Longitudinal Transducer is placed along the long axis of the body, i.e. head to toe. Patient's anatomy usually appears in the sagittal plane.

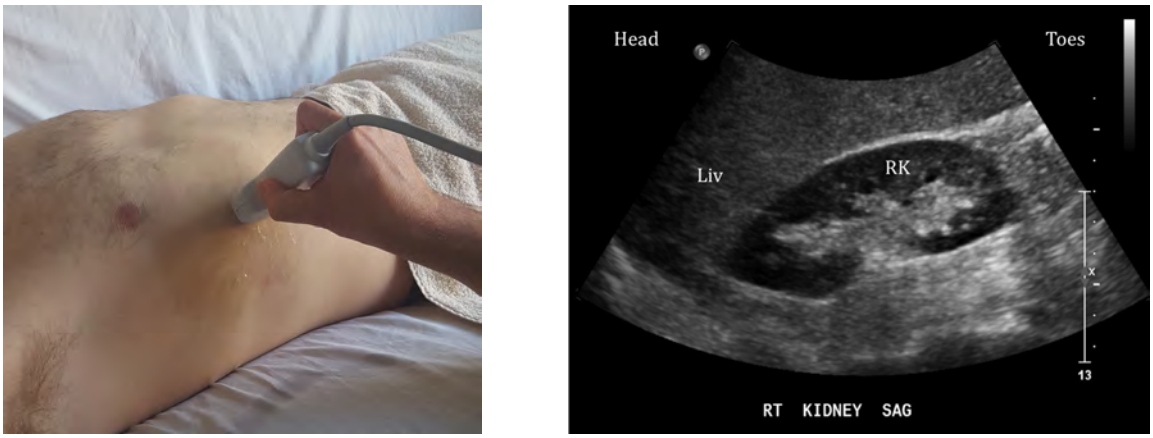


Figure 2: Longitudinal transducer position demonstrating the anatomy in the sagittal plane

Transverse Transducer is placed across short axis of the body, i.e. left to right. Patient's anatomy appears in the axial plane.

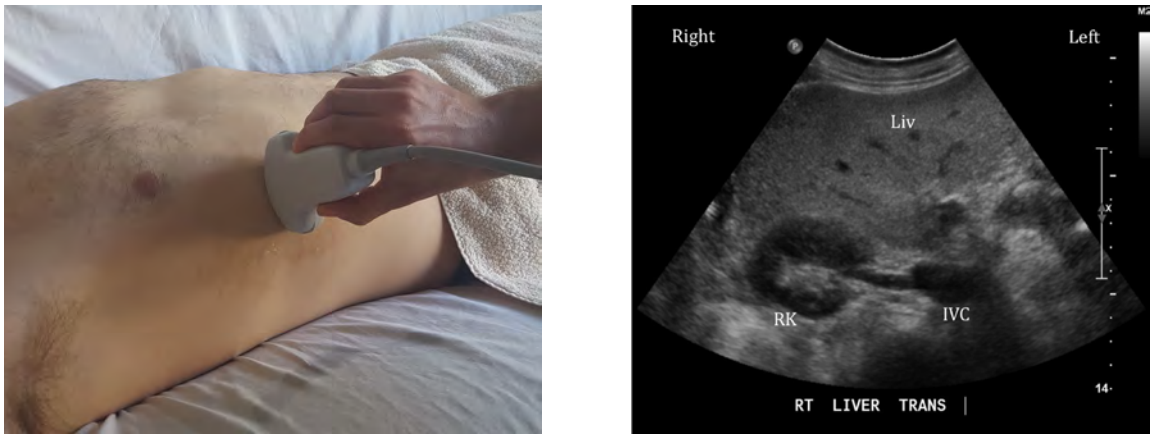


Figure 3: Transverse transducer position with the anatomy in the axial plane

Tissue attenuation

Echogenic A material that produces echoes. The more echogenic a substance is, the whiter the image appears.

Echolucent A material that does not produce echoes. The more echolucent a substance is, the blacker the image it produces.

Image interpretation

Anechoic Producing no echoes at all. The resulting image is therefore completely black.

Hyperechoic More echogenic, therefore whiter / brighter, than surrounding tissue.

Hypoechoic Less echogenic, therefore darker, than surrounding tissue.

Simple fluid is visualised with ultrasound as being anechoic, i.e. black.

Blood clots and bone are visualised as hyperechoic, i.e. white.

Organs are more echogenic than fluid, and less echogenic than bone, therefore they appear as shades of grey.

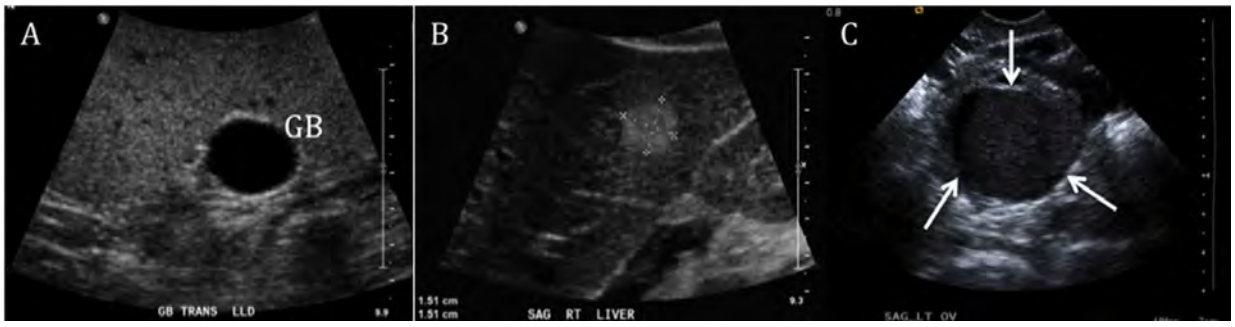


Figure 4: Anechoic, hyperechoic and hypoechoic structures commonly encountered include the anechoic (black) simple fluid-filled gallbladder (GB) in A; hyperechoic (echogenic) liver haemangioma (cursors) in B; and hypoechoic hemorrhagic ovarian cyst (arrows) in C.

Ultrasound fields

Ultrasound field	The region covered by the ultrasound beam as displayed on the screen.
Near field	The top half of the ultrasound field, which represents anatomy closer to the transducer.
Far field	The bottom half of the ultrasound field, which represents anatomy further away from the transducer.

Image resolution

Spatial resolution	Ability to distinguish two points as separate, i.e. detail of image.
Axial resolution	Ability to distinguish two points as separate in the direction parallel to the ultrasound beam.
Lateral resolution	Ability to distinguish two points as separate in the direction perpendicular to the ultrasound beam.
Temporal resolution	Ability to detect that an object has moved over time. Also called the 'frame rate'.

1.5 Documentation of ultrasound examinations and results

Documentation of the ultrasound examinations is important in the continuation of and provision of care for patients. As opposed to a dedicated ultrasound examination ultrasound findings in a point of care or bedside ultrasound often do not provide a full written report, however, the findings of the scan must documented in the patient notes as this will form part of the medical records. This may be a hand written notes, and / or in the case of an Obstetrics / Gynecology scan a worksheet (Annex 7).

Information to be includes in the patient notes:
- Date / time of examination
- Type of scan
- Written results (even if negative)

- Print out of representative image of positive findings (if possible):
  - Image annotation as appropriate (e.g. image orientation, location, measurements)
  - All print out images must include the correct patient identifying information (including: name, patient identification number / hospital number, time and examination type)
- Name and position of the person performing the examination

This does not need to be a lengthy report but must communicate clearly to others the procedure and results, for example: 01/01/2001, 0900HRS, FAST US, negative exam; no free fluid / organ injury detected, J. Smith ER MD.

If there are positive or non-routine results, it is the responsibility of the person performing the examination to notify the primary care giver, or the person responsible for follow up action. This should be clearly documented in the patient notes.

A separate ultrasound register should be kept of patients having an ultrasound examination. It should include the following:
- Exam number
- Date / time of examination
- Patient name
- Patient date of birth / age
- Patient identification and or hospital number
- Type of examination
- Ward / service e.g. ICU, OPD
- Name of person performing the scan

A template is provided in Annex 8.

2. Ultrasound equipment and basics of imaging

2.1 Overview of equipment

Ultrasound machine

The M-Turbo (SonoSite, USA) unit is the standard MSF ultrasound machine (Medical Catalogue, Volume 2, Part B). It is a compact and portable ultrasound machine with high image resolution. It is battery powered lasting up to 2 hours, weighs only 3-4 kg and has a robust magnesium case. It is easy to use and has capacity for clip storage and image exportation (via USB). It includes advanced imaging options such as colour Doppler, pulsed wave and continuous Doppler and extensive measurement tools and annotation options.

For the standard MSF configuration of the M-Turbo and optional accessories see Annex 1.

Figure 1: M-Turbo (SonoSite, USA)
Image sourced from: https://www.sonosite.com/product/m-turbo

The MicroMaxx and NanoMaxx are both SonoSite ultrasound machines that are either no longer available or no longer the preferred choice for purchase but may still be present in some projects. This manual includes some technical details about all three SonoSite ultrasound machines.

Transducers (Probes)

The transducer is the attachment to the ultrasound machine used on the patient that produces sound waves and receives the echoes. Transducers come in many shapes and sizes with different ultrasound frequencies.

These different components determine the size and shape of the ultrasound field, depth and resolution of the image. The standard ultrasound transducer supplied with the SonoSite M-Turbo machine is a 5-2 MHz, curved array abdominal transducer with a scan depth of 30 cm. This transducer is optimal for most general uses including abdomen, pelvis, and 2nd and 3rd trimester obstetric examinations.

There are specialized ultrasound transducers for more diverse applications including vaginal, paediatric, cardiac and vascular transducers, each with a range of linear and curved array sizes and frequencies, and which must be ordered separately. Specialized transducers should only be used by experienced operators for specific indications.

Figure 2: SonoSite C60x curved array transducer
Image sourced from: https://www.sonosite.com/transducers

For the different transducer options for SonoSite ultrasound machines and their applications, see Annex 2.

Transducers are expensive and very fragile, please handle with utmost care!

Ultrasound (coupling) gel

Ultrasound gel is a consumable (Medical Catalogue, Volume 2, Part A) which is used to improve contact between the transducer and the patient while promoting transmission of sound through the skin. Use of proper ultrasound gel not only enhances the image but also allows easy manipulation of the transducer across the skin surface into a variety of positions. If ultrasound gel is not available, water based lubricants, such as KY Jelly, water-based lotion or plain water may be used. Oils must not be for ultrasound examinations as this damages the transducer and results in a voided warranty.

Only use ultrasound gel or water based lubricants on the transducer.

Oil-based lubricants damage the transducer and must not be used!

2.2 Basic principles of ultrasound imaging

How does sound make an image?

Diagnostic ultrasound uses a high frequency sound beam to generate an image of internal structures of the body along the trajectory of the beam. The beam is created by passing an electric charge through a crystal located in the transducer, causing the crystal to change shape and produce a high frequency sound wave, i.e. ultrasound.

The ultrasound beam, focused by the transducer, can penetrate most tissues (e.g. fluid, soft tissue organs) relatively easily but is completely reflected off the surface of others structures containing air (e.g. lung, bowel) and is completely absorbed by structures such as bone, gallstones or kidney stones thereby obscuring any structures deep to them.

The transducer also acts as a receiver and converts the reflected sound into an image depending on the time of the returning echo and the echo intensity. These parameters are translated as depth and image brightness, respectively.

Ultrasound images are obtained by using a pulse-echo technique with the transducer serving as both a sound producer and a sound-receiver. A brief (microsecond) pulse of ultrasound energy is directed into the patient. The transducer then becomes a receiver detecting ultrasound beams, i.e. echoes reflected back to the transducer from tissues in the patient (Figure 3). The round trip time-of- flight measured from when the sound beam was produced to when the echo was received determines the depth of the structure. The intensity of the echo determines the brightness of the structure. The ultrasound computer assumes that the speed of sound in tissue is a constant, i.e. 1540 meters/second.

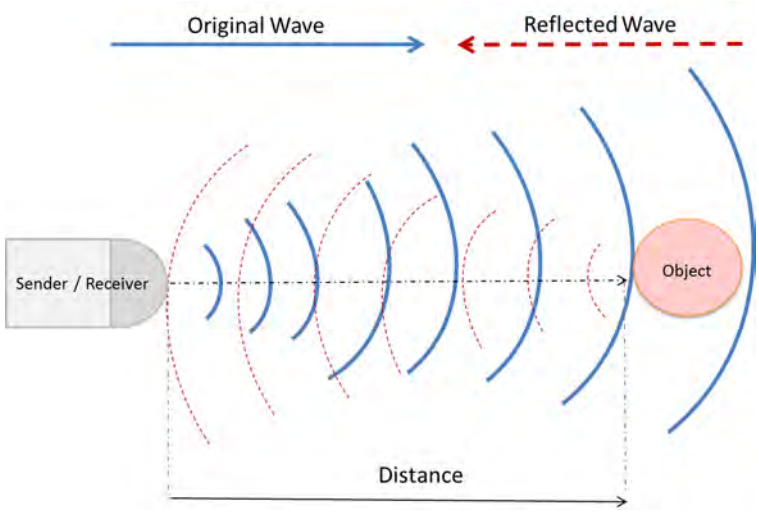


Figure 3: Diagrammatic representation of the sound wave generating an image
Adapted from: https://theultrasoundsite.co.uk/physics-of-musculoskeletal-ultrasound/

The effect of different tissues

As the beam penetrates tissue, such as the liver, the sound wave is partially absorbed and partially reflected. The amount of absorption and reflection depends on the composition of the tissue and the distance from the transducer. The energy of the sound beam progressively decreases with distance from the transducer.

If the beam penetrates tissue easily with little sound absorption or reflection, e.g. fluid in the bladder, no echoes are reflected and the image appears black or anechoic. If the beam is completely reflected as with structures containing air, the intensity of the echoes is stronger and the structure will appear white or hyperechoic. No image will be created by air-containing structures or bone as they create an 'acoustic shadow' because the beam cannot pass through air or bone.

Tissues of varying composition will return differing intensity of echoes creating different shades of grey in an ultrasound image. This allows the user to differentiate and visualize anatomy.

In the example below skin and subcutaneous tissue are organized in fascial planes of different echogenicity, i.e. levels of whiteness. The liver is hyperechoic compared to the right kidney. The gallbladder is anechoic because it is filled with fluid. The inferior vena cava and the right renal vein are hypoechoic because they contain blood cells, which weakly reflect sound waves. The spine shows the anterior cortex as hyperechoic, i.e. white, with posterior shadowing artefact because the ultrasound beam is progressively absorbed by bone (Figure 4).

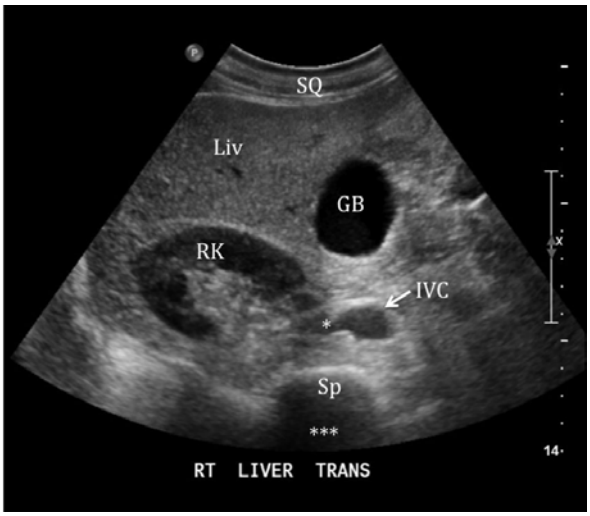


Figure 4: Image of right upper quadrant displaying the regional anatomy with tissues of varying density and therefore varying sonographic appearance. Skin and subcutaneous tissue (SQ), right kidney (RK), gallbladder (GB), inferior vena cava (IVC), right renal vein (*), spine (Sp) posterior shadowing artefact (***).

Acoustic (sonographic) window

Ultrasound image quality can be improved by the use of a good acoustic window. An acoustic window is a portion of the anatomy in the area of interest that transmits sound waves very efficiently, and allows improved imaging of structures deep to the window. Good use of acoustic windows also reduces artefacts and image degradation from structures such as bowel gas.

The classic example is using the full urinary bladder as a window to the uterus and ovaries (Figure 5), distal ureters or prostate. Also as seen above (Figure 4), the liver provides a useful acoustic window for examining the right kidney.

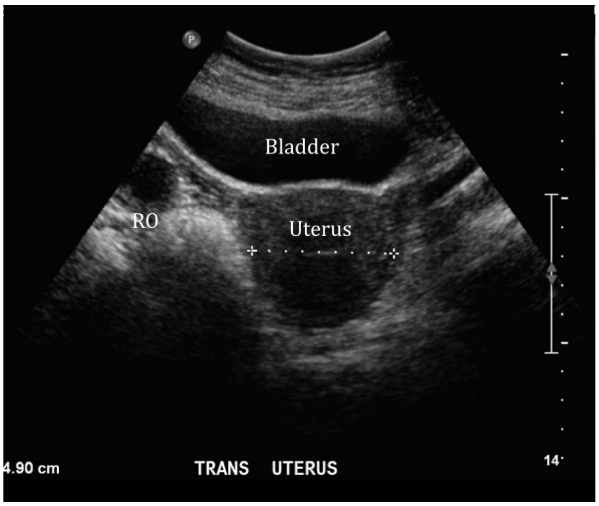


Figure 5: Transverse image of the female pelvis The image demonstrates using urine in the bladder as an acoustic window to achieve high resolution images of the uterus and right ovary (RO).

It is often possible to improve the ultrasound imaging of a particular structure in a given patient by arranging the patient's position (e.g. supine, decubitus, sitting or standing) and the transducer position in such a way so as to create an acoustic window to the organ of interest. For example, the gallbladder filled with liquid bile, can be used as an acoustic window to see structures in the pancreatic head region or the retroperitoneum and around the inferior vena cava (Figure 6).

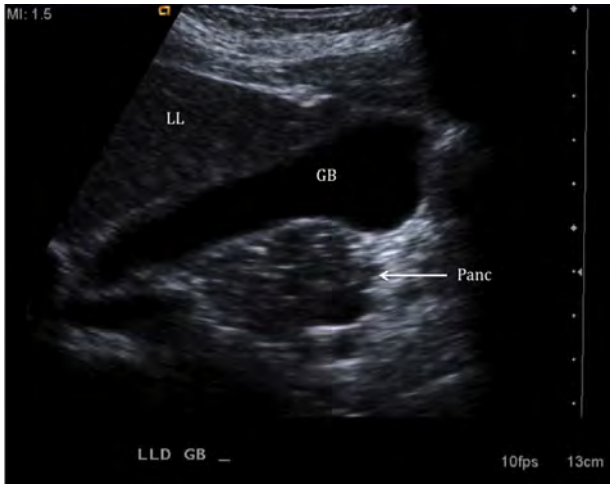


Figure 6: Longitudinal image through the left lobe of the liver (LL) and gallbladder (GB)
The patient is in the left lateral decubitus position to move the fluid-filled gallbladder directly overlying the pancreas. The gallbladder then acts as an acoustic window to the pancreatic head.

2.3 Ultrasound machine basics

Each ultrasound machine will have a variety of buttons depending on the type of machine. It is important to know and understand the basic buttons / functions that control image quality.

The basic layout of the control panel and function of the buttons of the MSF standard M-turbo ultrasound machine and screen are shown below. The most common buttons / functions are described in more detail later.

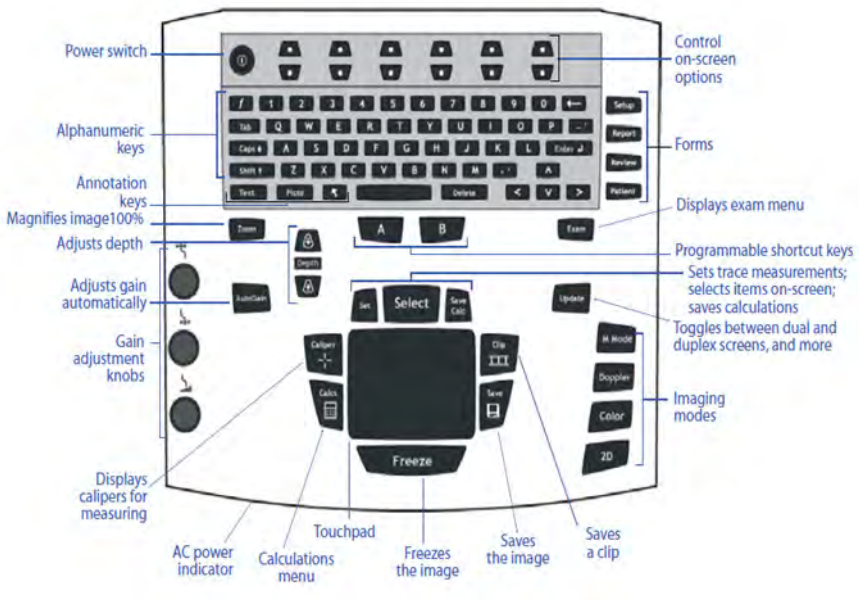


Figure 7: Sonosite M-Turbo control panel
Image courtesy of Sonosite Ultrasound System: Quick start guide
https://www.sonosite.com/sites/default/files/support_docs/M-Turbo_1.3_UG_P07662-03B_e.pdf

Figure 8: Sonosite M-Turbo screen layout
Image courtesy of Sonosite Ultrasound System: Quick start guide
https://www.sonosite.com/sites/default/files/support_docs/M-Turbo_1.3_UG_P07662-03B_e.pdf

Ultrasound modes

An ultrasound machine can be set for different modes:

– *B-mode* stands for 'brightness mode' and is a two dimensional image showing anatomy in different shades of grey. It is the most commonly used mode.

– *M-mode* stands for 'motion mode' and shows echoes in one line of sight of the B-mode image displaying movement as a function of time. The result is a wavy line. M-mode is most commonly used for cardiac ultrasound and to document foetal cardiac activity.

– *Doppler mode* shows the presence, direction and velocity of blood flow. Doppler velocities can be displayed as a line graph, i.e. spectral Doppler, or as a colour display overlaid on the grey-scale image, i.e. colour Doppler.

Transducers: frequency, penetration and resolution

The frequency of the transducer that is selected is very important.

– High-frequency transducers, e.g. 5-12 MHz give better spatial resolution, i.e. image detail, but are limited in their depth penetration and are useful for superficial structures, e.g. vascular structures and the thyroid gland.

Figure 9: Example of a high frequency transducer
Image sourced from: https://www.sonosite.com/transducers

– Lower frequency transducers, e.g. 2-5 MHz, are useful for deep visualization such as for abdominal imaging in adults but they have poorer spatial resolution. The trade-off is, therefore, depth for detail.

Figure 10: Example of a low frequency transducer
Image sourced from: https://www.sonosite.com/transducers

The M-Turbo has broad band transducers that offer a range of frequencies around the centre-frequency so there is no need to manually select required frequency on the machine once the appropriate transducer is connected (Annex 1).

To improve an image and get better spatial resolution, i.e. display of detail, you would choose a high frequency transducer but would be restricted by sound penetration and the depth of structures that can be visualized.

To improve depth penetration in a large patient one would choose a low frequency transducer but with decreased spatial resolution.

On the M-Turbo, the 'optimize' on-screen options adjust the relationship between resolution and penetration:
– *Res* shows the best possible resolution
– *Gen* shows a balance between resolution and penetration
– *Pen* shows the best possible penetration

As transducer frequency increases:
penetration decreases and resolution increases.

As transducer frequency decreases:
penetration increases and resolution decreases.

What else do I need to know about ultrasound parameters before I start?

How to attach the transducer:

Line up the connectors, and gently attach the appropriate transducer as shown below (Figure 11). Do not force or use excessive power – you will damage the connections!

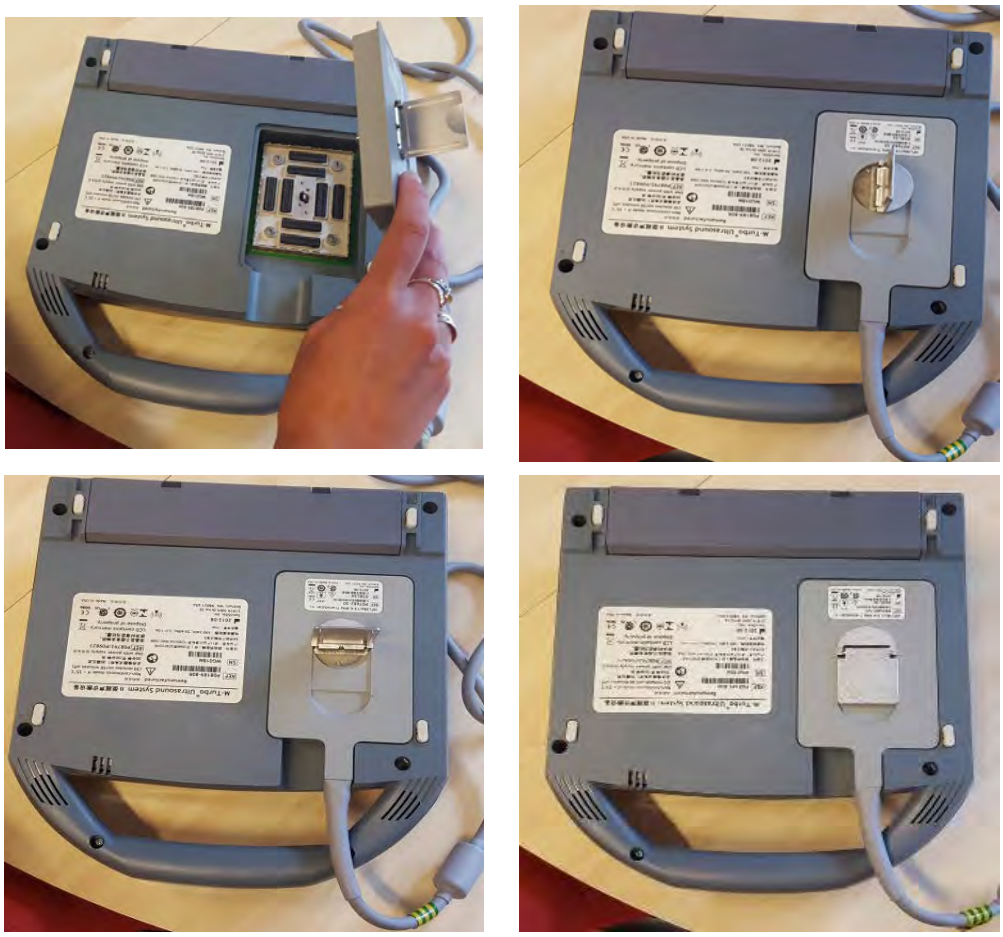


Figure 11: Connecting a transducer
Place the M-Turbo upside down, line up the connections for the transducer with the silver latch in the vertical position and gently fit into position.
Rotate the latch counter clockwise and pull the latch down to lock the transducer into place.

Patient details and exam type:

Firstly, always select the relevant type of exam from the pre-set menu according to scan type being undertaken, e.g. abdominal, obs / gyn. The available exam types depend on the transducer. Patient details are entered on the same screen (Figure 12).

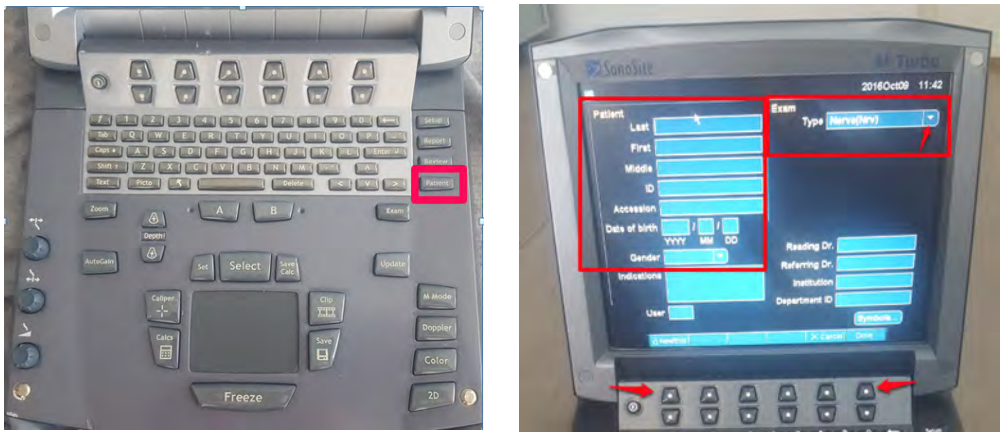


Figure 12: Adding a new patient and selecting the exam type
To add a new patient, press the patient button (highlighted) in the image on the left.
From the image on the right, press the new/end button (arrow bottom left of screen), enter the patient's details (highlighted box). Select the appropriate exam type from the drop down menu (highlighted box with arrow), then click 'Done' (arrow bottom right of the screen) to start scanning

Other main selections are:

Depth

Depth selection increases or decreases the depth of the ultrasound image: how far into the body from the transducer is displayed on the image.

The depth setting should be adjusted to optimally display the object of interest. Aim to make the object of interest as large as possible in the displayed image. (Figure 13).

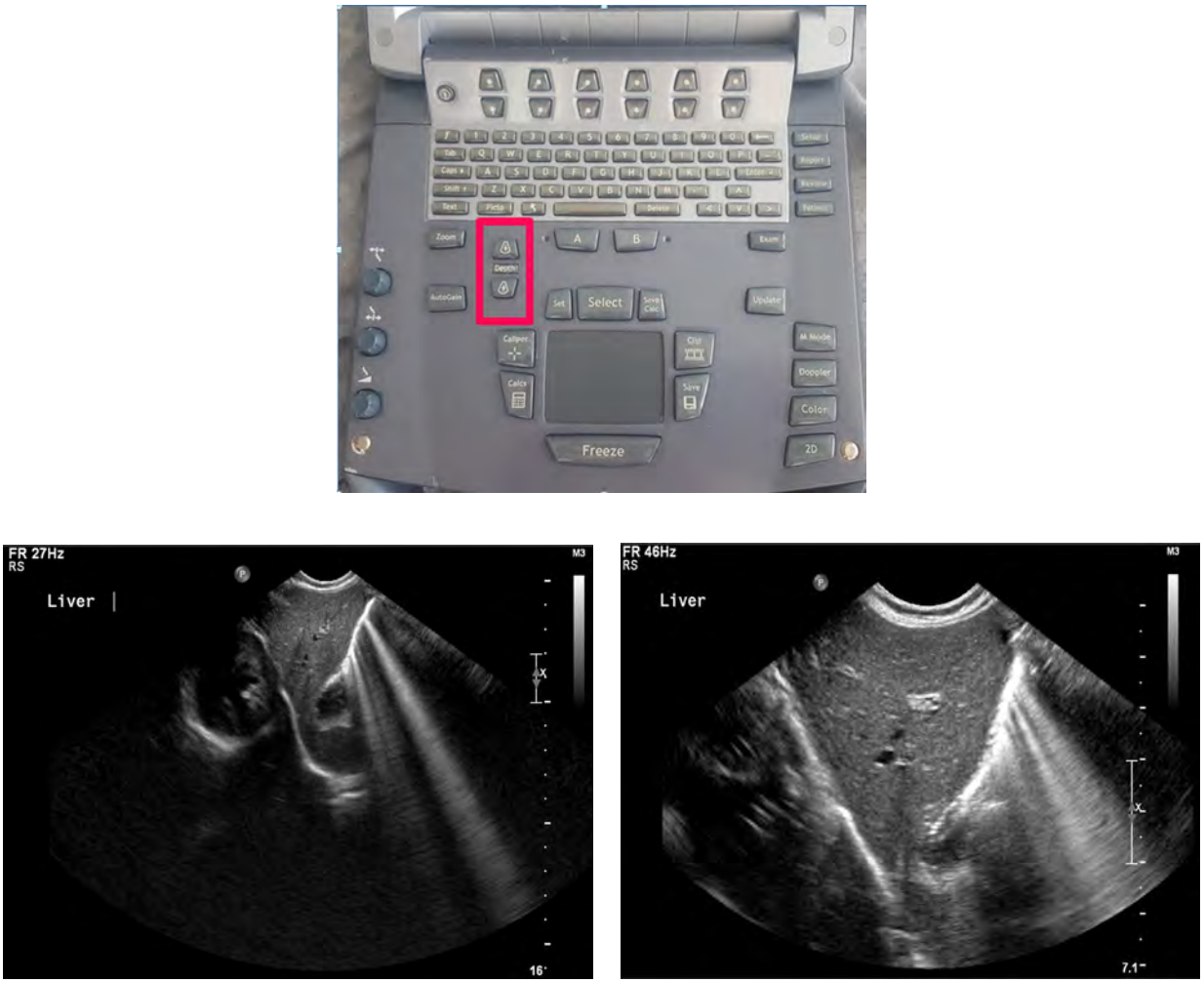
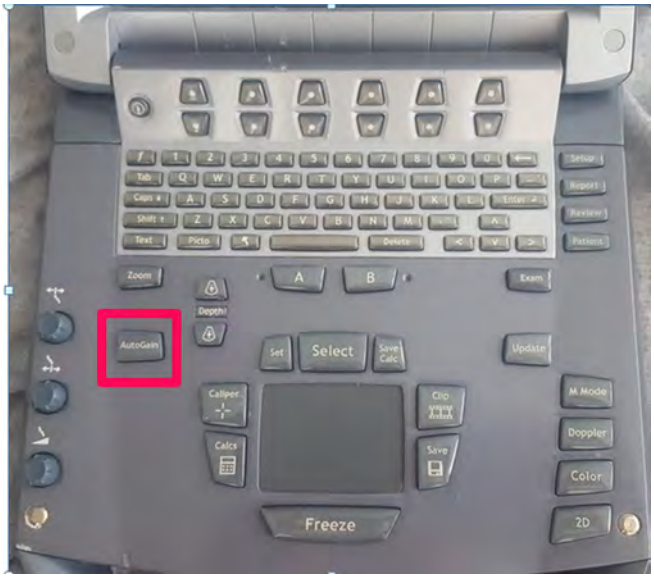


Figure 13: The Depth button and the effect of Depth on image quality
The depth button (highlighted) on the keyboard on the top image.
The image on the left has incorrect depth settings which limits the image quality.
This is corrected in the image on the right which displays the liver with more appropriate depth settings, and better image quality.

Gain

Gain changes the overall strength of the returning echoes and will adjust how bright the image appears. Gain should be adjusted to produce a pleasing uniform display of echoes on the image. To adjust the gain automatically, press the 'AutoGain' button. The gain is automatically adjusted each time the button is pressed.

If the gain settings are incorrect the image will appear either too bright, i.e. too much gain, or too dark, i.e. too little gain. A balance is required to produce a uniform ultrasound image. Increasing or decreasing the gain can also be used to highlight certain structures in the image (Figure 14).



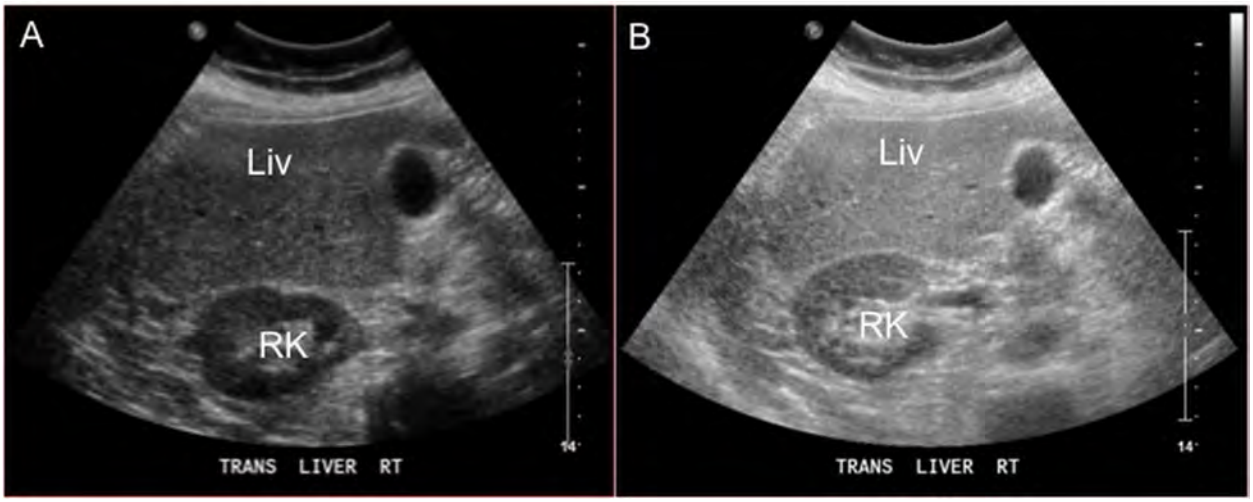


Figure 14: The Auto gain button and the effect of gain on image quality.
The Auto Gain button (highlighted) on the keyboard on the top image.
In A, the gain setting is good for the depiction of the liver (Liv) although the right kidney (RK) is too dark and the detail suboptimal. In B, with the gain turned up, the image quality in the RK is improved, although the liver appears so bright that detail is lost.

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Freeze

'Freeze' pauses/resumes scanning allowing the user to scroll through the last 30-60 seconds of scanning to review images.

The user can use this function to select appropriate image(s) for measurements and/or to save a copy of image(s). The image number in the set of stored images using the freeze button is displayed on the screen (Figure 15).

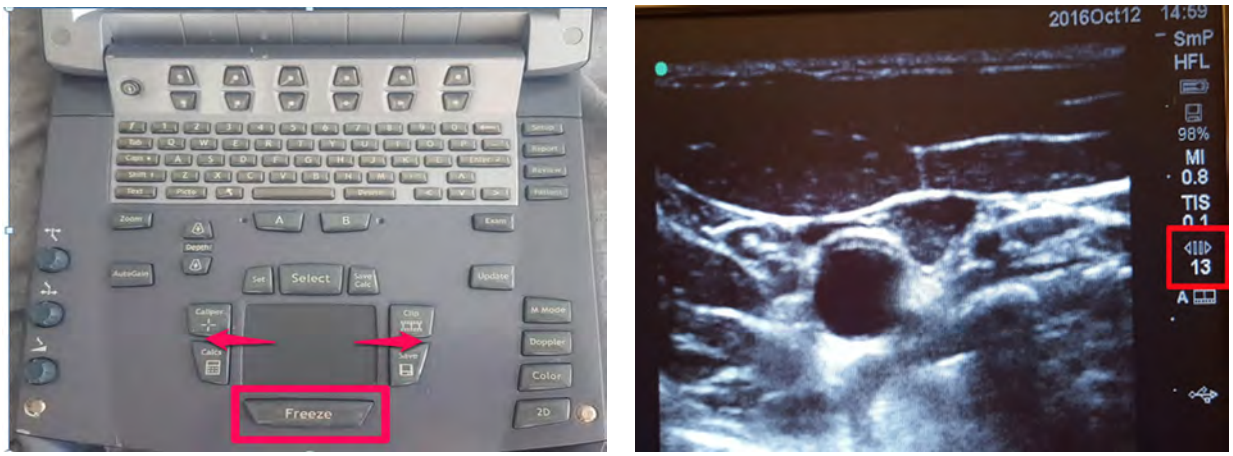


Figure 15: The freeze button
The 'freeze' button (highlighted. Use the track pad to scroll forward or back in direction of the arrows (highlighted) through the last 30-60 seconds of scanning in the image on the left.
An image from scanning is displayed with the number of the image in series (highlighted).

Measurements

Measurements can be done using the callipers and the cursor, e.g. for foetal biometrics.

There are different types of measurements but the most common is the callipers measurement. Users can use the freeze button (above) to first select an appropriate image. Then, by clicking the 'calliper' button and using the track pad move the cursor into position and click select. Then move the second cursor into position. The measurement(s) then display on the bottom left of the screen (Figure 16).

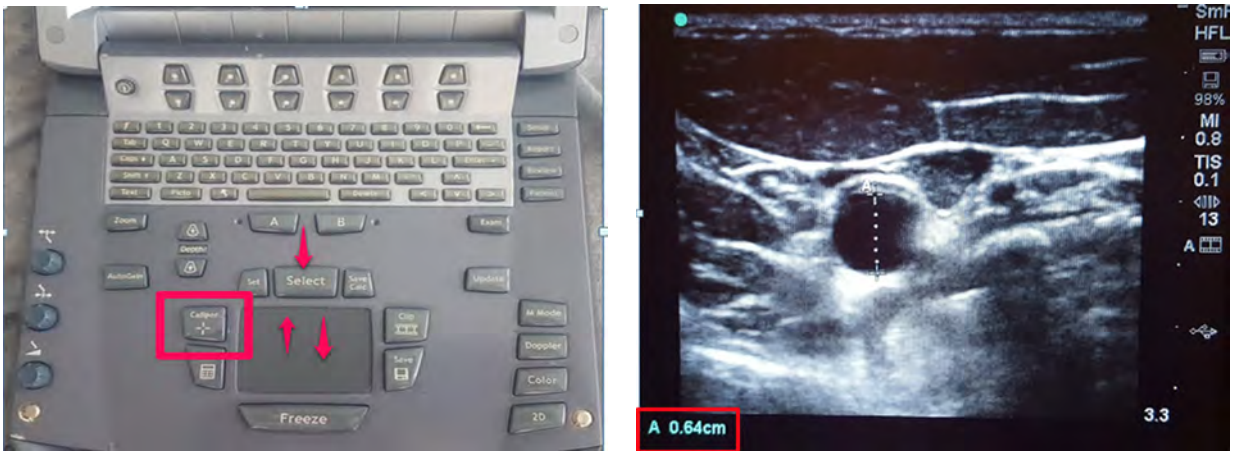


Figure 16: Callipers measurement
The callipers button (highlighted) and controls on the keyboard to make a measurement (arrows) in the image on the left.
The Callipers measurement is displayed on the screen (dotted line) with the measurement in cm highlighted in the image on the right.

Save

Save stores images to the patient folder on the internal memory of the machine.

These images can be reviewed in the patient's folder on the machine after the scan and can be exported for viewing or consultation via the USB port. A percentage of the internal memory remaining is displayed on the screen (Figure 17).

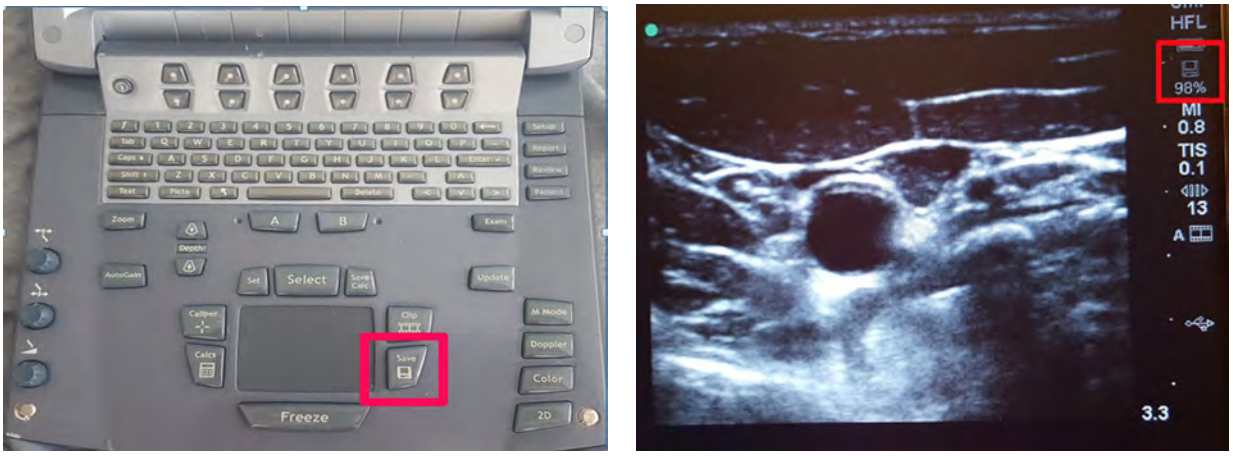


Figure 17: Save button
The 'save' button on the keyboard (highlighted) in the image on the left.
The remaining internal memory of saved images/clips (highlighted) in the image on the right.

Zoom

Zoom magnifies the area in the displayed box by 2–3 times.

Press the Zoom button once to activate, a box is displayed on the screen that can be moved to the area of interest using the touch pad. Click 'zoom' again to magnify (Figure 18).

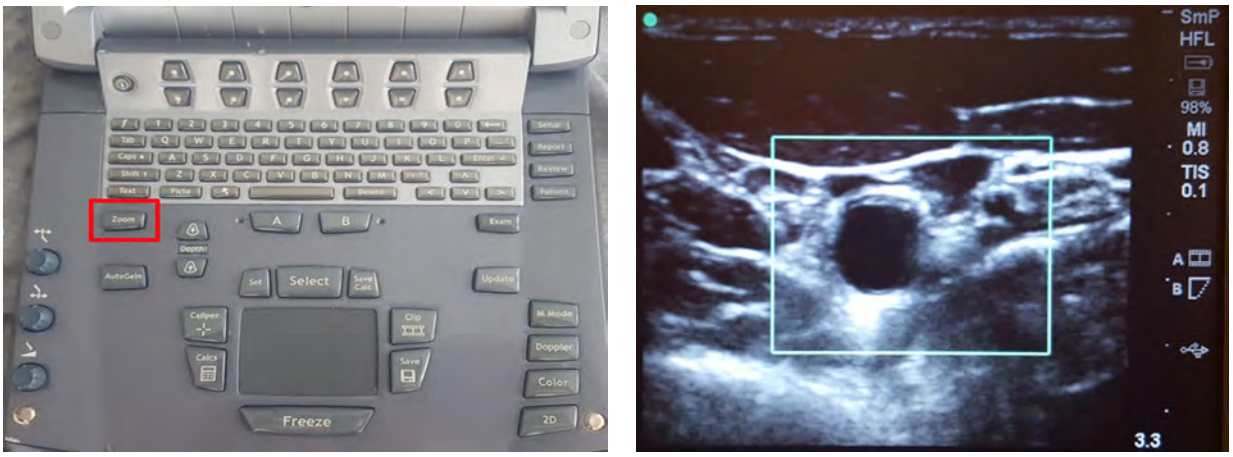


Figure 18: Zoom button
The 'zoom' button on the keyboard (highlighted) in the image on the left.
The displayed box on the screen (highlighted) in the image on the right; by pressing the 'zoom' button again the selected area is magnified.

Clip

Clip records a short video clip or movie of the scan; it can be used to scan through an area of interest, sometimes called a sweep.

Pressing the 'clip' button starts the recording. The clip can be saved to the internal memory of the device and reviewed and/or exported e.g. via USB (Figure 19). For more information see the section on exporting images (Annex 3 and Annex 5).

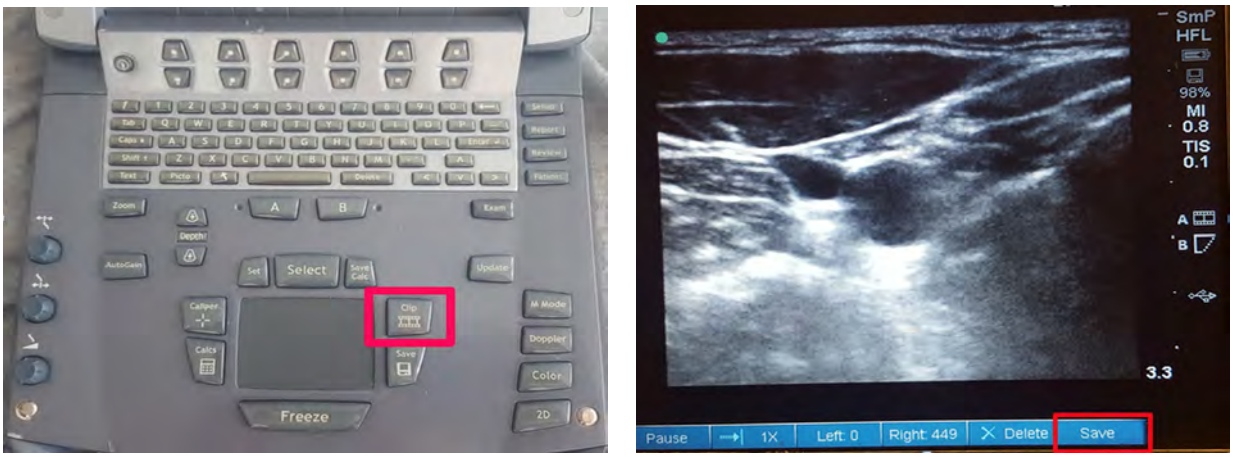


Figure 19: Clip button
The 'clip' button on the keyboard (highlighted) in the image on the left.
The clip can be saved by pressing the button on keyboard below the save function (highlighted) on the image on the right.

Focus / focal zone

Focus will add or change focal zones in the image. Focus should be adjusted to maximize image resolution at the depth of the object of interest. The more focal zones, the slower the frame rate, and, therefore, the less accurate the depiction of movement.

If the focal zone is incorrect, a given structure may not be as clear or artefacts present not present at all (Figure 20). For example, even with a normally shadowing structure like a gallstone, there may be no shadowing visible with the focal zone placed away from the depth of the artefact (Figure 20B).

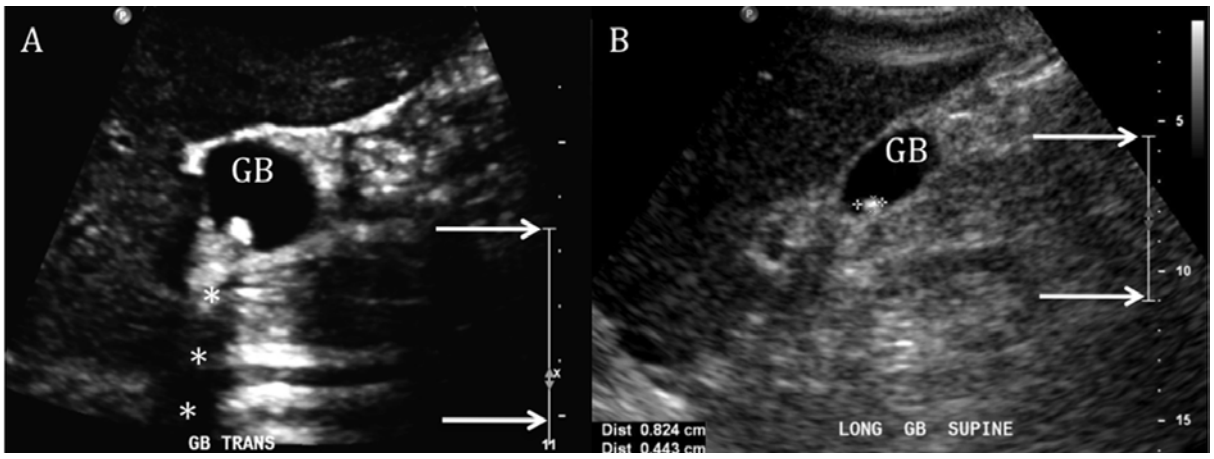


Figure 20: A: Transverse and B: Longitudinal image of the gallbladder with the depth of the focal zone is indicated by the bar along the right side of the image on this unit (between arrows).
A - Dense shadowing (*) is obvious with the focal zone deep to the gallbladder, which is the location of this ultrasound artefact.
B – No shadowing is visible as the focal zone is centred on the gallbladder (GB) rather than the tissue deep to the gallbladder.

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.

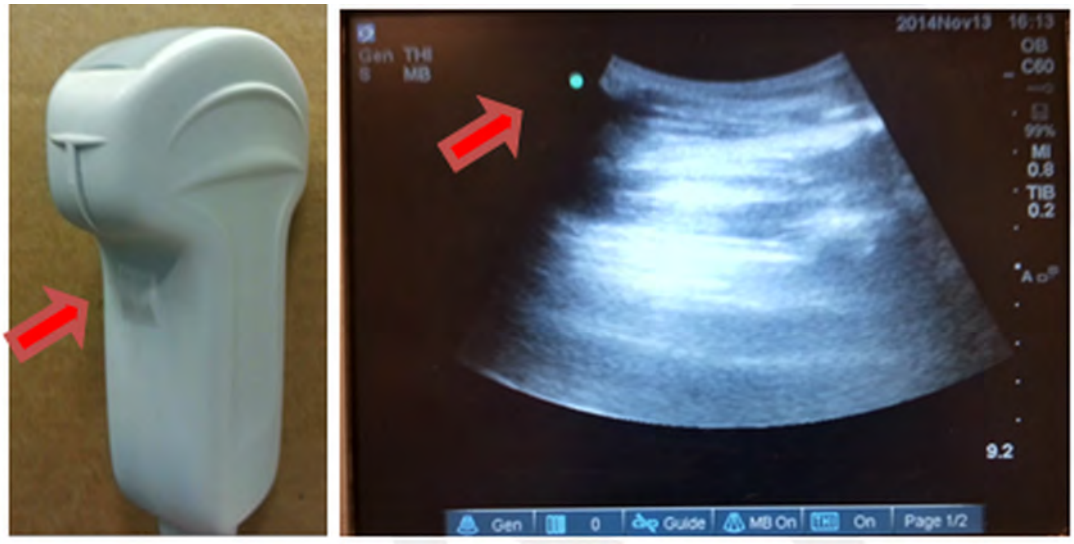


Figure 21: Transducer marker
A marker on the transducer corresponds to a dot displayed on the ultrasound screen to guide the user.

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).

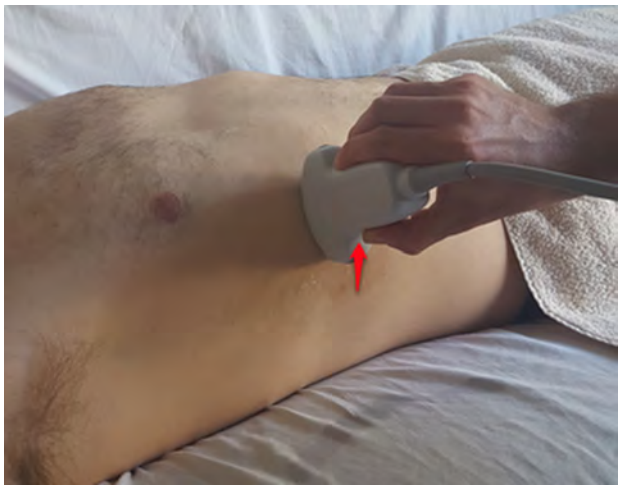


Figure 22: Transducer in transverse position with the marker (arrow) of the transducer pointing towards the patients' right.

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).

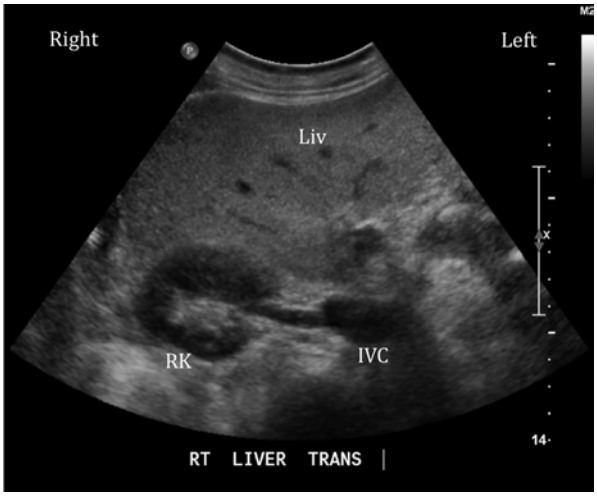


Figure 23: Transverse image through the right upper abdomen
This image to the right of the midline, shows the right lobe of the liver (Liv) and, deeper, the right kidney (RK), connected to the Inferior Vena Cava (IVC) by the right renal vein. The patient's right (Right) displays on the left side of the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

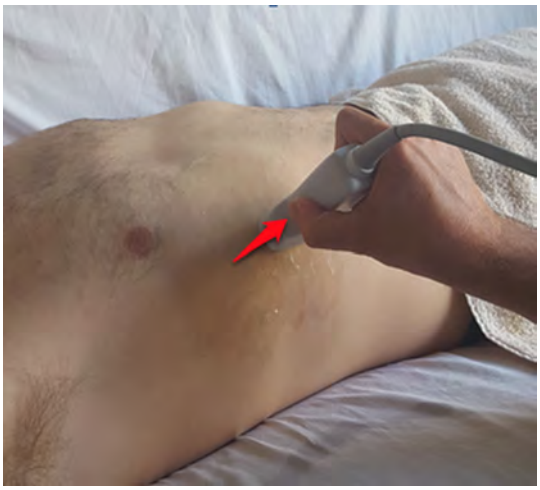


Figure 24: Transducer in longitudinal position with the marker (arrow) pointing towards the patient's head

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).

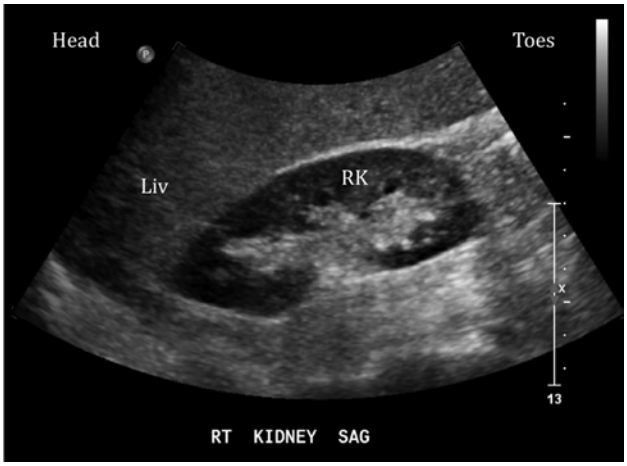


Figure 25: Longitudinal image through the right upper abdomen with the marker of the transducer pointing towards the patient's head.
This image to the right of midline shows the right lobe of the liver (Liv) towards the patient's head on the left side of the image, and below (inferior) to the liver,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

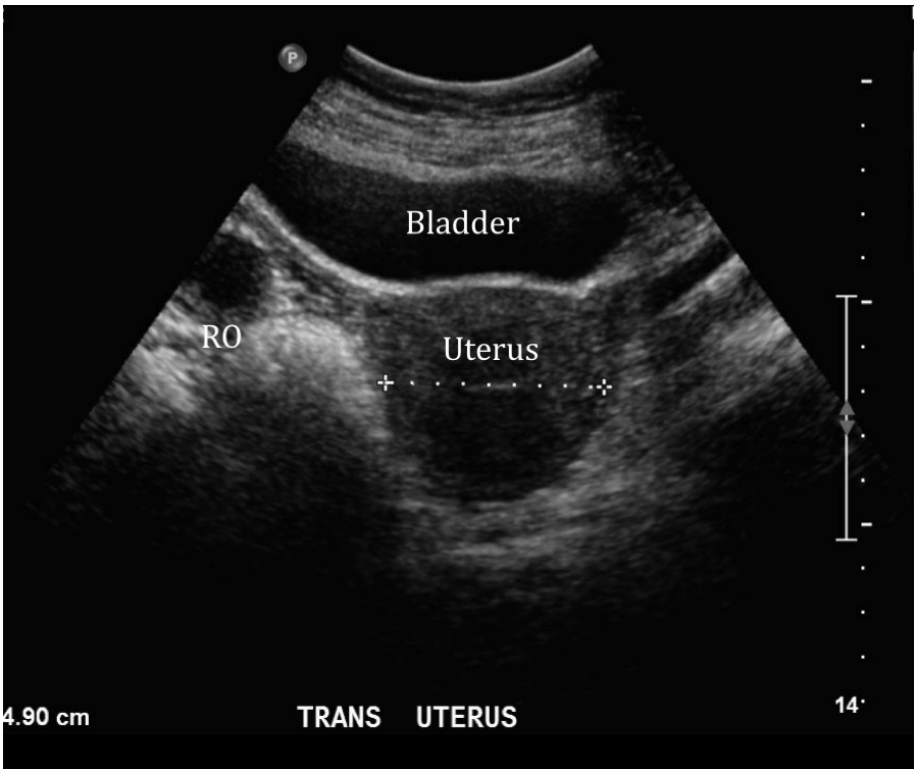


Figure 26: Same image as Figure 5, transverse imagine of the female pelvis
The right ovary (RO) on the left side of the screen is not well visualized.

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).

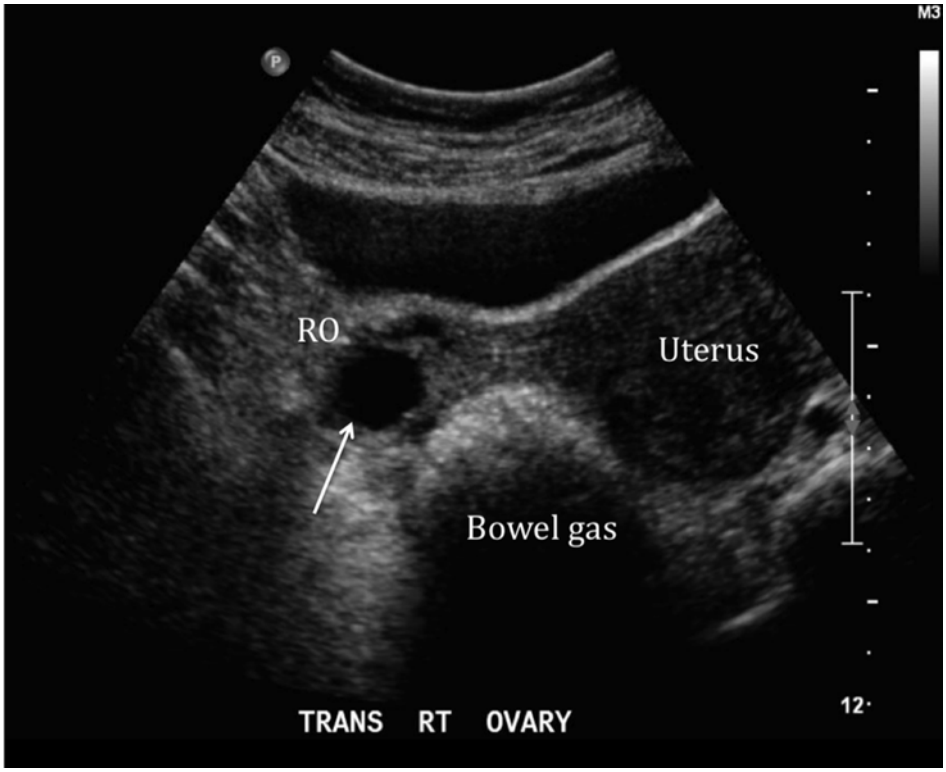


Figure 27: Similar image as Figure 26, transverse image of the female pelvis
Manipulation of the transducer as described above centres the right ovary (RO) so that the right ovary and simple cyst (arrow) are better visualized.

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.

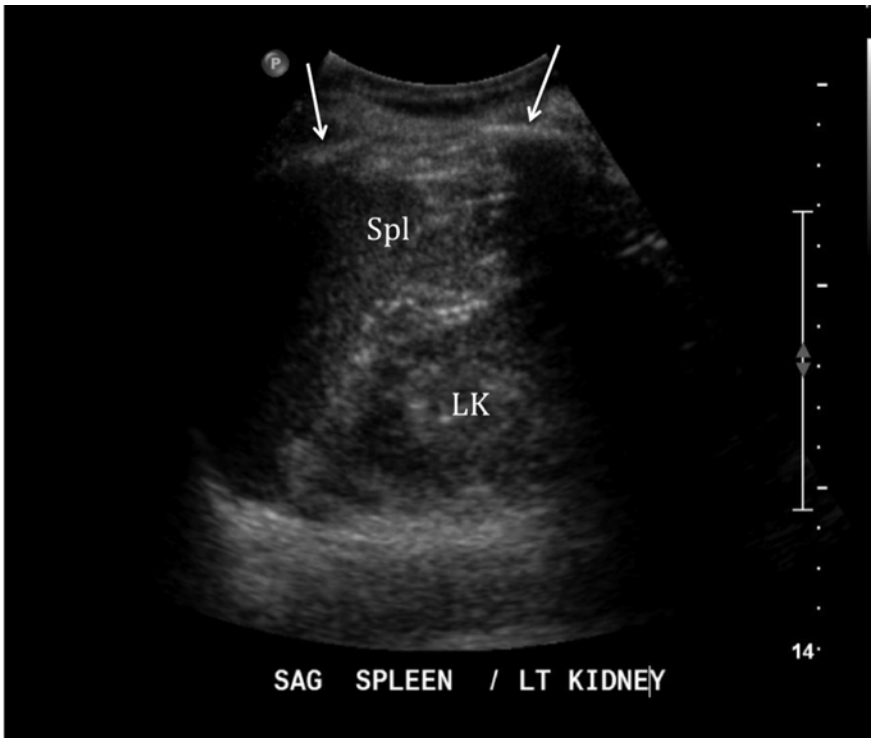


Figure 28: Longitudinal image of the left upper quadrant
with the patient in the right lateral decubitus position.
The spleen (Spl) and left kidney (LK) are obscured by shadowing from the left ribs (arrows).

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).

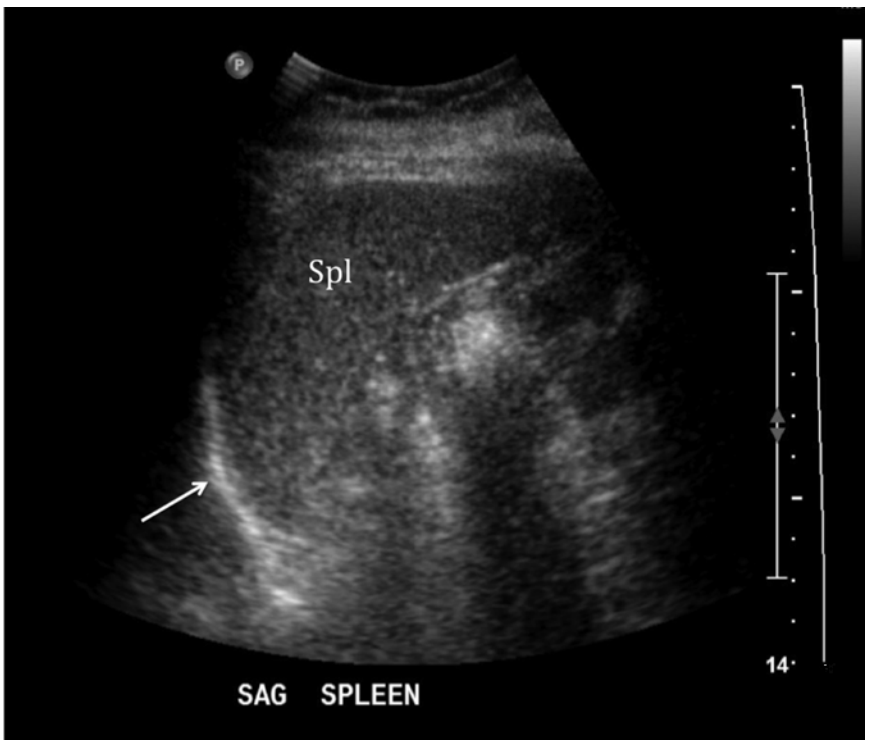


Figure 29: Longitudinal image of the left upper quadrant.
Manipulation of the transducer from the position of Figure 28 as described above
to avoid the ribs allowed visualization of the entire spleen, and the bright echogenic line
of the diaphragm (arrow).

Moving and angling the transducer in multiple planes

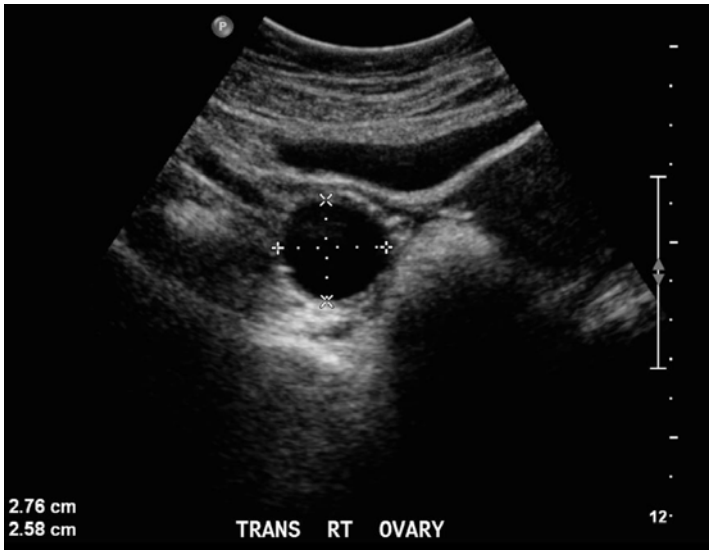
How to manipulate the transducer in the best way will vary for each particular situation. Moving or angling the transducer or using a combination of both may be required to improve the visualisation of the area of interest. With experience and using the different transducer positions as well as varying 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.

A



B

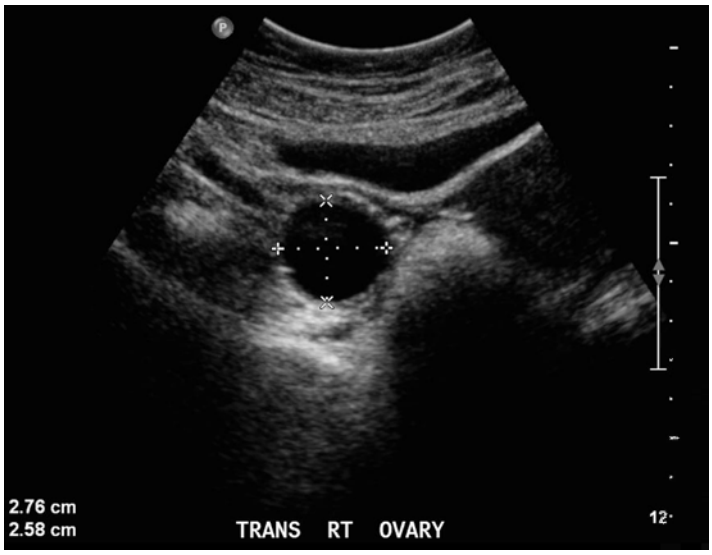


Figure 30A and B: Transverse images of the female pelvis.
Compare the view of the right ovarian cyst (arrow) in A with its appearance in B (between cursors). In Figure B the cyst is now centred and the image plane is through its midpoint for the most accurate size measurement.

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.

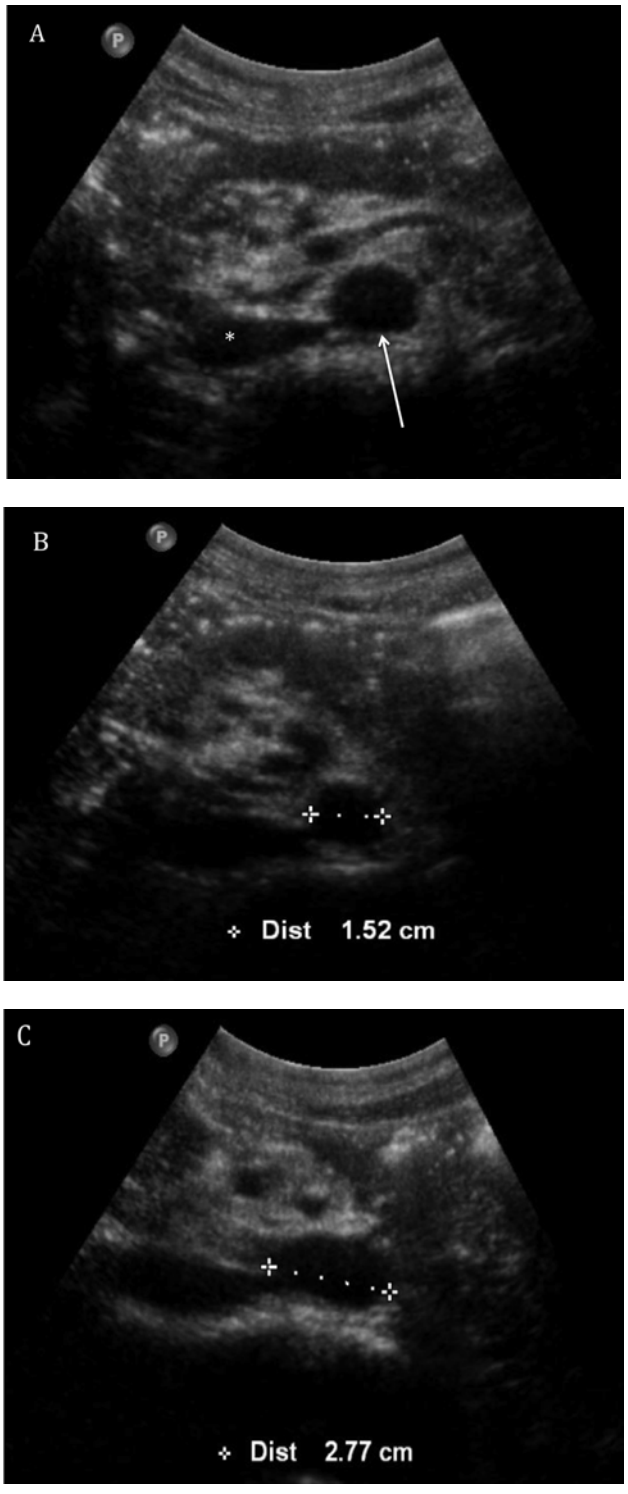


Figure 31: A-C: Transverse midline images through aorta
Image A - the aorta (arrow) and IVC (*).
Image B - correct orientation of the imaging plane with the aorta in true cross-section, with accurate measurements (between cursors).
Image C - incorrect orientation of the imaging plane in relation to the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

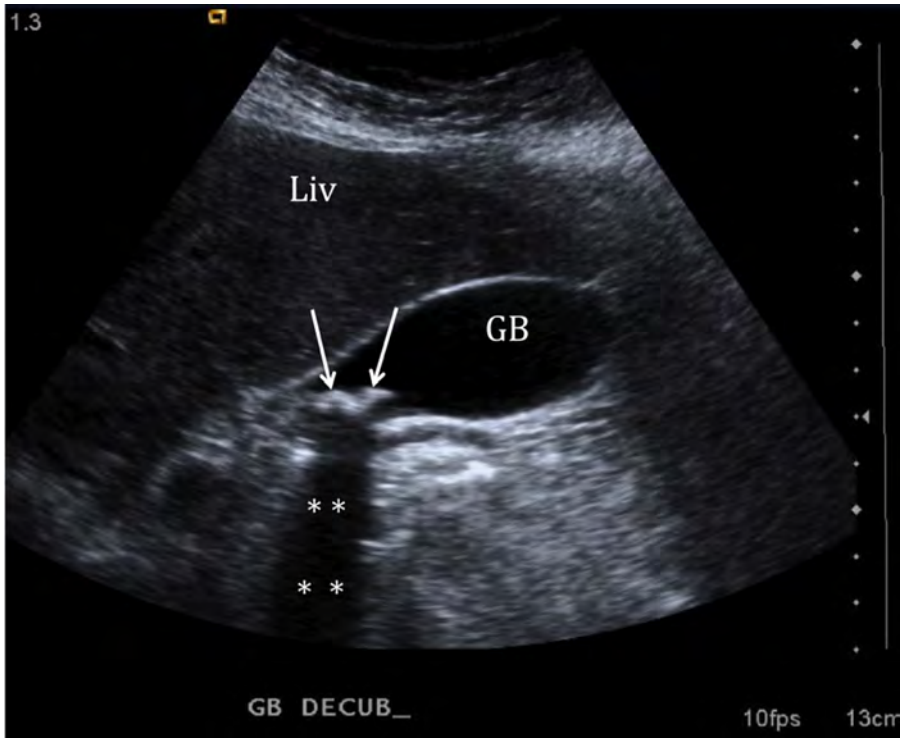


Figure 32: Left decubitus view of the gallbladder (GB)
A collection of small stones (arrows) is seen in the proximal gallbladder (GB), with dense shadowing (*) deep to the stones.

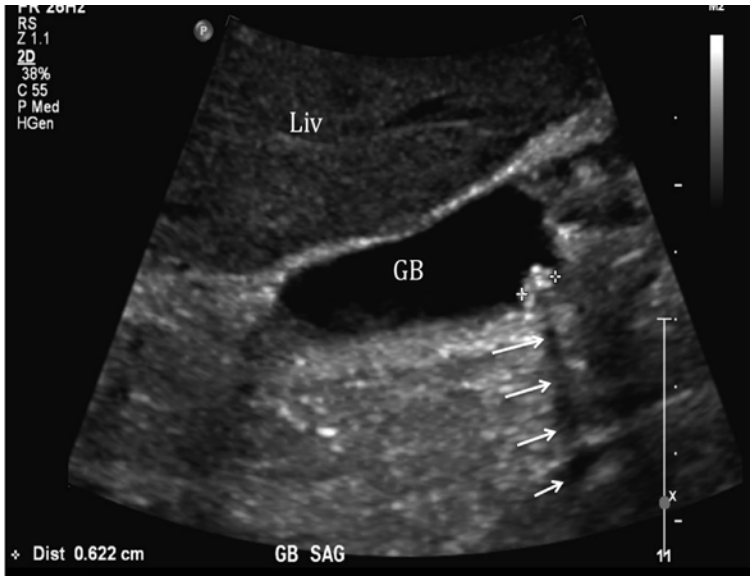


Figure 33: Longitudinal image of the gallbladder in the left decubitus position
A 6 mm gallstone (between cursors) demonstrating dense shadowing (arrows) deep to the stone.

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.

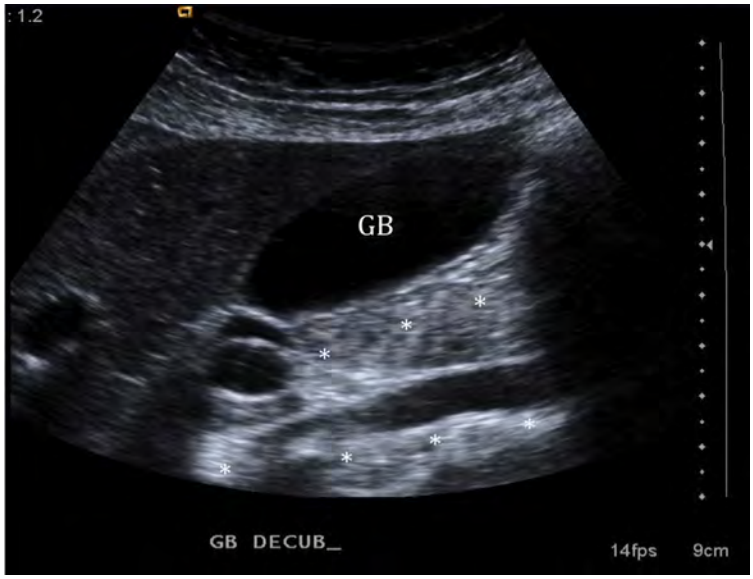


Figure 34: Decubitus view of the gallbladder (GB) with posterior enhancement
Posterior enhancement / increased through-transmission) is evident by the broad band of more echogenic (whiter) tissue indicated by asterisks (*), always located deeper to the tissue (liquid bile in the gallbladder in this case)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

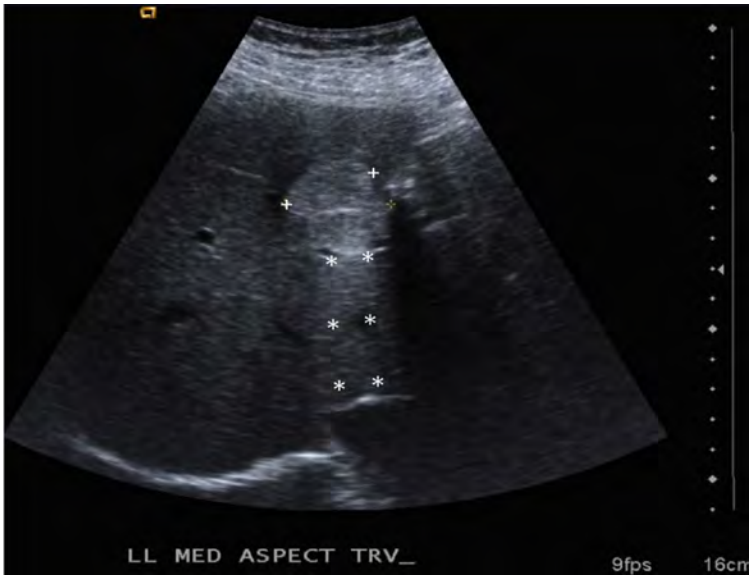


Figure 35: Transverse scan through left lobe of liver, showing an echogenic (bright) haemangioma (between the cursors), and obvious posterior enhancement / increased through-transmission (*) deep to the haemangioma.

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.

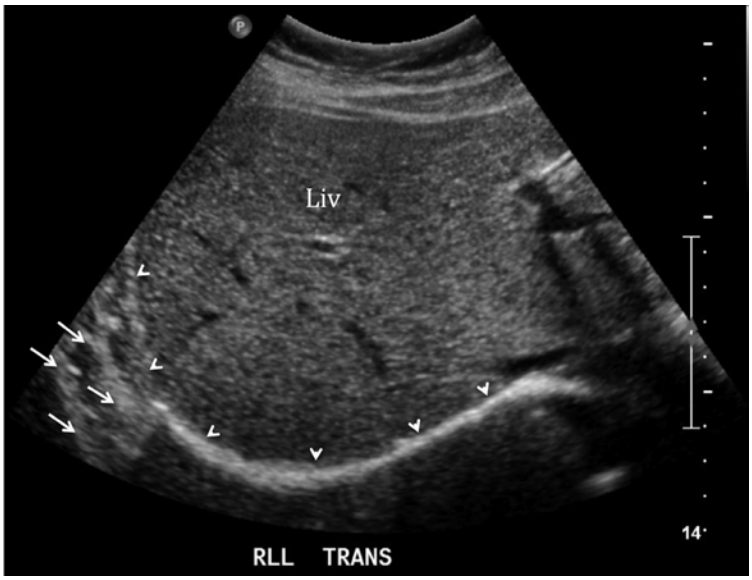


Figure 36: Reverberation artefact caused by the interface of the liver (Liv) and diaphragm (arrowheads), a strong acoustic reflector, with a series of copies of the liver / diaphragm interface (arrows).

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).

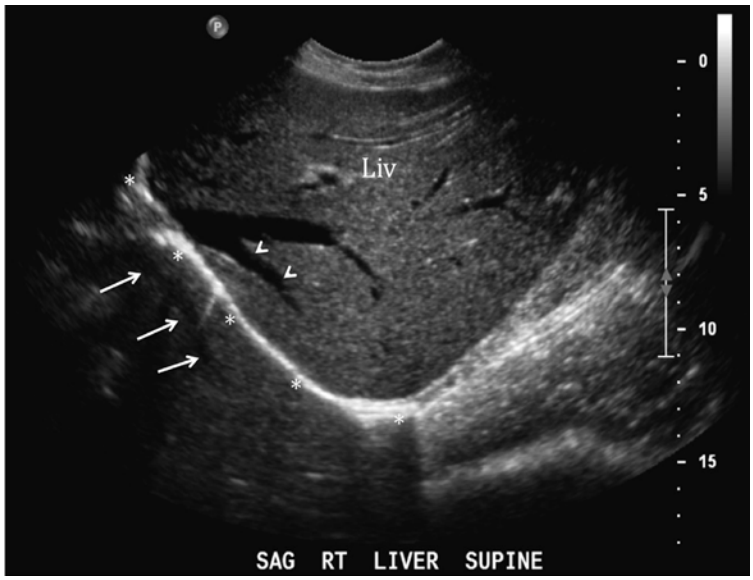


Figure 37: Mirror image artefact of hepatic vein across the diaphragm
Longitudinal image of the right upper quadrant and shows a mirror image artefact of the hepatic vein across the right diaphragm (*). A right hepatic vein branch (arrowheads) is projected as a mirror image (arrows) on the other side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

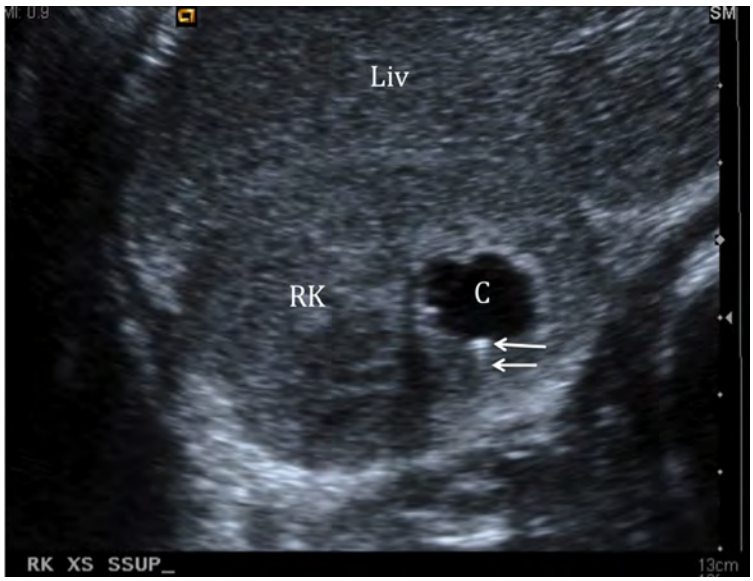


Figure 38: Comet tail artefact in a cyst wall
Transverse scan through the right upper quadrant showing the right kidney (RK) deep to the liver (Liv). There is a bright echogenic focus (arrows) in the wall of a cyst (C) of the kidney caused by a small calcification in the cyst wall. There is a triangular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

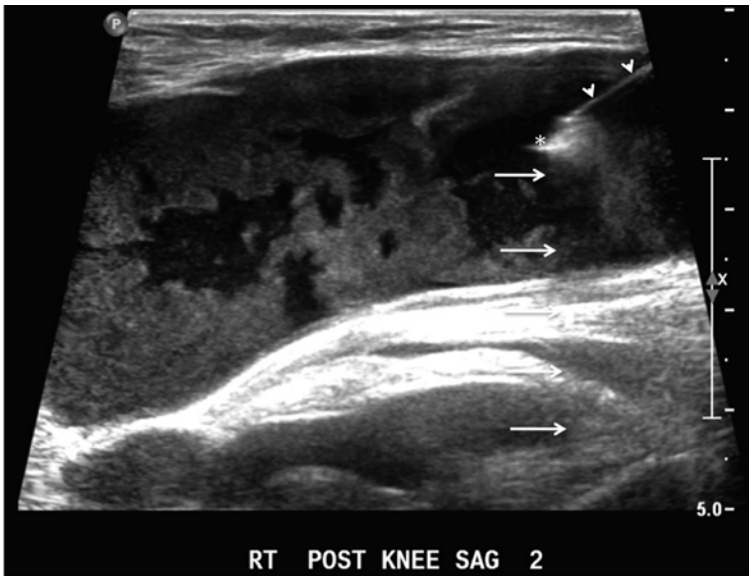


Figure 39: Aspiration biopsy needle reverberation artefact
There is a large thick walled cavity in the right knee, and a needle aspiration under direct sonographic guidance shows the echogenic needle (arrowheads), reverberation artefact from the needle with the edge of the artefact marked by arrows,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

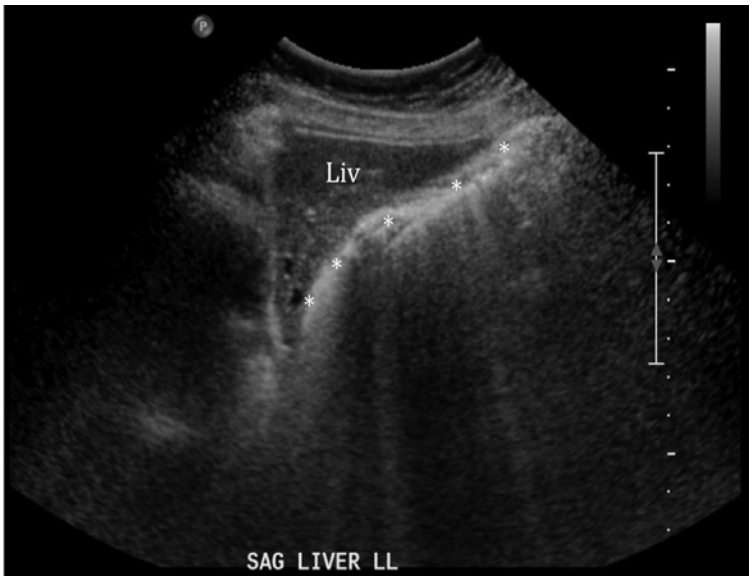


Figure 40: Dirty shadowing pattern of artefact from gas in the stomach
Longitudinal image through the left lobe of the liver (Liv), with a gaseous distended stomach just beneath the liver causing complete non-visualization of tissue deep to the anterior wall of the stomach, marked by the anterior margin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

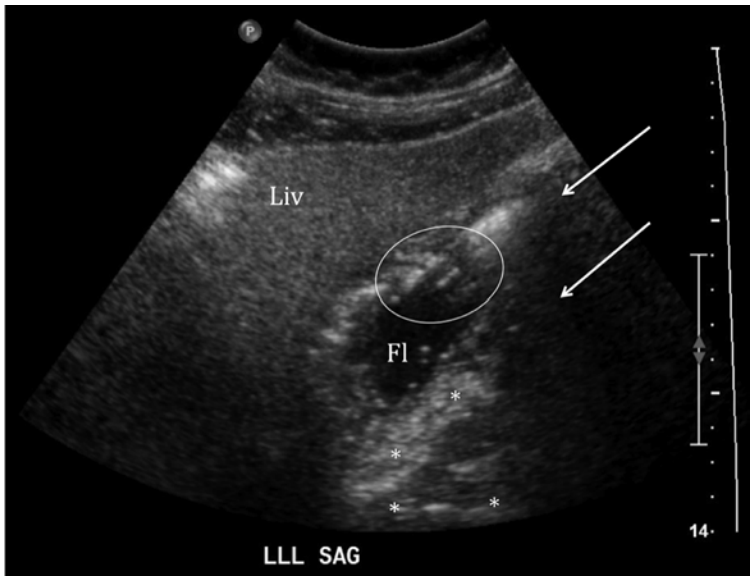


Figure 41: Longitudinal image through the left lobe of the liver (Liv) and stomach demonstrating three typical artefacts from gas and fluid in one image.
Fluid (Fl) in the stomach just inferior to the liver, with dirty shadowing from gas in the stomach (arrows). Reverberation artefact (circled) where 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.

Does an ultrasound machine require installation?

There is no installation required for an ultrasound machine. Even though functions are generally similar across different makes of ultrasound machines, achieving the best results depends on specific knowledge of the individual unit, its functionality and the software selections that should be made. All users should spend time to consult the user manual and explore the different functions of the ultrasound machine that they are using.

Where should we perform ultrasound examinations?

Ultrasound can be performed in a dedicated room or at the bedside. However, there should be patient privacy as the transducer needs to make adequate skin contact at various parts of the body. Certain obstetric or gynaecological examinations may require inserting a transvaginal transducer into the vagina and therefore a dedicated private room is required. There should also be the option of improving the ambient lighting for better visualisation of the image. The recommendation is for a dedicated ultrasound suite with an examination table for performing examinations supine and prone.

Do we need to archive the images?

An ultrasound machine has a limited space to store images and clips that are saved to its hard drive. The capacity of the M-Turbo is 8 GB. Once the hard drive capacity is full, it will not allow further images to be saved. When capacity has been reached, all images should be exported via the export function to a USB key and then saved to a DVD, external hard drive or a picture archiving and communication system (PACS) if available and kept as a part of medical records, following general practice for storage of patient information.

For instructions on how to export images from SonoSite M-Turbo, MicroMaxx and NanoMaxx, see Annex 3, Annex 4 and Annex 5 respectively.

Do we need a special power supply?

Power supply at MSF facilities may be unreliable and intermittent. Imaging systems that operate on batteries as a backup system have significant advantages of being functional when the main power supply is lost. The M-Turbo can be charged from a standard wall plug and the battery can last for up to 4 hours of use.

> The ultrasound machine must always be protected by a surge protector when charging.

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3. Care, maintenance and service of an ultrasound machine

3.1 Ultrasound machine and transducer care

The ultrasound machine and transducers should be considered as a potential source of microbial transmission similar to other instruments used on a patient. Therefore, both the exterior surface of the ultrasound system and the ultrasound transducers must be cleaned using specific cleaners and disinfectants.

The **transducers** must be cleaned after every use.

The **exterior surface** of the ultrasound system should be cleaned at least at the end of each working day.

Transducer disinfection

For disinfection of ultrasound transducers Hexanios should be used. MSF Medical Catalogue, Vol. 1: DRUGS, Disinfectants:

DDISMHEX5B-	'Hexanios'	DETERGENT/DISINFECTANT for med. equip.	5 L tin + dosing pump

Instructions for use

Transducers must be disinfected after every use.

1. Preparation of a 0.5 % Hexanios solution: Mix 25 mL of Hexanios, i.e. 1 stroke of dosing pump, in 5 litres water. The prepared Hexanios solution of 0.5 % can be kept for a maximum of 24 hours. Divide the diluted solution into two separate containers if a transvaginal transducer and other superficial transducers must be disinfected and label the containers accordingly.
2. Vaginal transducer disinfection: To disinfect the transvaginal transducer, disconnect it from the ultrasound machine. Emerge the vaginal transducer in one of the containers with the 0.5 % Hexanios solution and leave for 15 minutes. Do not immerse the connector or any portion of the cable.
   Regular transducer (e.g. abdominal transducer) disinfection: Wipe the abdominal or other superficially used transducer with 0.5 % Hexanios solution. Once per week a soak for 15 minutes is required. Do not immerse the connector portion of the cable in any fluid.
   Do not soak transducers in the solution longer than 15 minutes; especially not overnight.
3. Rinse the transducer thoroughly with clean water and dry with a clean cloth.

Vaginal transducers should be covered by a new sterile protector for each use. A condom (MSF code: SMSUCOND1--) may be used to cover the transducer. Ultrasound gel (MSF code: EDIMULTS1CA) is to be placed on the transducer face prior to application of the sterile covering. Additional ultrasound gel is placed onto the covering or condom. The gel promotes easy insertion of the transducer into the vagina and improves image quality by promoting sound transmission through the vaginal wall.

Exterior surface cleaning/disinfection of the ultrasound machine

For disinfection of the exterior surface of the ultrasound machine Surfanios should be used. Surfanios is a detergent/disinfectant used for the cleaning and disinfection of medical equipment surfaces. MSF Medical Catalogue, Vol 1: DRUGS, Disinfectants:

DDISSURF2S-	'Surfanios'	DETERGENT/DISINFECTANT for med. equip.	20 mL mono dose sachet
DDISSURF5B-	'Surfanios'	DETERGENT/DISINFECTANT for med. equip.	5 L tin + dosing pump

Instructions for use

The external surface of the ultrasound machine must be cleaned every day:

1. Preparation of a 0.25 % Surfanios solution: Mix 20 mL, i.e. one sachet or one stroke, in 8 litres of water. This solution can be transferred into a bottle or spray bottle (local purchase) and be kept for 7 days. Label the bottle(s) incl. the date of preparation.
2. Disconnect the ultrasound from the power supply.
3. Apply the solution a lint free cloth, not directly to the machine.
4. Wipe the exterior surface of ultrasound machine clean using the 0.25 % Surfanios solution on the cloth. Do not let any solution leak into the system.
5. Let dry for 15 minutes and do not rinse.

To clean the LCD screen:

1. Dampen a clean, non-abrasive lint free cloth with water.
2. Carefully wipe the screen; be careful not to scratch it.

3.2 Maintenance and servicing

The SonoSite ultrasound machines do not require regular preventative maintenance, however, quality control checks of the user interface, the transducer and the electrical entry points should be performed regularly and faults should be recorded and reported for repair or replacement if necessary.

Each US machine should have a detailed maintenance record and service book that logs the scheduled checks and repairs.

Check the general condition of the M-Turbo every 6 months

1. Switch off and disconnect the device from any power supply.
2. Check the general condition of the equipment. Replace or repair the parts if they are damaged:
   - AC power cord, the power supply and the plug.
   - Transducer face, housing and cable.
3. Test the battery as follows:
   a) Disconnect the system from the power supply.
   b) Press the 'Power' key to turn the system on.
   c) Allow the battery to discharge completely. This may take 1-2 hours.
   d) Connect the system to the power supply and check for proper charging of the battery.
   e) If the battery does not charge or drains abnormally fast, change it.

SonoSite ultrasound machines are supported by a 5 year warranty and transducers are supported with a 1 year warranty. The main unit is metal cased and can withstand falls from up to 1 meter. However, the transducers are made crystals with rubber for support and are extremely fragile on the contact surface where the crystal is unprotected. Any damage of the crystal results in a black, image-free area, that renders the transducer non-diagnostic. Transducers cannot be repaired and if damaged, must be replaced. It is very important that transducers be handled carefully and not dropped. When not in use transducers should be placed in a stable location or within a specialized holder that is part of the ultrasound unit. When not in use transducers should not be placed on the patient, as patient motion may cause the transducers to fall.

For repair of an ultrasound machine, please contact the biomedical engineer at your operational centre.

Take care of your US machine!

- If you run out of ultrasound gel do not be innovative. Simply replace with water or a water based gel. Never use alcohol, oil or any other fluids as they can damage the transducer.
- Handle your transducer with great care! The crystals inside are easily damaged and cannot be repaired. The cost of a replacement transducer is € 2,000-3,000.
- Follow the cleaning instructions provided in this manual.

4. Ultrasound use and teleradiology

4.1 Ultrasound use

Prior to performing any ultrasound examination it is crucial that the operator has a good understanding of anatomy, and familiarises themselves with the normal presentation of anatomy, and common pathologies for the examination.

Ultrasound assists in making a diagnosis or supports a decision with regards to a patient's management. Always make careful records of ultrasound findings in the patient's medical records.

The list of indications in this manual is not exhaustive, but considers some common indications of ultrasound in MSF programs. The treating physician can decide that an ultrasound is indicated for additional reasons, other than those listed here, with respect to contraindications.

Contraindications for ultrasound

Correct use of ultrasound requires experience and every user has the responsibility to respect their judgement skills.

Absolute contraindications for use of US are:
- Lack of experience or lack of clinical knowledge of the user.
- Ultrasound for fun - such as scanning without a clinical indication. It goes without saying that ultrasound scanning remains a medical procedure that should only be performed when clinically indicated to solve a medical problem.
- Use of ultrasound solely for the purpose of determining foetal gender or to produce home movies is strongly discouraged by all professional ultrasound societies and is illegal in many locations.

It should always be kept in mind that:

- Clinical judgement is the most important factor in assessing a patient.
- Ultrasound cannot at any time replace the clinical judgement of a patient's condition.
- In an unstable patient, stabilising is the priority; assessment with ultrasound comes afterwards.
- In the hands of an untrained or poorly trained person, ultrasound may be misleading and even dangerous.

Important

- The scanning instructions and ultrasound findings provided within this manual demonstrate some common clinical presentations and ultrasound findings but are by no means exhaustive, nor is that the intention.
- This manual does not replace formalized education and training in ultrasound.
- This manual is not intended as a replacement for elective scans performed by experienced ultrasound technicians, physicians or radiologists.
- This manual is aimed at operators who have undergone ultrasound training to assist diagnosis and clinical decision making.

4.2 Teleradiology

Teleradiology is the use of telecommunications to deliver radiological images including ultrasound from one location to another for the purposes of interpretation and / or consultation.

Teleradiology improves patient care by allowing radiologists to provide radiographic reporting without actually having to be at the location of the patient. Radiologists are specialists in interpreting radiographs, which is particularly valuable especially in complex areas such as tropical medicine.

The introduction of simplified image exportation features from ultrasound machines and wider access to internet networks means that ultrasound can now be transmitted to different locations.

Teleradiology experience in MSF

Radiographic images from our project sites are sent with a summarized patient history via the internet to a radiologist for consultation. Typically within 24 hours a report is then sent back to the requesting site. Teleradiology services are provided to all MSF projects free of charge. This is of enormous benefit to MSF project sites and encouraging its implementation into programs is a priority of the DIWG.

To date various programs have benefited from teleradiology:
1. TB / HIV (including paediatrics)
2. Paediatric
3. Orthopaedic
4. Surgical
5. Obstetrics and Sexual & Reproductive Health

How can we set up teleradiology in our project?

To arrange a reporting service suitable for your project, please email the intersectional radiographer or: diagnostic-network@msf.org.

An account will be created and user instructions will be sent to each referrer.

Who provides the teleradiology reporting service?

Consultant radiologists via the MSF Telemedicine system are available to provide a reporting service (currently available in English, French and Spanish). A relevant summary of the patient's clinical history should accompany the image using the 'patient information required for reporting', found below.

What kind of internet connection is needed?

Each ultrasound image is approximately 100 kB in size therefore the internet connection must be adequate enough to transmit an attachment of that size. The size of a clip varies depending on the length of the recording and type of scan. A 15 second clip will be approximately 5-10 MB.

> Clips are more informative for telemedicine consultation and preferred over the simple 'standing' image.

How do I export images from my SonoSite ultrasound machine?

Ultrasound images and cine clips can be easily exported from SonoSite ultrasound machines to a USB as JPEG images or MPEG stream clips. For instructions on how to export ultrasound images clips from the M-turbo, MicroMaxx and NanoMaxx machines, see Annex 3, Annex 4 and Annex 5 respectively.

Patient information required for reporting

When sending ultrasound images for teleradiology, it is important to include patient information and relevant clinical history to aid interpretation.

It is imperative that images are labelled and clearly marked with an identification number: 'L' = left, 'R' = right, 'RLQ' = right lower quadrant, 'LUQ' = left upper quadrant etc.

Patient's information needed for optimal interpretation that should be sent with the digital image must include:

1. Patient's identification number (not the patient's name).
2. Age and gender of the patient.
3. Brief description of current medical problem: current symptoms and relevant positive physical examination and laboratory findings.
4. Significant past medical history: past surgeries or treatment as they apply to the current medical problem.
5. Specific questions about the image.
6. Each image should be labelled with the date that the image was obtained. Please add this information to the file name of the digital file.

For reasons of confidentiality when sending images via the telemedicine platform, a patient identification number must be provided in place of the patient's name.

Teleradiology is also an opportunity for the referring clinicians to further develop their skills in image interpretation. Clinicians will be able to compare and learn what they observe on the image with the reported findings by the radiologist.

Information on follow-up of patients for our consulting radiologists is also welcome to encourage a dynamic and interesting process, for example, informing them of the impact of the radiological findings to the patient's treatment or final outcome.

4.3 Creating cine clips of ultrasound examinations

An ultrasound cine clip, sometimes called a 'sweep' or simply 'clip' is a short movie or video recording of a part of the ultrasound scan. Cine clips, of an ultrasound examination of a given organ, region or abnormality can be very useful for training, storing, subsequent review, and uploading to the telemedicine platform for radiologist and other specialist consultation.

Cine clips are exceedingly helpful as a training tool or for a consultant radiologist on the telemedicine platform, because it closely simulates the experience of real-time sonography. A sweep through an organ in the transverse and longitudinal planes affords a remote specialist the ability to form the same 3-dimensional image as if standing at the bedside, scanning.

Creating cine clips

The best method for creating cine clips will vary depending on the patient, anatomy and pathology. Anatomical specific scanning guides can be found earlier in this manual can be used as reference. In general however, the principal for creating cine clips is to cover the area of interest, starting just before the region, scanning slowly through to past the opposite side of the region in one plane, then repeating the process at 90 degrees.

For example, if the region of interest is the kidney, locate the kidney in both the longitudinal plane and transverse plane (as discussed in the scanning guides).

Starting in the longitudinal plane begin just posterior to the kidney. Push the 'clips' function and slowly scan through the kidney until you have passed anterior to the kidney. Immediately thereafter reverse the scan direction and continue the sweep from anterior-to-posterior, still

along the longitudinal plane of the kidney. One might take 3 or 4 seconds to sweep through in one direction for the kidney, 10 seconds for the liver.

It is important to use a steady pace while sliding the transducer, or sometimes merely angling the transducer at a steady rate, to cover the organ or region evenly. Of course, excellent sonographic coupling using adequate gel is essential for high quality sweep images, as in any sonographic application.

Then turn the transducer 90 degrees and perform the same sweep function from just above the kidney, through the kidney in the transverse plane, until you have passed through the lower pole of the kidney; one can then reverse direction and cover the kidney from bottom to top.

Cine clips are saved to the internal memory of the ultrasound machine and can be reviewed by the user. Clips can also be exported from the device and uploaded with the relevant history to consulting radiologists or other specialists on the MSF Telemedicine platform.

Step by step guide to creating a cine clip

1. Identify the area of anatomy of interest.
2. Press the 'Clip' button on the keypad. The clip will record for the pre-defined time duration (15, 30 or 60 seconds) in the settings.
3. Slowly scan through the area or anatomy of interest in one direction and back in the longitudinal plane.
4. Repeat in the scan in the transverse plane.
   - If the 'Prev/Off' function is selected, the clip saves automatically to the devices internal memory.
   - If 'Prev/On' is selected, the clip plays back automatically but does not automatically save. Save the clip using the 'save' button.
5. Play the clip and review it for accuracy.
6. For more information on how to export cine clips (or images) please see Annex 3, Annex 4 and Annex 5 on exporting ultrasound clips or images on SonoSite M-Turbo, Mircomaxx and Nanomaxx respectively.

Notes: There are numerous options to change the clips settings including from prospective to retrospective acquisition, automatic preview on / off, length of clip and playback speed. For more information refer to the ultrasound device user guide.

5. Ultrasound training

Ultrasound training courses within MSF

Currently several internal MSF ultrasound training courses are under development via the Anaesthetic Working Group covering topics such as emergency medicine, anaesthetics and PICC line insertion.

Ultrasound training in the field is always possible via an expat training visit. This could be with a sonographer, radiologist, obstetrician, midwife or emergency physician depending on the clinical area requiring training. For example, for obstetrics and gynaecology ultrasound training, an expat could work together with midwives and MDs offering a mix of theoretical and practical training while working together on the wards. This could be one-on-one, or with several trainers and trainees delivered in a more structured way.

For more information on opportunities for ultrasound training in the field or via working groups, please contact the relevant working group or one of the intersectional diagnostic imaging advisors at: diagnostic-network@msf.org.

> The international office has an in-house M-Turbo ultrasound machine with an abdominal and high frequency linear transducer that may be borrowed for field visits or trainings. To request a loan of the ultrasound machine please contact: diagnostic-network@msf.org.

External ultrasound courses

Several external courses for ultrasound are available that range from clinical ultrasound in tropical infectious diseases to more applied training on the practical use of ultrasound in resource-constrained settings.

For more information on recommended external courses please contact the DIWG or one of the intersectional diagnostic imaging advisors at: diagnostic-network@msf.org.

6. Ultrasound in obstetrics and gynaecology

Ultrasound has been used for over 30 years in obstetrics without danger for mother or foetus. It can be used safely in all stages of pregnancy. Ultrasound can be an invaluable diagnostic tool when confirming or excluding a diagnosis. Remember the caution regarding use of Doppler ultrasound in the first trimester of pregnancy (see Chapter 2.5).

MSF recommends the use of ultrasound in all Comprehensive Emergency Obstetric and Neonatal Care (CEmONC) centres. Ultrasound must be performed by a skilled and trained person in ultrasound and obstetrics, e.g. obstetrician or a midwife, preferably in proximity to an obstetrician. The following recommendations on indications to guide the use of ultrasound are intended for programmes with a gynaecological and obstetrics component.

6.1 Indications for ultrasound in obstetrics and gynaecology

The use of ultrasound is divided into 3 levels, depending on the programme's capacity and the experience of the user:

Level I: Emergency indications for ultrasound

Indicates the use of ultrasound in emergency cases in gynaecology and/or obstetrics programmes.

1. Antepartum haemorrhage (APH).
2. Vaginal bleeding or pelvic cramping in the 1st trimester (threatened abortion).
3. Confirmation of live intrauterine pregnancy.
4. Confirmation of an ectopic pregnancy.
5. Number of foetuses and / or position of foetus in labour, if in doubt.
6. Diagnosis / confirmation of intrauterine foetal death (IUFD) or molar pregnancy.
7. Identification of placental location.
8. Diagnosis / confirmation of retained products of placenta postpartum or post abortion (not compulsory in Basic Emergency Obstetric and Neonatal Care [BEmONC] before performing a manual vacuum aspiration).

Level II: Assessment of high risk cases and suspected pathologies

Indicates ultrasound use in obstetrics and gynaecology for programmes that have capacity for use beyond emergencies.

1. **Indications gynaecology:**
   a. Amenorrhea with suspicion of pathology / pregnancy (not compulsory)
   b. Suspicion of pelvic mass
   c. Abnormal vaginal bleeding or discharge
   d. Checking position of intrauterine devices (IUD) in case of complications
   e. Profuse abdominal pain, e.g. possible ruptured cyst

2. **Indications obstetrics**

   Early ultrasound (i.e. before 24 weeks gestation)
   a. Suspicion of low lying placenta (APH after 16-18 weeks)
   b. Confirmation of multiple gestation
   c. Suspicion of abnormal amount of amniotic fluid

d. Exclusion / confirmation of molar pregnancy
e. Suspicion of extrauterine pregnancy
f. Missed abortion / incomplete abortion
g. Presence of foetal heart activity
h. Gestational age related to termination of pregnancy (TPR)

Late ultrasound (i.e. after 24 weeks gestation)
a. Suspicion of low lying placenta (APH after 16-18 weeks)
b. Confirmation of intrauterine foetal death (IUFD)
c. Estimated foetal weight in selected cases and dating gestation.
   Note: discrepancy of 15 % is normal when estimated in late pregnancy and dating after 24 weeks is very imprecise!
d. Suspicion of abnormal amount of amniotic fluid
e. Suspicion of multiple gestation
f. Position of foetus when abnormal, i.e. non-vertex, position is suspected

Postpartum ultrasound
a. Secondary postpartum haemorrhage (PPH) when retained products are suspected as a cause

Level III: Routine use of ultrasound in ante-natal care

If a programme has the capacity to scan each pregnant woman on a routine basis, a single scan in the second trimester, e.g. 20 week scan, is recommended. A scan can help to detect pathologies early, e.g. potential placenta praevia, and have influence on the patient's management, and thus a potential reduction of morbidities and mortalities. However, it is realised that routine scanning is not feasible in most MSF programmes.

A routine scan in the second trimester should document the following parameters:
1. Number of foetuses
2. Presentation of the foetus
3. Foetal heart beat: present / absent
4. Placental location including suspicion of low lying placenta
5. Closed length of the cervix
6. Amniotic fluid volume
7. Gestational age and foetal growth

In selected cases an additional third level scan can be performed:
1. Pre-external version (position of umbilical cord)
2. Congenital anomalies
3. Diagnosis and follow-up of IUGR (intrauterine growth restriction) especially in cases of severe pre-eclampsia (umbilical Doppler may be useful).

6.2 Basic scanning protocol in obstetrics

A basic user has sufficient competencies to perform the basic scan below. All images of the below findings must be saved.

Scan process	Trimester	Image documentation
1. Number of foetuses	1st, 2nd, 3rd	Identify number of foetuses.
2. Presentation	2nd, 3rd	Describe foetal position. Use with the annotation function on the scanner to annotate the image with orientation, as required.

Scan process	Trimester	Image documentation
3. Foetal viability	1st, 2nd, 3rd	Detection of foetal heart rate.
4. Gestational age	1st, 2nd, 3rd	Measurements appropriate to gestation: • Crown-rump length (1st) • Bi-parietal diameter (2nd / 3rd) • Head circumference (2nd / 3rd) • Abdominal circumference (2nd / 3rd) • Femur length (2nd / 3rd)
5. Quantity of amniotic fluid	2nd, 3rd	Measurement of largest pocket of amniotic fluid.
6. Length of cervix	2nd, +/-3rd	Measurement closed length of cervix in sagittal plane.
7. Placental location	2nd, 3rd	Relationship to cervical OS.

6.3 Scanning techniques in obstetrics and gynaecology

6.3.1 Transabdominal scan

Transabdominal imaging is often used in combination with transvaginal imaging. It involves moving a transducer over the lower part of the abdomen to assess the female pelvic region. It is often used as an overview of the pelvic region and to assess for larger pathology such as pelvis masses that may not be clearly seen on the transvaginal scan.

Patients should avoid urinating prior to the examination. Optimal bladder filling shows the urine-filled bladder just above the level of the uterine fundus on a longitudinal midline scan which is used as an acoustic window. Transvaginal scan on the contrary is ideally performed with an empty bladder.

Transabdominal imaging is performed by using a 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo (Annex 1).

6.3.2 Transvaginal scan

Transvaginal imaging is often used in combination with transabdominal images. It involves introducing a specialised transducer into the vagina in order to place the tip of the transducer closer to the anatomy under evaluation. This results higher resolution images and greater accuracy compared to transabdominal imaging for many gynaecological and obstetrical indications, especially in patients with a large body habitus.

Despite the transvaginal scanning often being medically preferred it is not always possible due to cultural / contextual considerations. In such situations transabdominal scanning may be used alone, but the operator must be familiar with the limitations.

An ICTx 8-5 MHz tightly curved array transvaginal transducer, which is compatible with the MSF standard M-Turbo, is preferred.

Some extra points to consider when performing transvaginal scanning:
– The procedure should be fully explained to the patient prior to the start of the examination and at minimum, oral consent obtained.
– Patients who cannot provide consent, have not been sexually active, or decline the examination, must only be assessed with transabdominal imaging.
– A dedicated private room or area should be arranged, and a cover such as a sheet or towel provided for privacy. If possible, the ultrasound examiner should be a woman, or a woman should be present in the examination room.

- The operator is responsible for ensuring the transducer has been cleaned correctly prior to and after the procedure. See Section 3.1 'Ultrasound machine and transducer care' for cleaning instructions.
- An empty bladder is recommended for transvaginal scanning; have the patient void the bladder prior to the transvaginal scan.
  However, keep in mind that if you aim to also carry out an abdominal scan, carry out the abdominal scan first as a filled bladder serves as acoustic window.
- The patient is positioned supine with a pillow or similar placed underneath to elevate the bottom, with legs drawn towards the chest.
- Gloves are to be worn by the operator.
- Place a generous amount of coupling gel on the transvaginal ultrasound transducer and cover with a condom, removing any air bubbles. Additional gel should be placed on the outside of the transducer to ease insertion into the vagina. The operator must take great care to ensure the condom remains in place.
- The patient may experience some discomfort but generally the test is well tolerated. It shouldn't cause pain.

6.3.3 Translabial scan

Translabial examination to assess placenta previa can be carried out when no transvaginal transducer is available and the user is experienced in this technique. Translabial scanning is recommended for placenta previa assessment when there is a risk of cervical dilation (see Chapter 9). In this situation a translabial scan is safer than a transvaginal scan as there is no risk of injuring the placenta.

The scanning steps for performing a translabial scan can be found in Annex 6.

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7. Gynaecology

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The main role of ultrasound in gynaecology is to differentiate causes of profuse abdominal pain and / or abnormal vaginal bleeding including pathological causes such as pelvic masses, complications from intrauterine devices or pregnancy.

Patients are initially scanned transabdominal, ideally with a full bladder which is used as an acoustic window for a general overview of the pelvis to identify the cervix, uterus and ovaries and any pelvic masses. Patients are then typically asked to empty their bladder and are re-scanned transvaginally (as appropriate) in greater detail.

7.1 Scanning technique - gynaecology

Transducer

Begin with transabdominal scanning, a 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

If appropriate, repeat with transvaginal scanning. An 8-5 MHz tightly curved array transducer, such as the ICTx which is compatible with the MSF standard M-Turbo, is preferred. See section on transvaginal scan.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine.

The patient should ideally have a filled bladder in order to use it as acoustic window.

For the transvaginal scan, a pillow or similar placed underneath to elevate the bottom, with legs drawn towards the chest.

Scanning steps for transabdominal scanning

1. Start with the transducer in the longitudinal position (marker pointing to the patient's head) just superior to the symphysis pubis in the midline of the body.
2. Identify and assess the bladder.
3. Identify and evaluate the uterus and surrounding structures. Confirm its orientation: anteverted or retroverted.
4. The vagina and cervix can also be evaluated using this view.
5. Rotate the transducer 90 degrees into the transverse position (marker pointing to the patient's right) and re-evaluate the uterus.
6. Now reposition the transducer slightly left of the midline and angle right laterally to identify the right ovary and adnexa. With the transducer to the left of midline, use the urine in the bladder as an acoustic window to see the right adnexa better. Rotate the transducer back to the longitudinal position to re-evaluate the right ovary in the sagittal plane.

7. Repeat the previous step, with the transducer positioned slightly right of the midline and angled left laterally to evaluate the left ovary and adnexa, again using the urine in the bladder as an acoustic window.
8. Ovaries may be difficult to locate, especially pre-pubescent, post-menopausal patients or those who have had a partial hysterectomy.

Scanning steps for transvaginal scanning

Ensure a private space is properly prepared, consent obtained and bladder emptied, see section on transvaginal imaging.

1. Place a generous amount of coupling gel on the transvaginal ultrasound transducer and cover with a condom, removing any air bubbles. Additional gel should be placed on the outside of the transducer to ease insertion into the vagina. The operator must take great care to ensure the condom remains in place.
2. Point the transducer marker to the ceiling, i.e. 12 o'clock position as it is initially inserted. Evaluate the uterus and endometrial thickness from this longitudinal plane.
3. Assess the cervix, bladder and cul-de-sac. Slight adjustment of the transducer may be required either inferior, superiorly or laterally to improve visualisation. Be sure to move and rotate the transducer slowly and gently. Note: The urinary bladder is usually better assessed with the transabdominal transducer.
4. Rotate the transducer 90 degrees counter clockwise (by turning the marker on the patients' right) to evaluate the uterus and the ovaries in the transverse / coronal plane.
5. Sweeping the transducer laterally is required to identify the adnexal region and surrounding structures including the ovaries. Typically ovaries are located in similar positions on either side, so identifying one may assist in locating the other.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

7.2 Uterus

A normal non pregnant uterus is a pear shaped thick walled organ that is located in the middle of the pelvis, posterior to the bladder. The two main portions of the uterus are the body and cervix. The uterus changes in size and appearance during menstruation, also becoming more vascular. The endometrium line of the uterine cavity varies in thickness according to hormonal influences of the menstrual cycle and pathological processes, such as endometrial cancer (Figures 1-5).

Depending on its orientation it can be described as anteverted, i.e. tilted anteriorly towards the bladder, or retroverted, i.e. tilted posteriorly. The uterus changes in position with the degree of bladder filling. Retroflexion of the uterus is a normal variant (Figure 5), but may be misinterpreted on physical examination as a mass posterior to the uterus.

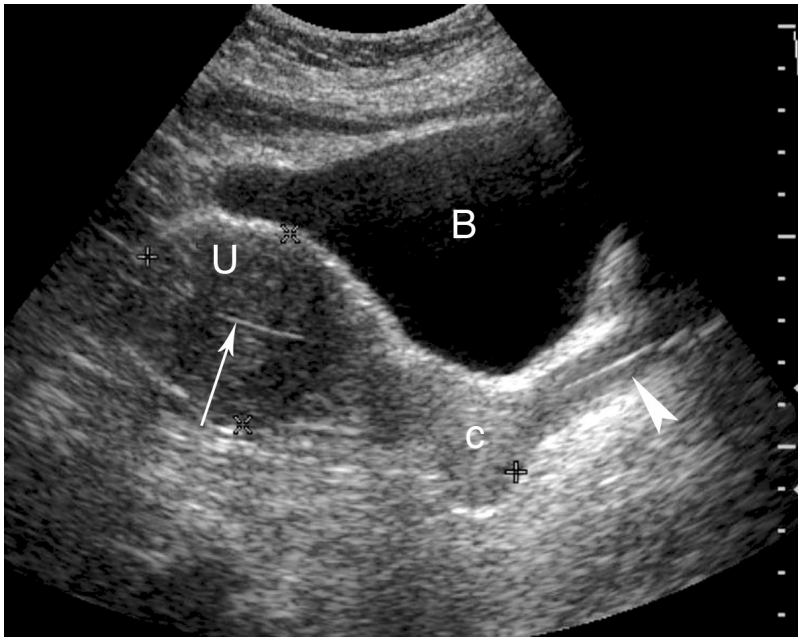

Figure 1: Normal longitudinal transabdominal uterus
Scan obtained with the transducer in longitudinal orientation placed just above the pubic bone shows the normal uterus (U, between callipers, +, x), cervix (c), and vagina (arrowhead). The full bladder (B) serves as an excellent acoustic window to the pelvic organs. The normal endometrium (arrow) is thin, typical in appearance of the endometrium immediately following menstruation.

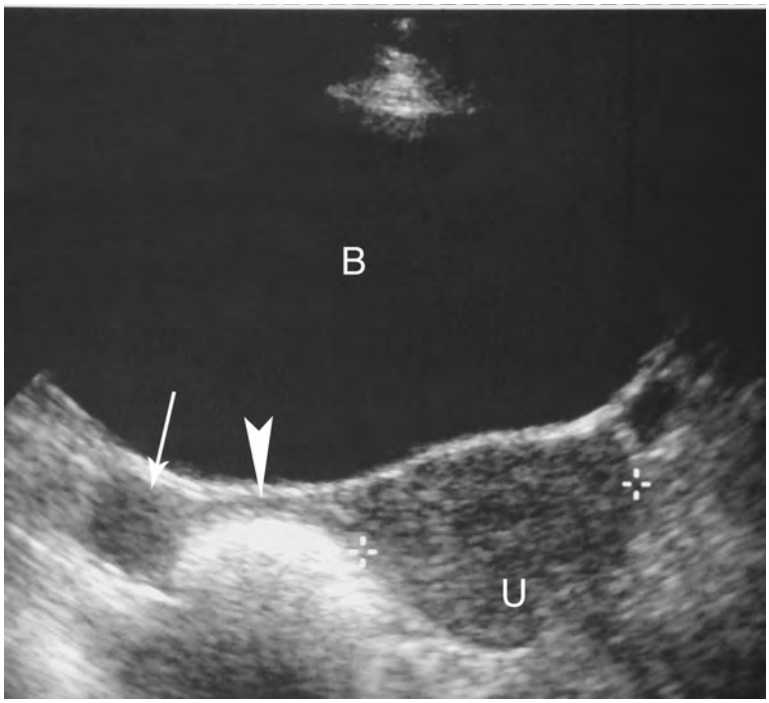

Figure 2: Normal transverse transabdominal scan
Scan through the full bladder (B) with the transducer in transverse orientation shows the normal uterus (U, between callipers, +) and right ovary (arrow). The broad ligament (arrowhead) extends to the ovary enveloping the fallopian tube.

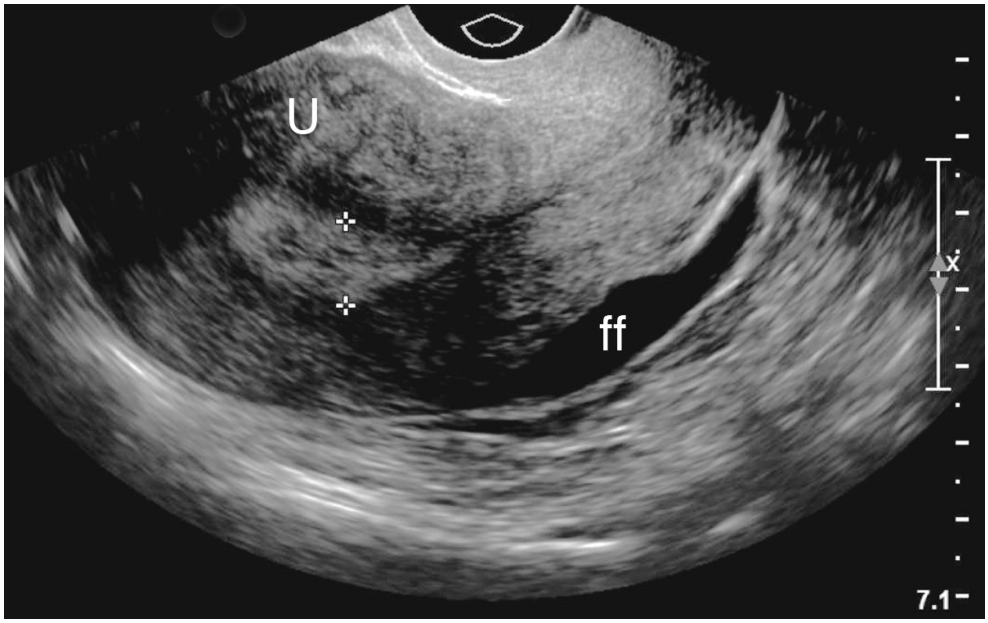

Figure 3: Normal Longitudinal transvaginal scan
Scan performed transvaginally in a longitudinal plane shows the normal uterus (U). A small volume of free intraperitoneal fluid (ff) is present in the cul-de-sac. This is a normal finding in a woman of menstrual age. In this case the normal endometrium (between callipers, +) is thickened to 9 mm, an appearance and thickness typical of secretory phase endometrium.

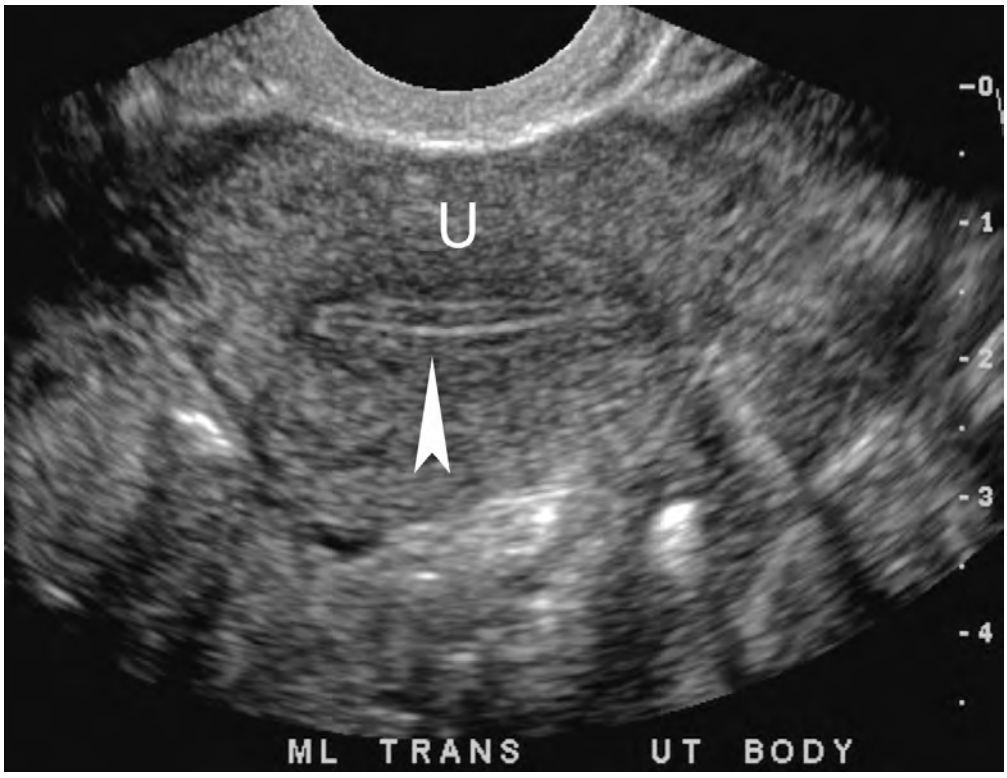

Figure 4: Normal transverse transvaginal scan
Scan performed transvaginally in a transverse plane in a different patient shows the mid-body of the normal uterus (U). In this case the endometrium (arrowhead) shows the three-echogenic line appearance typical of proliferative phase endometrium.

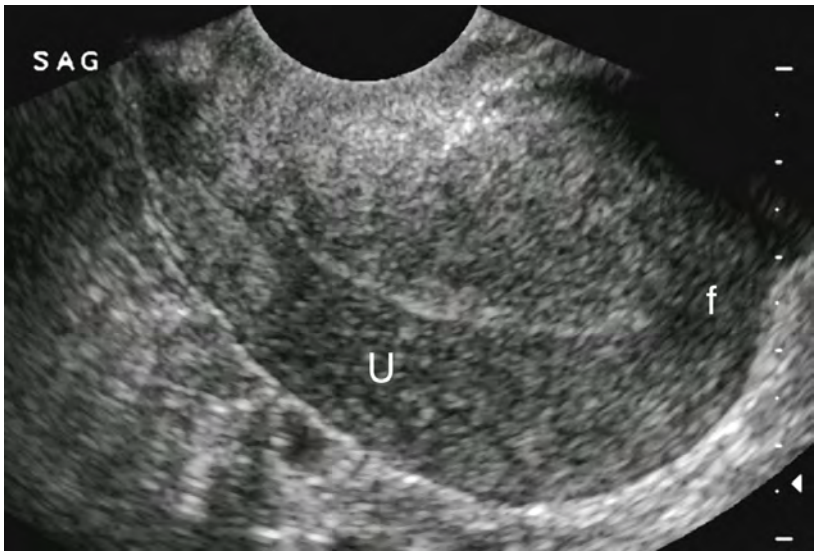

Figure 5: Normal reflexed uterus transvaginal
Longitudinal tranvavaginal scan shows a retroflexed uterus (U) with the fundus (f) of the uterus directed posteriorly toward the sacrum. Compare to Figure 3. Retroflexion of the uterus is a normal variant.

Uterine leiomyoma (fibroid)

Leiomyomas (also called fibroids) are solid benign uterine neoplasms composed of smooth muscle and fibrous tissue. They are the most common tumour of the female pelvis occurring in 40 % of women over age 35. They range in size from a few mm to 20 cm and are commonly multiple. Leiomyomas appear on ultrasound as round or oval solid masses slightly hypoechoic compared to the normal myometrium. They may extend from the surface of the uterus (Figure 6), be embedded within the myometrium, or grow within the uterine cavity (Figure 7). Haemorrhage, necrosis, and calcification are common producing cystic and echogenic changes within the tumours. Many are asymptomatic but menorrhagia, dysmenorrhea, pelvic pain, infertility, and discomfort of a large pelvic mass are common.

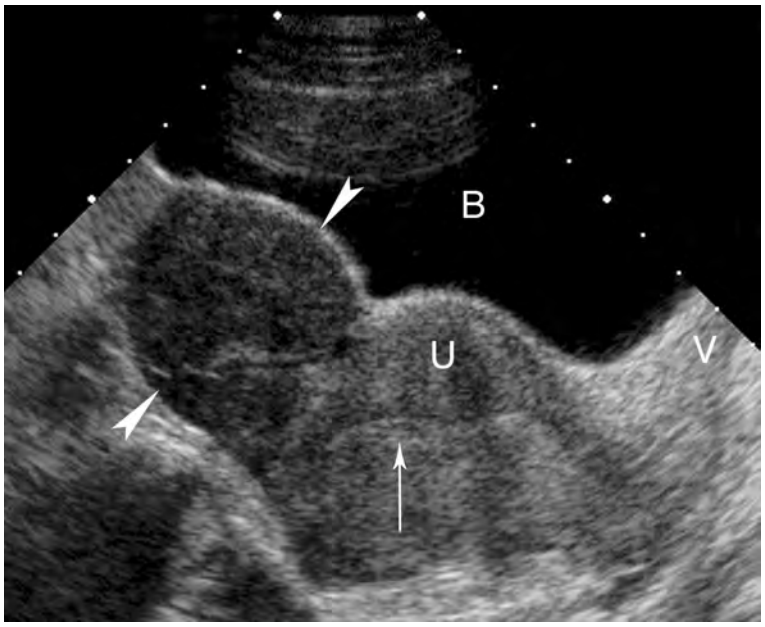

Figure 6: Large leiomyoma
Transabdominal scan through the full bladder (B) shows a large leiomyoma (arrowheads) extending superiorly from the fundus of the uterus (U). The endometrium (arrow) and vagina (V) are evident.

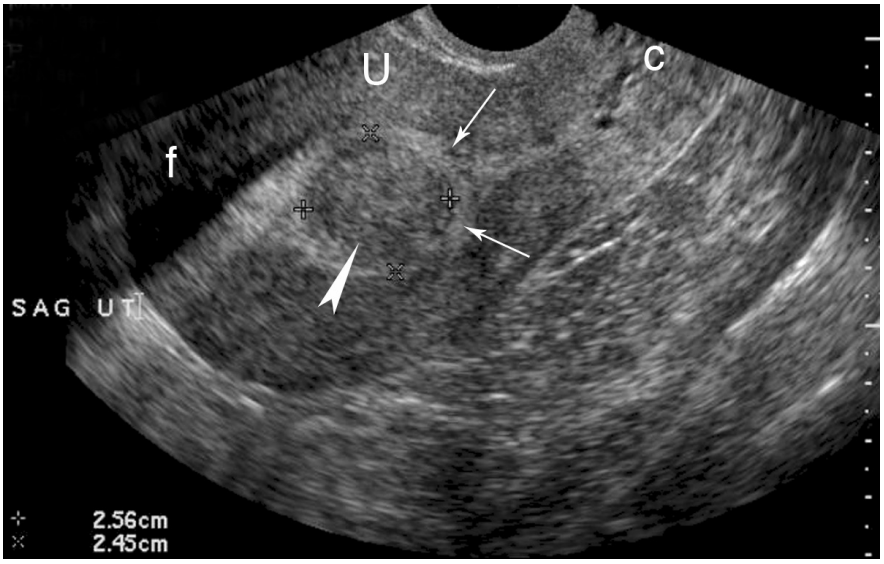

Figure 7: Leiomyoma in uterine cavity
Transvaginal scan in longitudinal plane shows a small leiomyoma (arrowhead) distending the uterine cavity identified by the echogenic endometrium (arrows). Leiomyomas in this location commonly present with menorrhagia. A polyp arising from the endometrium may have a similar appearance. The fundus (f) and cervix (c) of the uterus (U) are identified.

Endometrial carcinoma

The most common gynaecological malignancy is a carcinoma that arises from the endometrium (inner lining of the uterus). Most (80 %) occur in post-menopausal women. In post-menopausal women presenting with vaginal bleeding, a thickened endometrium (> 4 mm) as measured transvaginally in a true longitudinal plane warrants further investigation. Thickening of the endometrium > 15 mm in a postmenopausal women likely represent malignancy (Figure 8). The thick endometrium is echogenic, often with irregular contours. Cystic changes occur in 24 %.

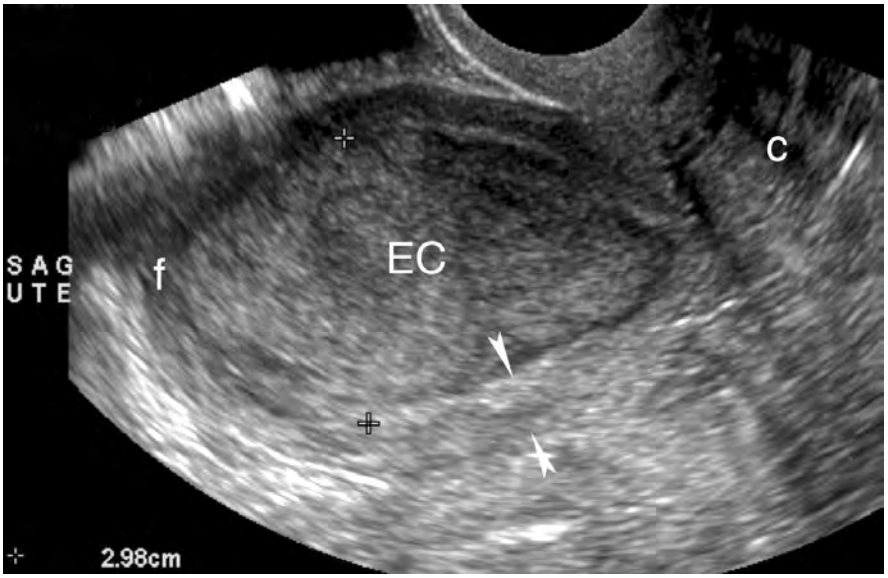

Figure 8: Endometrial carcinoma
Longitudinal transvaginal scan of the uterus in a post-menopausal woman with vaginal bleeding reveals a large solid mass (EC, between callipers, +) distending the uterine cavity. Endometrial thickness is 3 cm, markedly abnormal. The myometrium (between arrowheads) is thinned. The fundus (f) and cervix (c) of the uterus are labelled. The mass was proven on endometrial biopsy to be a poorly differentiated endometrial carcinoma.

Intrauterine Device (IUD)

IUDs are a commonly used contraceptive method. There are two main types of IUDs: copper based (small plastic device wrapped in copper wire), and hormonal based (consisting of a small tube that releases a hormone into the uterine cavity). Most devices are T-shaped and all have a string that exits the cervix. Complications include inappropriate location, which also lowers the effectiveness of the IUD as a contraceptive, expulsion from the uterus, penetration of the myometrium, perforation of the uterus, and infection, i.e. pelvic inflammatory disease (PID). Currently available IUDs are 95-98 % effective as contraceptives and lower the risk of ectopic pregnancy compared to women who do not use contraception. However, a pregnancy with an IUD in situ is more often an ectopic one than a pregnancy with no IUD.

Ultrasound is used to confirm the correct position of the IUD and to assess for any complications. Copper IUDs are highly echogenic and easy to visualize within the uterus. Hormone IUDs are somewhat less echogenic and a bit more difficult to visualize with ultrasound. A properly positioned IUD is within the uterine cavity with its T-arm positioned high in the fundus (Figures 9, 10 and 11). Malposition low in the uterine cavity or near the cervix is associated with impaired contraception (Figure 12). Arms of the IUD shown embedded within the myometrium are malpositioned and at risk for perforation of the uterus. A lost IUD string is a common indication for ultrasound examination. If the IUD is not identified within the uterus it may have been expelled or may have perforated the uterus. If the IUD is not visualized a radiograph of the pelvis is useful to confirm whether the device is within the pelvis outside of the uterus. All IUDs are radiopaque and easily visualized on a radiograph.

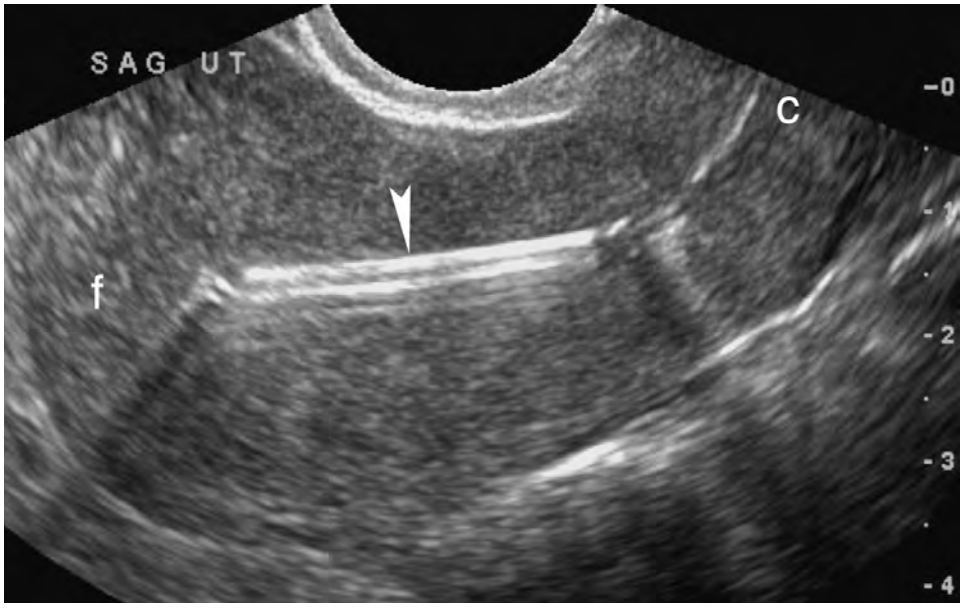

Figure 9: IUD in appropriate position
Longitudinal transvaginal scan show the IUD (arrowhead) as a highly echogenic linear structure centred within the uterine cavity. The IUD is so echogenic that it produces reverberation echoes seen as artefactual duplication of the IUD. The IUD also causes acoustic shadows darkening the echoes deep to the device. The fundus (f) and cervix (c) of the uterus are identified.

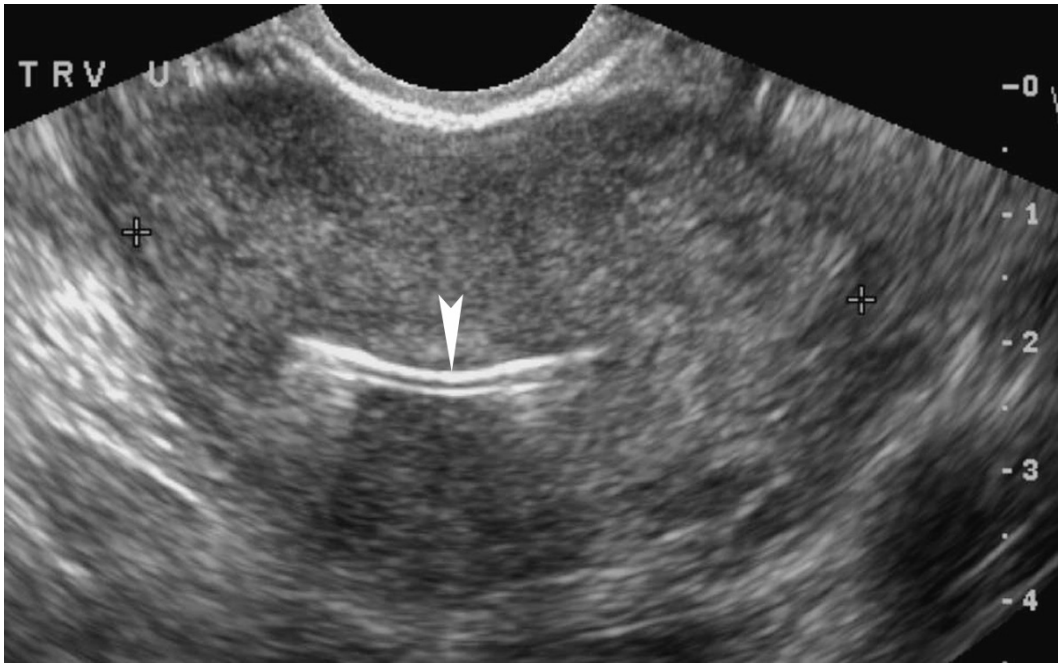

Figure 10: IUD in Appropriate position – Uterine fundus
Transverse transvaginal scan of the same patient as shown in Figure 12 shows the T-arms of the IUD (arrowhead) properly located in the wide portion of the uterine cavity near the fundus. Again the artefactual duplication of the IUD and the acoustic shadow deep to its T-arms.

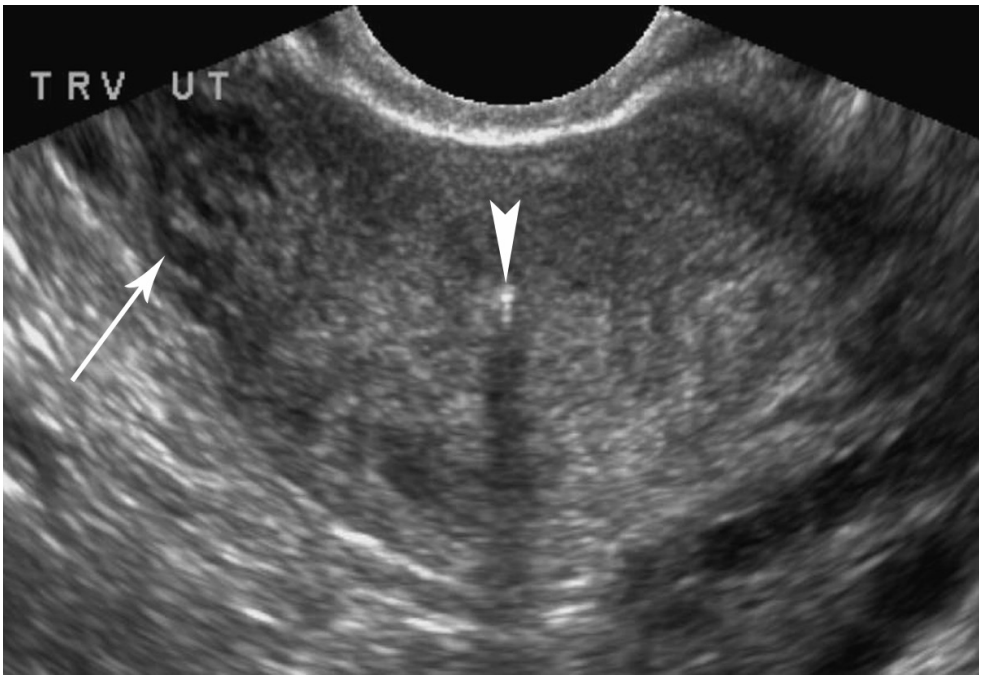

Figure 11: IUD in appropriate position – Uterine body
Mid-uterine body transverse transvaginal scan of the same patient as in Figure 13 and Figure 14 shows the thin long arm of the IUD (arrowhead) in cross section as an echogenic dot with a prominent acoustic shadow. Multiple scans of the uterus in various planes are required to confirm appropriate position of the IUD. A small partially degenerated leiomyoma (arrow) is noted in right lateral myometrium.

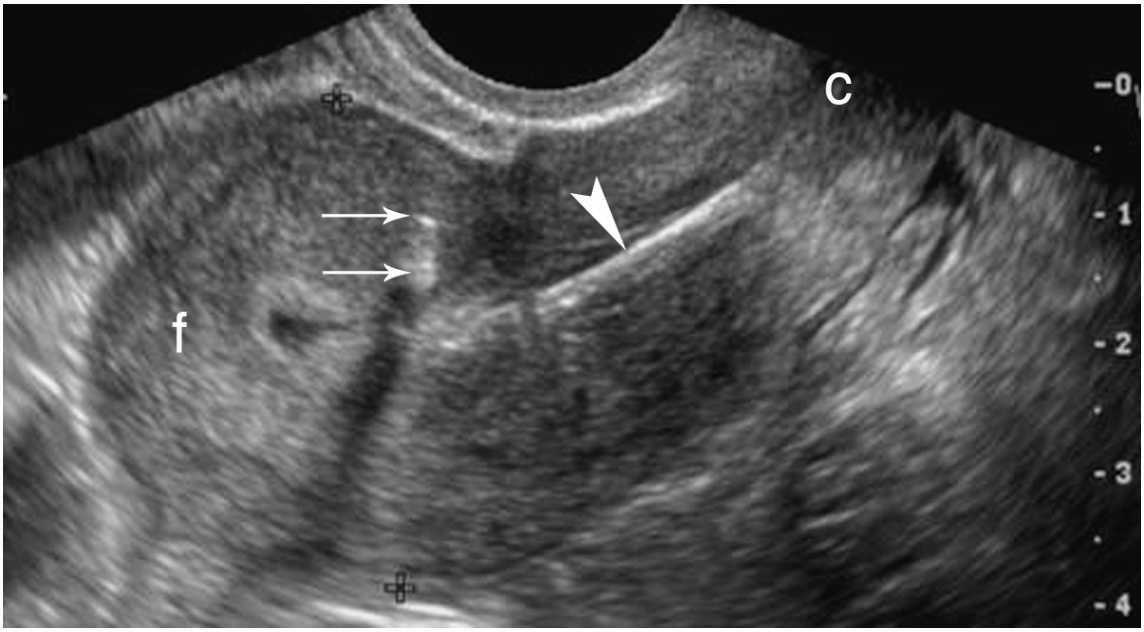

Figure 12: Malpositioned IUD
In this transvaginal longitudinal plane scan of the uterus the IUD (arrowhead) is found to be low in position closer to the cervix (c) than to the fundus (f) of the uterus. The T-arms (arrows) of the IUD are embedded in the anterior myometrium. This IUD position has limited effectiveness in contraception and may cause pelvic pain, uterine cramping, and excessive vaginal bleeding.

7.3 Ovaries and ovarian tubes

The appearance and size of normal ovaries change with age and the phase of the menstrual cycle. In girls under 8 years of age the ovaries are solid and small (1-3 cubic centimeters in volume). With menarche follicles develop on the ovaries appearing as multiple small anechoic thin-walled cysts (Figure 13). During the menstrual cycle a dominant follicle enlarges up to 3 cm in diameter (Figure 14). With ovulation the dominant follicle ruptures. In its place the corpus luteum develops appearing as a collapsed cyst, a thin-walled or thick-walled cyst, or a cyst containing low level echogenicity, representing haemorrhage. If pregnancy does not occur the corpus luteum involutes and a new menstrual cycle commences. In post-menopausal women the ovaries are small; generally < 6 cc, i.e. < 6 mL, in volume, and usually appear solid without follicles (Figure 15). It is essential that the appearance of the ovaries be correlated with the patient's age and phase of the menstrual cycle.

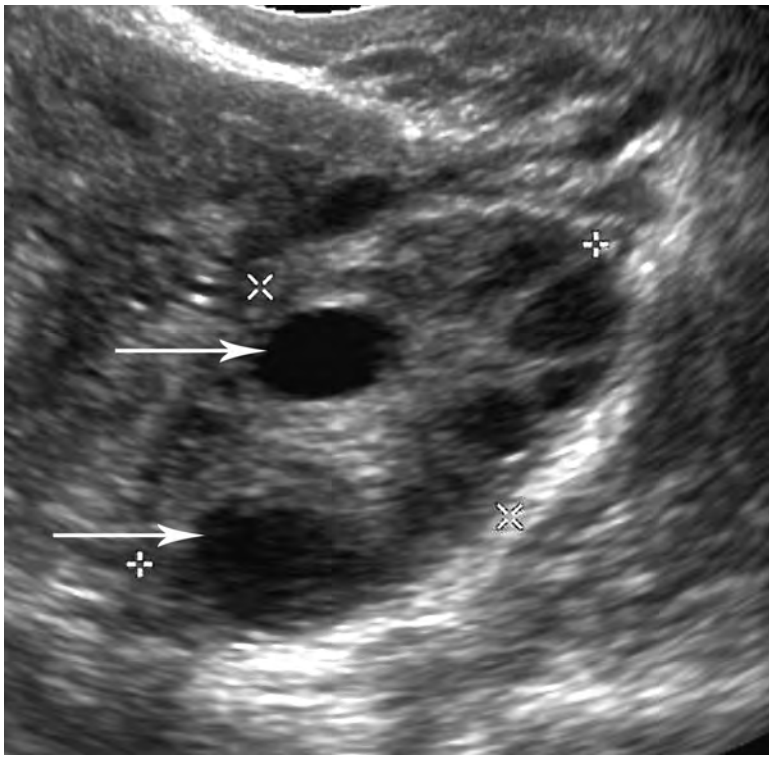

Figure 13: Normal ovary
Transvaginal scan of the right ovary (between callipers, +, x) shows a normal appearance of the ovary with multiple follicles (arrows) present. The presence of follicles confirms that the structure visualized is actually the ovary.

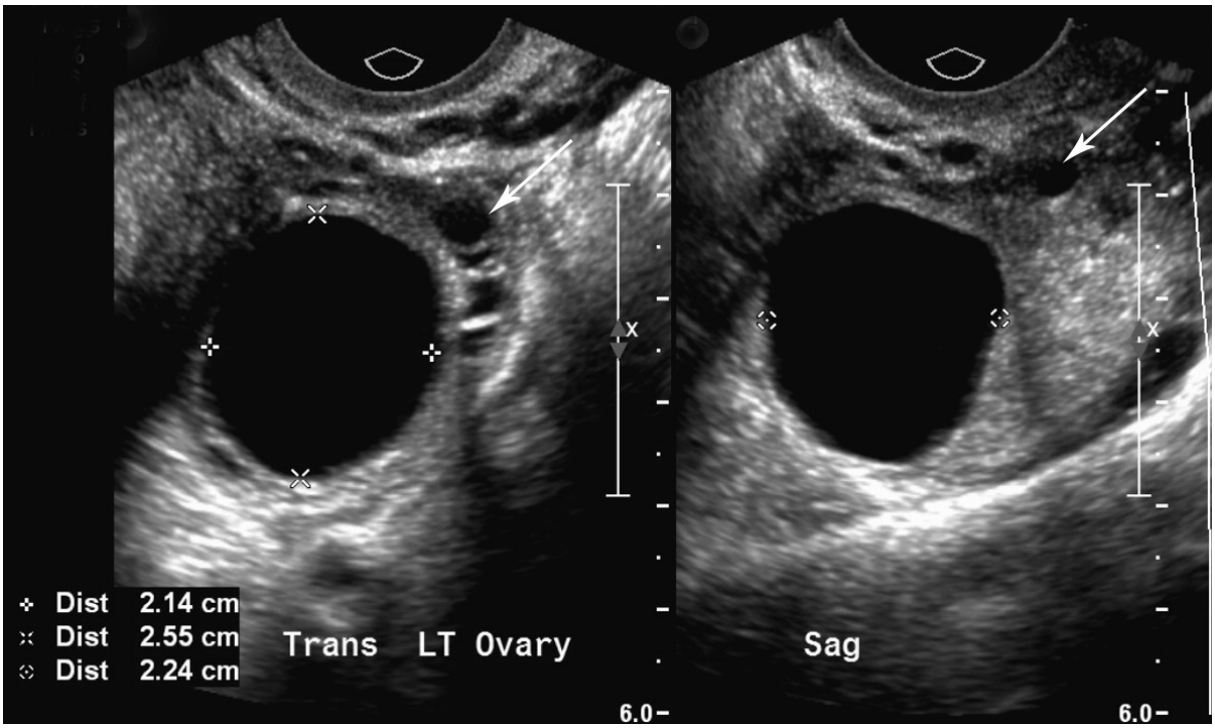

Figure 14: Normal ovary with dominant follicle
Transvaginal scans of the left ovary in transverse (left) and sagittal (right) planes a dominant follicle (between callipers, +, x) approximately 2.5 cm in diameter. Smaller, normal follicles (arrows) are seen in the periphery of the ovary. Anechoic ovarian cysts up to 3 cm diameter in a woman of menstrual age are a normal finding.

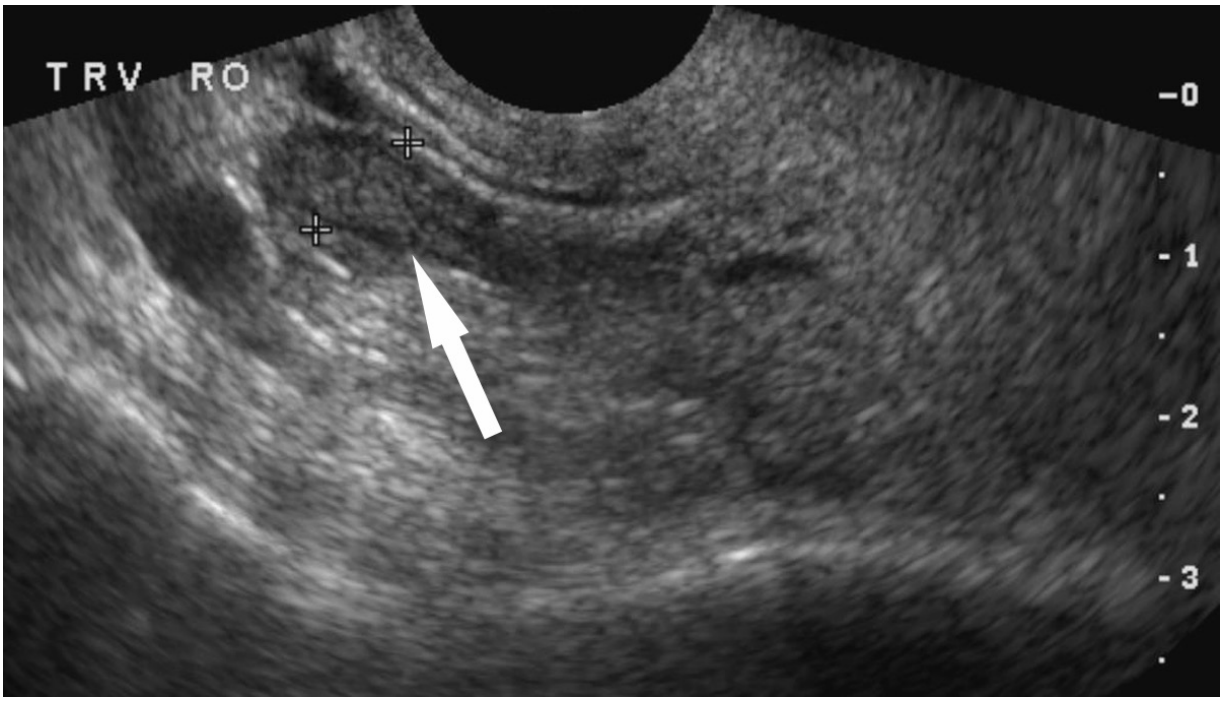

Figure 15: Postmenopausal ovary
Transvaginal scan of the right ovary (arrow, between callipers, +) in a 65 year old woman shows the normal appearance of the postmenopausal ovary. The ovary is oval in shape and solid in appearance without follicles present. Normal postmenopausal ovaries are difficult to identify even with transvaginal ultrasound.

Physiologic ovarian cysts

The normal physiologic changes of the ovary throughout the menstrual cycle should not be confused with ovarian pathology. Follicles appear as simple, smooth thin walled anechoic cysts without internal echoes. Developing follicles are 1-10 mm in size, while the dominant follicles may enlarge to 3 cm just prior to ovulation. The corpus luteum that develops at the site of ovulation is more variable in appearance. It may be a collapsed or thick or thin-walled cyst and may have internal low- level echoes (Figure 16). Doppler ultrasound shows intense blood flow at the periphery of the corpus luteum.

In summary, ovarian cysts up to 3 cm diameter in a woman of menstrual age may be considered physiologic.

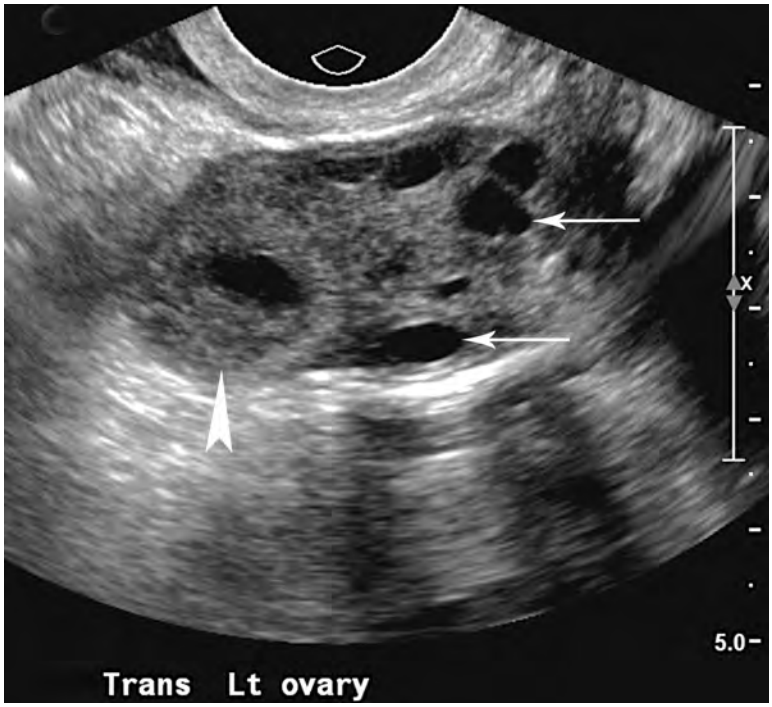

Figure 16: Normal corpus luteum
The left ovary shown in this transvaginal image, obtained in a woman who has recently ovulated, contains multiple normal follicles (arrows) and a normal corpus luteum (arrowhead) at the site of ovulation. In this case the corpus luteum appears thick-walled with layering internal echoes representing a normal small amount of haemorrhage associated with ovulation. Doppler ultrasound (not shown) reveals intense blood flow in the corpus luteum. If the patient becomes pregnant the corpus luteum persists and continues to secrete hormones to support the pregnancy. If the patient does not become pregnant the corpus luteum involutes by the time of the start of the next menstrual cycle.

Haemorrhagic ovarian cysts

Spontaneous haemorrhage may occur into an ovarian follicle or into the corpus luteum resulting in a haemorrhagic ovarian cyst. Acute haemorrhage is a common cause of abrupt pelvic pain in women of menstrual age. Haemorrhagic cysts may rupture and bleed into the peritoneal cavity increasing symptoms. On ultrasound haemorrhagic ovarian cysts are >3 cm, commonly 5-6 cm or larger, containing floating echogenic debris representing acute blood, or echogenic solid matter representing blood clots (Figure 17). A network of fine fibrous strands extending across the cyst, resembling a spider web, and representing evolving blood clot is common and characteristic (Figure 18). The cyst walls may be thick or thin. Echogenic fluid in the peritoneal cavity is common appearing as free fluid with low level echoes.

Note: careful adjustment of the 2D gain and focal zone settings on the ultrasound unit are critical for demonstrating these important and characteristic ultrasound features of haemorrhagic fluid. Most haemorrhagic cysts resolve in 2-8 weeks.

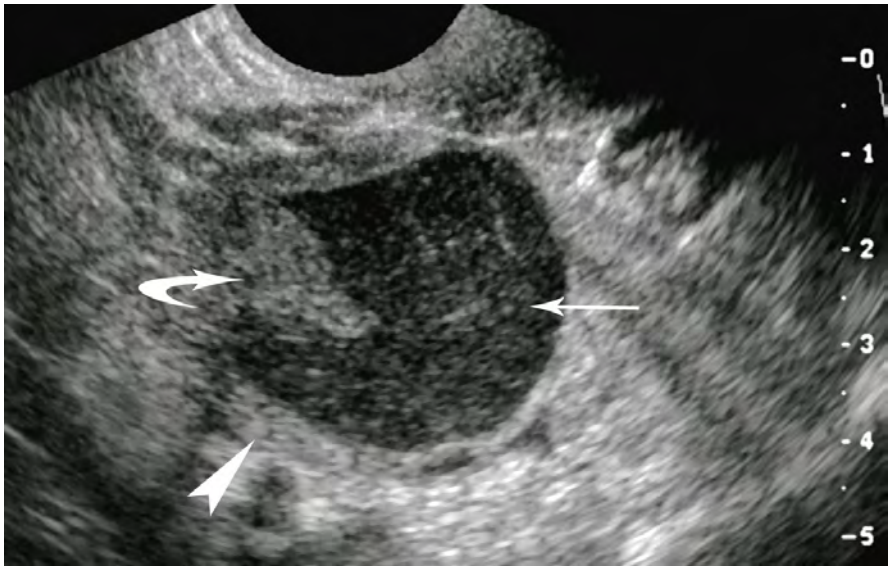

Figure 17: Haemorrhagic ovarian cyst – Clots and blood
Transvaginal image of the ovary shows a 4 cm cystic mass with fine floating internal echoes (straight arrow) representing blood in liquid form. A solid appearing structure (curved arrow) in the upper portion of the cyst represents a blood clot. Doppler ultrasound (not shown) typically shows no blood flow within the clot. The wall of the cyst (arrowhead) is thickened.
Follow-up ultrasound obtained following two menstrual cycles confirmed complete resolution of this haemorrhage cyst.

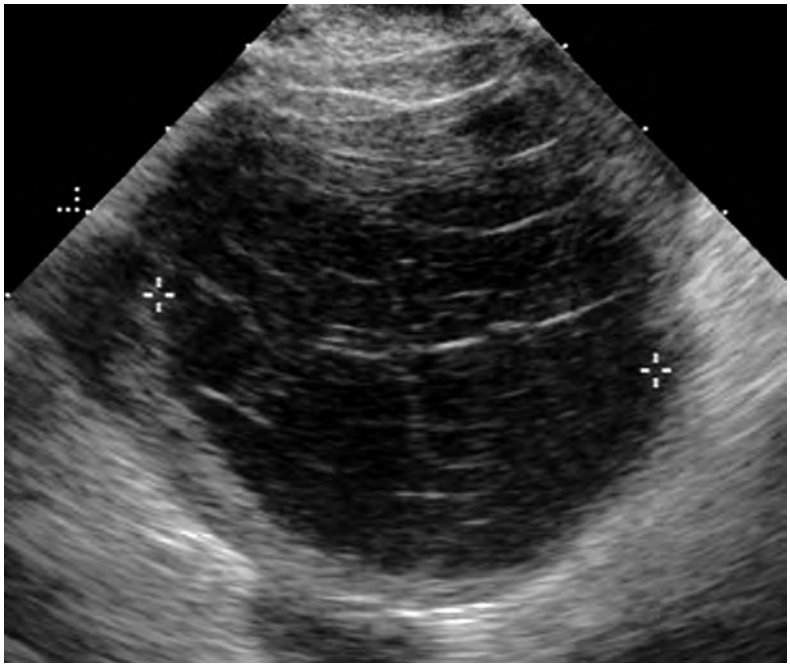

Figure 18: Haemorrhagic ovarian cyst – Spider web appearance
Transvaginal image of the left ovary in a woman with acute left pelvic pain shows a thick-walled cystic ovarian mass with fine septations extending across the cyst. This 'spider-web' appearance is characteristic of a hemorrhagic ovarian cyst. Doppler ultrasound evaluation shows no blood flow within these fine septa. Blood flow may be prominent in the thick walls of the hemorrhagic cyst.

Polycystic ovary syndrome (PCOS)

The diagnosis of PCOS is made clinically on the basis of infrequent or absent ovulation, infertility, androgen excess, hirsutism, and obesity. Ultrasound only defines the morphology of the ovaries and does not confirm or exclude the diagnosis. Typically in patients with PCOS the ovaries are enlarged, i.e. > 15 cc/mL in volume, and contain numerous follicles, i.e. > 12 mm. The follicles themselves are small, i.e. < 10 mm, and no dominant follicle is visualized. The normal shape of the ovary is maintained. Ovarian stroma is thickened and increased in echogenicity (Figure 19). In 30 % of cases the ovaries are normal in size. The diagnosis of PCOS is confirmed by biochemical analysis.

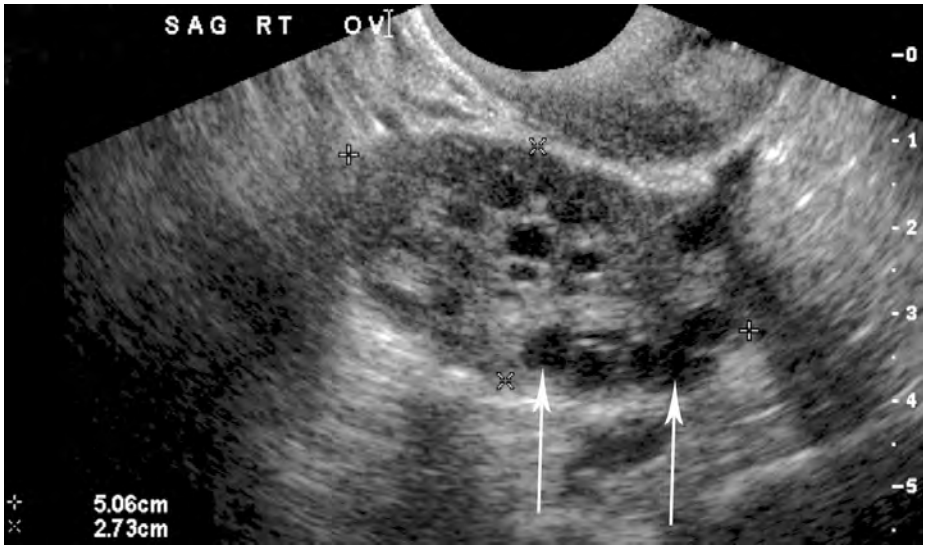

Figure 19: Polycystic ovary syndrome
Transvaginal image of the right ovary shows an enlarged ovary (between callipers, +. x) with numerous small follicles (arrows). The ovary is enlarged with a calculated volume (height x width x depth x 0.52) exceeding 28 cc/mL.
The stroma is prominent and increased in echogenicity.

Pelvic inflammatory disease (PID) / Tubo-ovarian abscess (TOA)

PID is usually caused by a sexually transmitted disease such as gonorrhea or chlamydia infection, but it may also occur as a complication of a postpartum infection, appendicitis, diverticulitis, or pelvic abscess. Patients present with acute pelvic pain, tenderness, fever, and vaginal discharge. Ultrasound shows the following findings:

– Thickening of the endometrium, i.e. >14 mm, with fluid and layering echogenic material representing pus in the uterine cavity is indicative of endometritis.

– Pyosalpinx refers to a dilated fallopian tube distended with fluid containing echogenic particulate matter, i.e. pus. The wall of the affected tube may be thickened.

– Tubo-ovarian abscess describes an inflammatory adnexal mass that incorporates the inflamed ovary, a dilated pus-filled tube, and purulent fluid bound by inflammatory adhesions. While PID can often be effectively treated with antibiotics, TOAs commonly require surgical drainage (Figure 20).

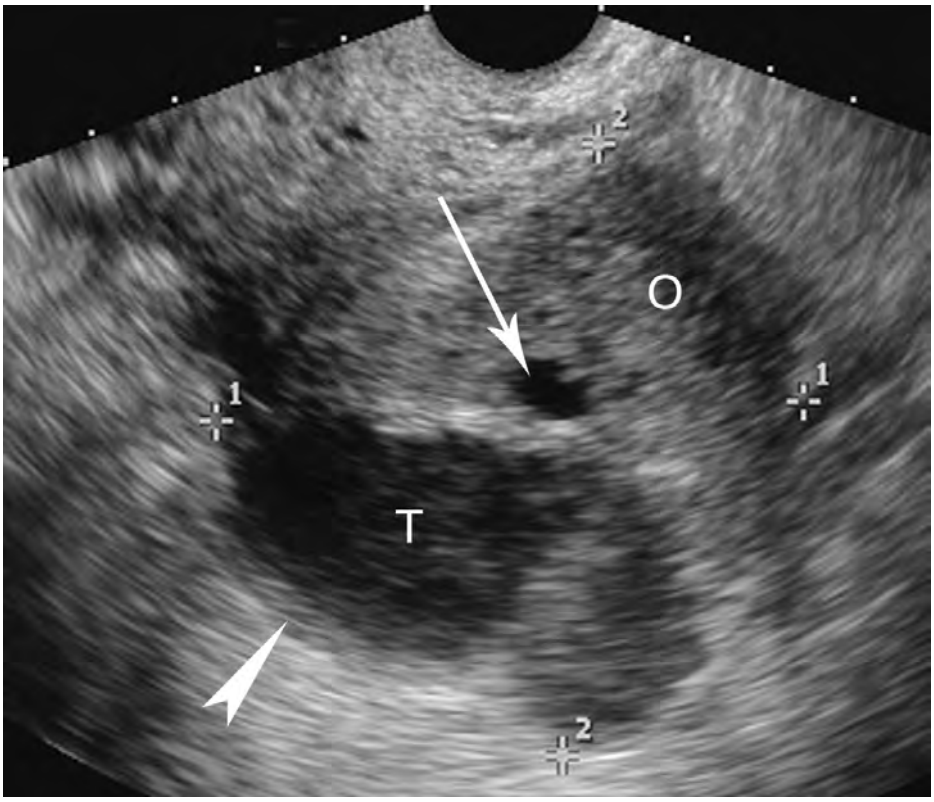

Figure 20: Tubo-ovarian abscess
Ultrasound image taken transvaginally shows an inflammatory mass (between callipers, +, x) in the right adnexa. The mass contains the right ovary (O) identified by the presence of a follicle (arrow) and a dilated pus-filled fallopian tube (T).
The wall of the inflamed tube is thickened (arrowhead).

Adnexal torsion

The ovary and / or fallopian tube may twist, i.e. torse, around their vascular pedicle resulting in compromised blood flow. Torsion may be acute and complete causing intense pelvic pain or intermittent or incomplete causing pain and tenderness that may mimic other conditions. Clinical and ultrasound diagnosis is often difficult, but is urgent in order to prevent irreversible damage and preserve fertility.

– Normal size and appearance of the ovary excludes torsion.
– The torsed ovary is always enlarged due to edema and an ovarian mass. Commonly a cystic teratoma, is often present, i.e. in 50 % of cases. The symptomatic side ovary volume exceeding 3 times the volume of the contralateral ovary is strong evidence for torsion (Figure 21).
– Free pelvic fluid or blood is often present.
– Because the ovary may torse intermittently Doppler ultrasound findings are unreliable. Doppler may show normal flow while torsion is present, or may show no flow while torsion is absent. In order to rely on Doppler findings highly skilled and experienced Doppler ultrasound examination is required in this setting.

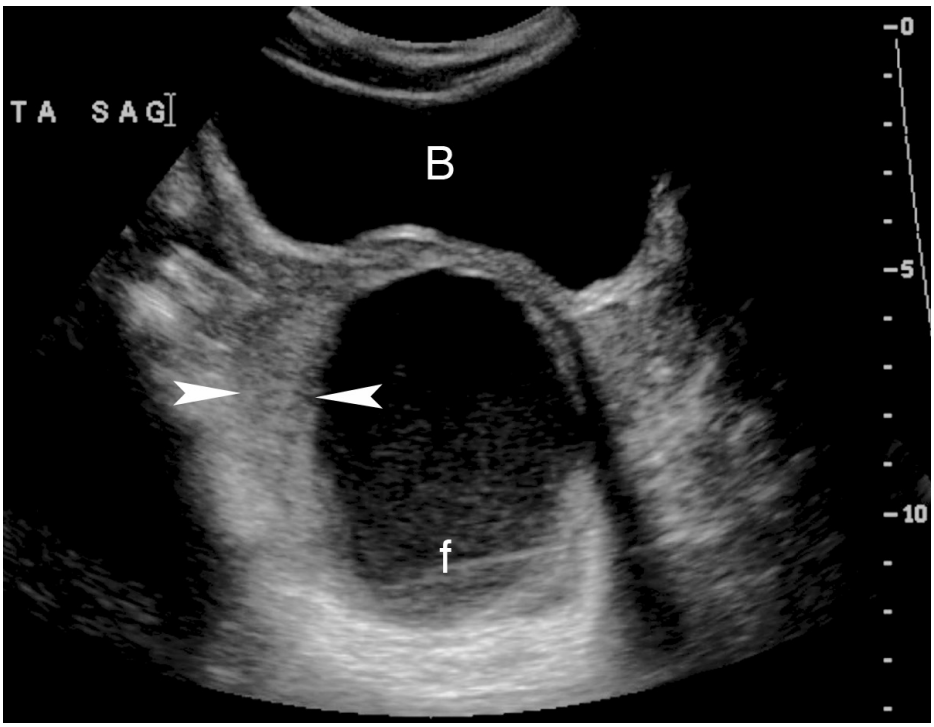

Figure 21: Ovarian torsion
Transabdominal ultrasound image obtained through the bladder (B) shows a large left ovarian cyst in a young woman with acute severe left pelvic pain. The cyst wall (between arrowheads) is asymmetrically thickened. Careful Doppler examination (not shown) demonstrated no blood flow in the cyst wall. Echogenic fluid (f) is layering within the cyst. Emergency surgery confirms complete torsion of the ovary. The cystic mass proved to be a benign cystic teratoma.

Ovarian malignancy

Ovarian cancer is the leading cause of death from gynecologic malignancy. Although it is curable if discovered early, two-thirds of all patients have spread of tumor beyond the pelvis at the time of discovery. Patients may present with abdominal pain or swelling, frequent urination, pelvic mass, or unexplained ascites. Early stage disease rarely causes any symptoms. Ultrasound findings that suggest ovarian malignancy include:

– Most cancers are predominantly cystic but any solid component suggests possible malignancy (Figure 22).
– Irregular thickened (>3 mm) wall or septa.
– Solid mural nodules or papillary projections - these may be seen both in ovarian malignancies as well as borderline tumors of the ovary and fallopian tube (Figure 23).
– Doppler findings of blood flow within any solid component of an ovarian mass (Figure 24).
– Size of an ovarian lesion >4 cm increases the risk of malignancy.
– Tumors are bilateral in up to 50 % of cases.
– Signs of tumor spread beyond the ovary include ascites, deposits of solid tissue on peritoneal surfaces, and hydronephrosis caused by tumor involvement of the ureters.

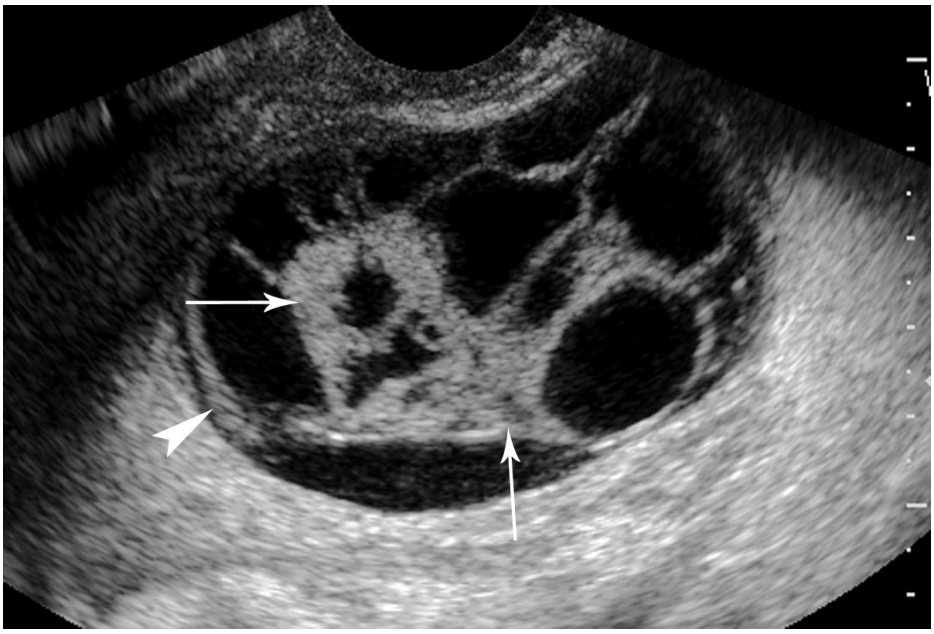

Figure 22: Ovarian carcinoma
Transvaginal image of the right ovary reveals a predominantly cystic mass with prominent thick solid septations (arrows). The wall of the lesion is irregularly thickened (arrowhead) exceeding 3 mm. This proved to be a clear cell carcinoma of the ovary.

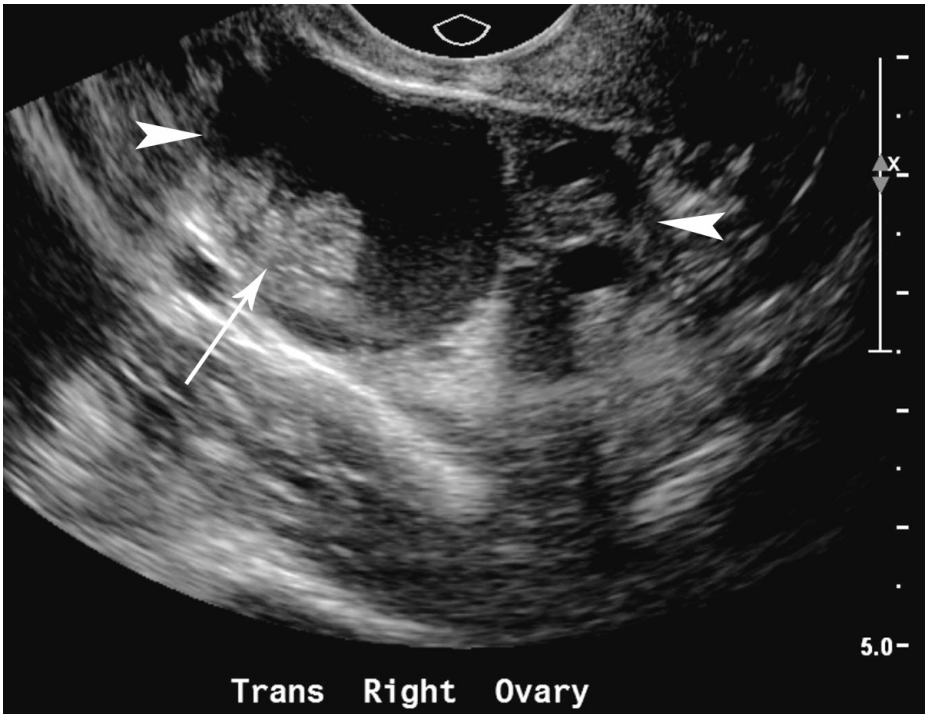

Figure 23: Papillary ovarian carcinoma
In a different patient transvaginal ultrasound shows a complex appearance of the right ovary (between arrowheads) with a solid papillary projection (arrow) in a cystic component of the lesion.

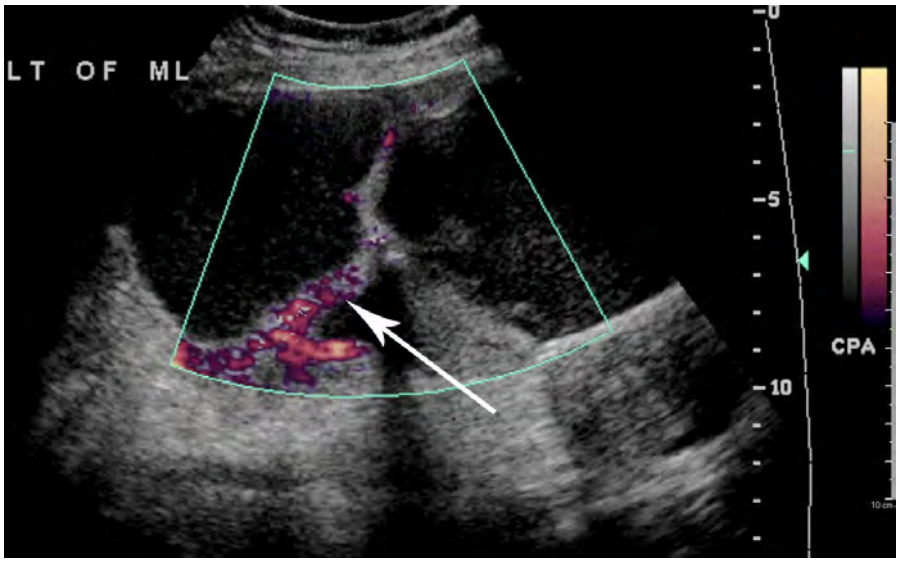

Figure 24: Blood flow in an ovarian carcinoma
Power Doppler ultrasound image of the left ovary in a 51 year old woman with pelvic pain and a palpable pelvic mass shows a cystic ovarian mass with prominent septa. Colour and spectral Doppler confirm blood flow within the septa, a sign highly suggestive of malignancy. Pathology confirmed a serous cystadenocarcinoma of the ovary.

Benign ovarian masses

Ultrasound findings that indicate that an ovarian mass is likely benign include the following:

- Masses that are purely cystic with thin walls and septa (<3 mm) and no solid components are nearly always benign and most often are functional ovarian cysts. Uniform thin septations are common in benign ovarian tumors such as serous cystadenomas.
- A markedly echogenic solid-appearing component without evidence of blood flow on Doppler ultrasound is indicative of benign cystic teratoma (Figure 25).
- Absence of blood flow on Doppler ultrasound is reliable evidence of a benign lesion. Blood clots appear within ovarian cysts as solid appearing masses without blood flow.

Cystic teratoma

Benign cystic teratoma, also called dermoid cysts, is the most common ovarian neoplasm. Most present as an asymptomatic pelvic mass, though some, up to 16 %, present with acute adnexal torsion and others may rupture causing acute peritonitis. Malignancy occurs in less than 2 % of lesions. Surgical removal is usually indicated. The tumours are cystic but may contain fat, hair, sebum, teeth, or bone that produce often distinctive ultrasound findings.

- The dermoid plug is most characteristic, consisting of a mixture of fat, hair, sebaceous material, and soft tissue. The nodular mass is highly echogenic and produces a prominent dirty acoustic shadow that obscures the deep portions of the mass.
- Teeth and bone produce highly echogenic foci with prominent acoustic shadows. A radiograph of the pelvis may confirm the presence of teeth or bone with the ovarian lesion.
- Fluid-fluid levels are common, caused by sebum layering on serous fluid within the cyst.
- Hair floating within fluid produces characteristic bright linear strands (Figure 26).
- The tumour may be entirely cystic, mimicking a physiologic ovarian cyst.
- Because of the wide variation in structure and ultrasound appearance of cystic teratomas, they are appropriately included in the differential diagnosis of many pelvic masses.

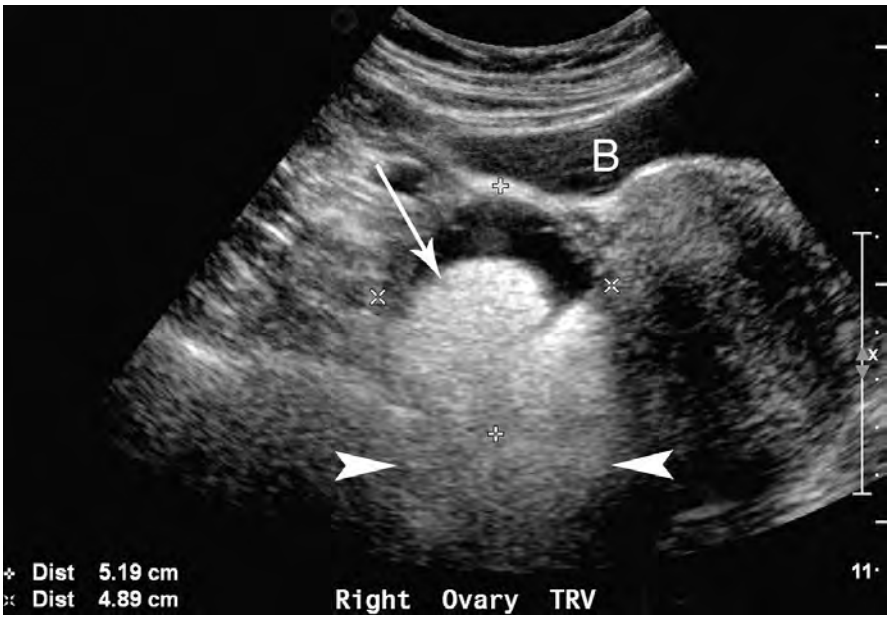

Figure 25: Benign cystic teratoma – Dermoid plug
Transabdominal image of the right ovary shows a cystic mass (between callipers, +, x) containing a highly echogenic nodule (arrow) characteristic of a dermoid plug. The dermoid plug casts a dirty (bright) acoustic shadow (between arrowheads) that obscures the deeper aspect of the lesion. Doppler ultrasound showed no evidence of blood flow within the echogenic nodule. A portion of the bladder (B) is evident.

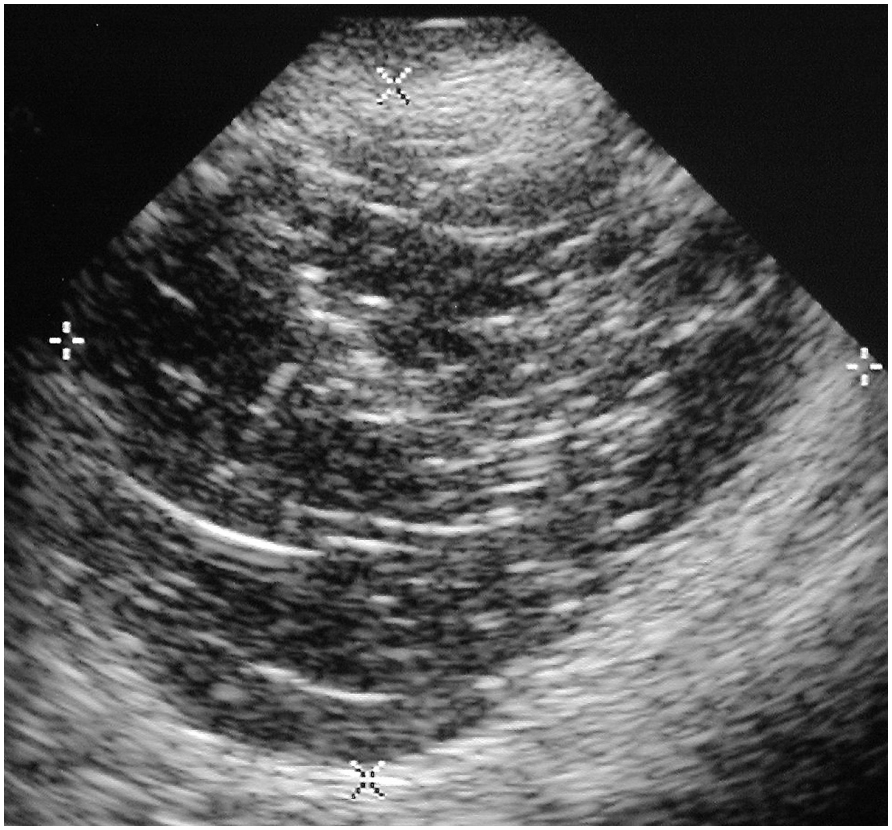

Figure 26: Benign cystic teratoma - Hair
Transvaginal image of the ovary (between callipers, +, x) reveals the characteristic appearance of hair floating in serous fluid within a benign cystic teratoma. The hair produces echogenic linear strands and dots.

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8. Obstetrics early ultrasound – first trimester

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By common usage pregnancy is divided into three trimesters, each approximately three months in length, are characterized by specific foetal development. The first trimester, defined as conception to 13 weeks gestational age, is a time of cell differentiation crucial to foetal development, as organ systems begin to develop. The second trimester, weeks 14-26, is a period of rapid growth with further development and maturation of organ systems. The third trimester, weeks 27-40 is the time of completing organ development and final foetal growth.

The main roles of early obstetric ultrasound imaging are: confirmation of viable intrauterine pregnancy, gestational dating, diagnosis of multiple pregnancy, the differential diagnosis of vaginal bleeding and pelvic pain in a woman in early pregnancy including the differential diagnosis of an ectopic pregnancy, foetal demise, peri-gestational haemorrhage from the placenta, and hydatiform mole.

8.1 Scanning technique – first trimester

Transducer

Begin with transabdominal scanning, a 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

If appropriate, repeat with transvaginal scanning. An 8-5 MHz tightly curved array transducer, such as the ICTx which is compatible with the MSF standard M-Turbo, is preferred. See section on transvaginal scan – below.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine.

The patient should ideally have a filled bladder in order to use it as acoustic window.

For the transvaginal scan, a pillow or similar placed underneath to elevate the bottom, with legs drawn towards the chest

Scanning steps for transabdominal imaging

1. Select ‘OB’ from the exam type in the drop down menu and enter the patient’s details. Include the last menstruation period (LMP) if known.
2. Start with the transducer in the longitudinal position, with the marker pointing towards the patient’s head, in the patient’s midline with the transducer positioned just above the symphysis pubis. Slowly move the transducer right to left and back. Repeat to cover the entire pelvic region.

3. Rotate the transducer 90 degrees into the transverse position with the marker pointing to the patient's right. Slowly move the transducer towards the patient's head and back. Repeat to cover the entire pelvic region.
4. After the entire pelvic area has been scanned once, re-locate the uterus and confirm if it is empty or not.
   The following basic parameters need to be recorded in a 1st trimester scan:
   - Number of foetuses
   - Foetal viability
   - Gestational age
5. Identify the number and position of foetus(es). If multiple foetuses are suspected use the same anatomical structure, e.g. head, to count and confirm.
6. For measurements and documentation label 'Baby A', 'Baby B' and so on. Note in the patient's chart if the foetuses are monochorionic, i.e. lie within the same gestational sac, or dichorionic, i.e. lie within two separate gestational sacs. This is most accurately assessed in the first trimester.
7. For each foetus locate the heart and confirm cardiac motion. Cardiac motion is usually visible after 6 weeks, when the foetal pole is >7 mm in size via transvaginal imaging. If there is no cardiac motion detected and the embryo measures 7 mm or greater in crown-rump length embryonic demise is likely.
8. If there is cardiac motion, M-mode can be used to further demonstrate the foetal heart rate and viability (see section on M-mode below) if required.
9. Estimate gestational age (see section gestational age below).
10. In a patient presenting with vaginal bleeding the differential includes: threatened abortion / foetal demise or ectopic pregnancy (see sections below on ectopic pregnancy and threatened abortion below).

Scanning steps for transvaginal scanning

Ensure a private space is properly prepared, consent obtained and bladder emptied, see section on transvaginal imaging.

1. Place a generous amount of coupling gel on the transvaginal ultrasound transducer and cover with a condom, removing any air bubbles. Additional gel should be placed on the outside of the transducer to ease insertion into the vagina. The operator must take great care to ensure the condom remains in place.
2. Point the transducer marker to the ceiling, i.e. 12 o'clock position as it is initially inserted. Evaluate the uterus and endometrial thickness from this longitudinal plane.
3. Assess the cervix, bladder and cul-de-sac. Slight adjustment of the transducer may be required either inferior, superiorly or laterally to improve visualisation. Be sure to move and rotate the transducer slowly and gently. Note: The urinary bladder is usually better assessed with the transabdominal transducer.
4. Rotate the transducer 90 degrees counter clockwise (by turning the marker on the patients' right) to evaluate the uterus and the ovaries in the transverse / coronal plane.
5. Sweeping the transducer laterally is required to identify the adnexal region and surrounding structures including the ovaries. Typically ovaries are located in similar positions on either side, so identifying one may assist in locating the other.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

Foetal heart rate (FHR) using M-Mode

A normal foetal heart rate (FHR) is detectable on ultrasound around 6 weeks of gestation. FHR usually ranges between 120-160 beats per minute and varies during gestation.

1. Identify the foetal heart and centre it on the screen adjusting depth and zoom as required.
2. Press the 'M-mode' button which displays a vertical line on the screen. Using the touch pad position the line through the beating heart.
3. Press 'M-mode' again, a series of wavy lines appear at the bottom on the screen.
4. Press the 'freeze' button to pause scanning.
5. Press 'calcs' and select 'FHR' from the menu. A vertical calliper appears, position the line at a peak in the wave using the touch pad and press 'select'. A second vertical calliper appears which is positioned at the peak of the next heartbeat. Note measuring trough to trough is also possible.
6. The measurement is displayed on the screen (Figure 1). Press 'save calc' to add the FHR to a report, or press 'save' to save the image with measurements.

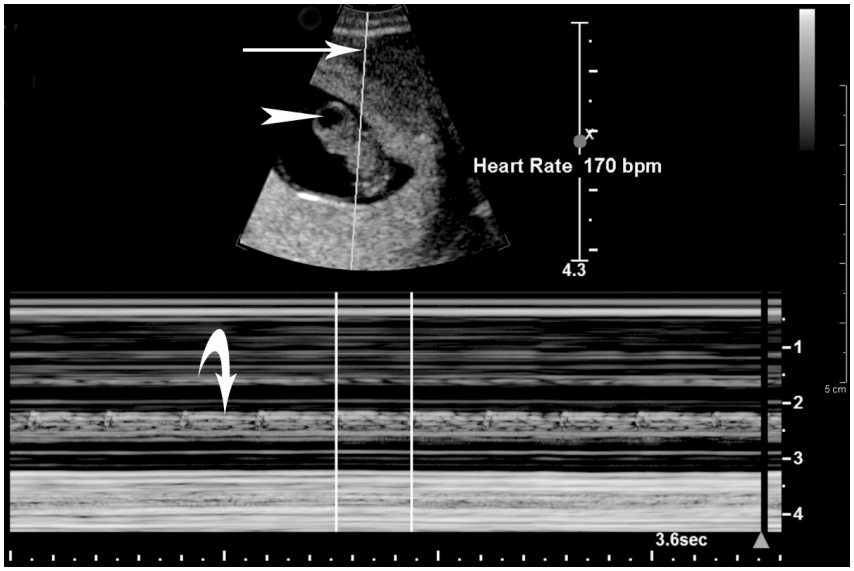


Figure 1: M-mode documentation of cardiac activity
Superimposed on the real time image of the embryo is a trace of the M-mode ultrasound beam indicated by the thin white line (arrow) that is directed through the visualized heartbeat of the embryo by the sonographer. The resulting M-mode trace is shown below the anatomic image. Cardiac activity produces the jagged line (curved arrow) in the middle of the graph. The operator then places two markers (vertical lines) between heartbeats to obtain the heart rate, in this case 170 beats per minute. Of additional note in this 7-week embryo is a prominent cystic space (arrowhead) within the cranium. This is a normal stage of development of the brain (the rhombencephalon) and is of no clinical concern.

Measurements of gestational age – first trimester

Dating a pregnancy by ultrasound in resource-constrained and remote settings can be very useful to assist health care providers and expecting mothers plan for the baby's birth in hospital or health care facility.

By clinical convention gestational age is dated from the first day of the last menstrual period (LMP). The charts stored in the computer in ultrasound scanning units report gestational age using this convention.

The earliest estimate of gestational age is made by measuring the mean diameter of the gestational sac (Figure 2). Mean sac diameter (MSD) is determined by measuring the height, width, and breadth of the gestational sac in orthogonal planes. Then add the three measurements together and divide by 3 to determine the mean diameter. As soon as the embryo can be visualized and up to 12 weeks gestational age, ultrasound dating is made by measuring crown-rump length (CRL) (Figure 3).

In the second and third trimesters ultrasound dating is made by averaging at least 4 measurements made on the foetus: biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). These measurements and illustrations are described Chapter 9.

1. Scan the uterus and identify a sagittal view of the embryo in its longest dimension (Figure 3).
2. Press the 'freeze' button to pause scanning. Using the touch pad scroll through the last 30-60 seconds to identify the best image. The CRL is determined by measuring the maximum length of the embryo from the top of the head, i.e. crown, to the bottom of the trunk, i.e. rump.
3. Press 'calcs' and from the options highlight 'CRL' and press 'select'.
   Note: If the OB Calc options like 'CRL' are not available make sure you have selected OB as the examination type.
4. The measurement trace will appear. Using the track pad, move one '+' to the top of the head, i.e. crown, and press 'select', then move the other bottom of the embryo, i.e. rump.
5. The CRL measurement and estimated gestational age is displayed on the screen. Time permitting, it is ideal to make several measurements of CRL and use the average, to allow for image variability.

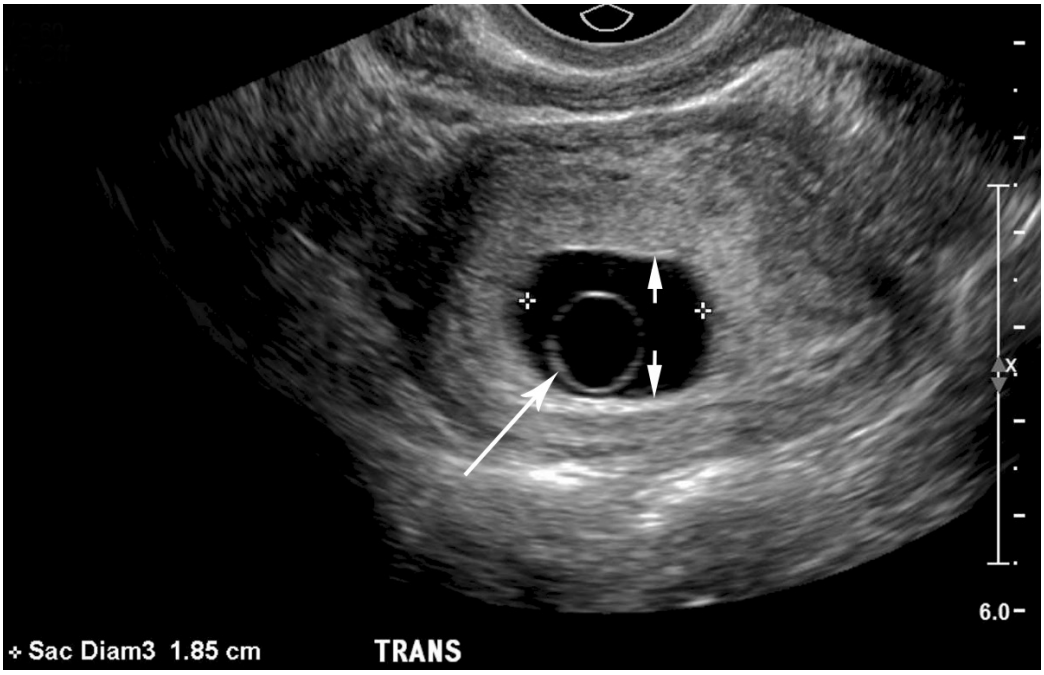


Figure 2: Mean sac diameter measurement
Transverse image of a gravid uterus shows measurement of mean sac diameter to estimate gestational age. The cursors (+) show a measurement of 1.85 cm. A second measurement indicated by the short arrows was 1.60 cm. The ultrasound transducer is then turned to a sagittal plane for a third measurement in longitudinal plane which was 2.35 cm. The three measurements are summed (5.8 cm) and divided by 3 to yield a mean sac diameter of 1.9 cm. Ultrasound charts indicate that 1.9 cm MSD corresponds to 7 weeks gestational age. The amnion (long arrow) is visible within the gestational sac. The outer limit of the gestational sac is defined by the chorion.

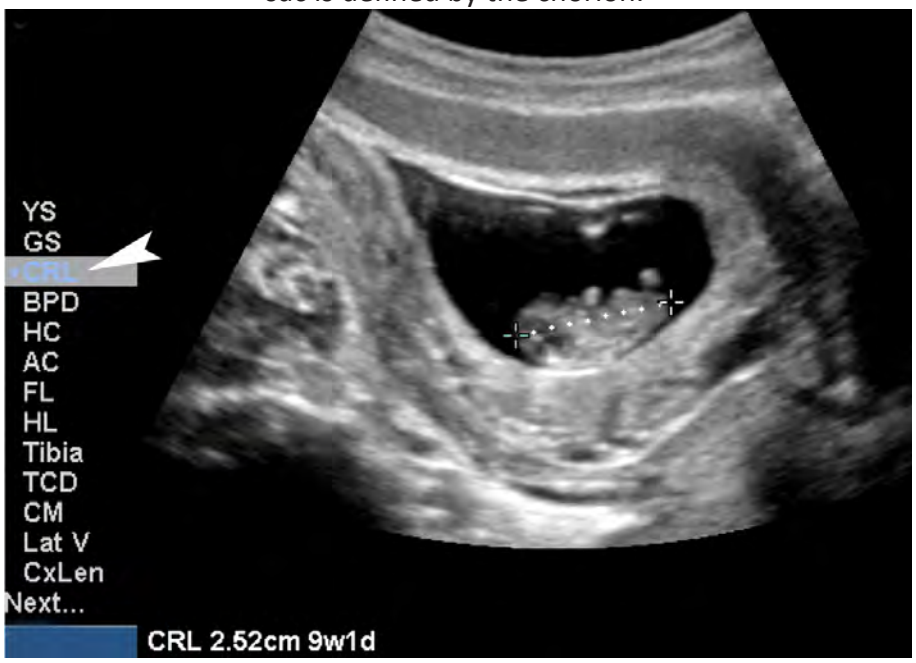


Figure 3: Crown-rump length measurement
Transabdominal image shows a single embryo at 9 weeks 1 day gestational age by crown-rump length measurement. CRL (arrowhead) is selected from the list of measurement options. The callipers (+) are placed in the appropriate location and the measurement and gestational age are reported at the bottom of the image.

8.2 Normal early pregnancy

It is critical to recognize the normal appearance of the developing early pregnancy in order to avoid misinterpretation and diagnostic errors. Understanding the physiology and detailed anatomy of early pregnancy as shown by transvaginal ultrasound is essential to recognizing the pathologic changes that occur in early pregnancy.

The early gestational sac is visualized by transvaginal ultrasound at 4-5 weeks gestational age as a tiny 2-3 mm cystic structure embedded in the endometrium. The gestational sac continues to enlarge appearing round or oval in shape, smooth in contour, and positioned in the fundus of the uterus. As the gestational sac enlarges the amnion may be seen as very thin membrane within which the embryo will develop. The chorion is defined as the outer border of the fluid-filled gestational sac.

Identification of the yolk sac, which at 5-6 weeks gestational age confirms that the cystic structure within the uterus is actually a gestational sac and that the early pregnancy is intrauterine. The yolk sac appears before an embryo is evident (Figure 4). The normal yolk sac is a round fluid-filled cyst 3-6 mm in diameter with a wall of medium thickness. The yolk sac appears in the chorionic cavity between the amnion and the chorion. The yolk sac is connected to the developing embryo by the vitelline duct (Figure 5). The normal yolk sac should always be visualized by transvaginal ultrasound when the mean sac diameter (MSD) exceeds 8 mm.

The embryo is first visualized as an echogenic disk-like structure about 2 mm size within the amniotic cavity at 6-7 weeks gestational age. The embryo grows approximately 1 mm per day in length. A distinct embryo should always be visualized by transvaginal ultrasound when the MSD exceeds 25 mm.

Embryonic cardiac activity may be detected by transvaginal ultrasound when the embryo is as small as 2-3 mm. All normal embryos should have a visible heart beat when the embryo exceeds 7 mm in CRL with a normal heart rate exceeding 100 beats per minute. The normal heart rate increases to 140-170 beats per minute by 9 weeks gestational age.

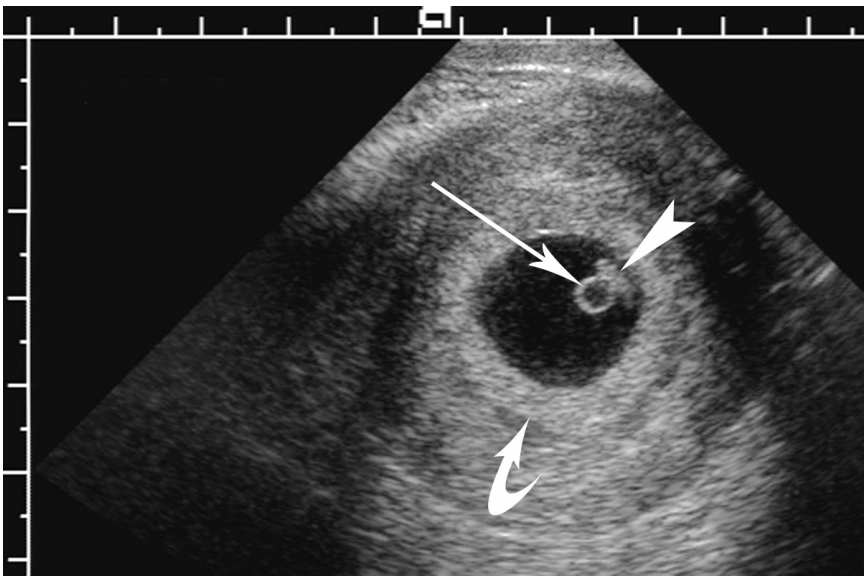


Figure 4: Yolk sac and early embryo
Transvaginal ultrasound image of the gravid uterus in very early pregnancy shows the normal yolk sac (arrow) and the very early appearance of the embryo (arrowhead) appearing as an echogenic disk-like structure. Even though the embryo measures only 4 mm in CRL cardiac activity was visible on real-time ultrasound. Note the normal thick and echogenic decidua (curved arrow). Decidua is maternal endometrium that has been acted on by the hormones of pregnancy to promote implantation of the fertilized ovum and to support continuing growth of the pregnancy. The placenta forms from union of the chorionic villi from the fertilized ovum and the maternal decidua. The 4 mm CRL of the visualized embryo correspond to 6 weeks gestational age.

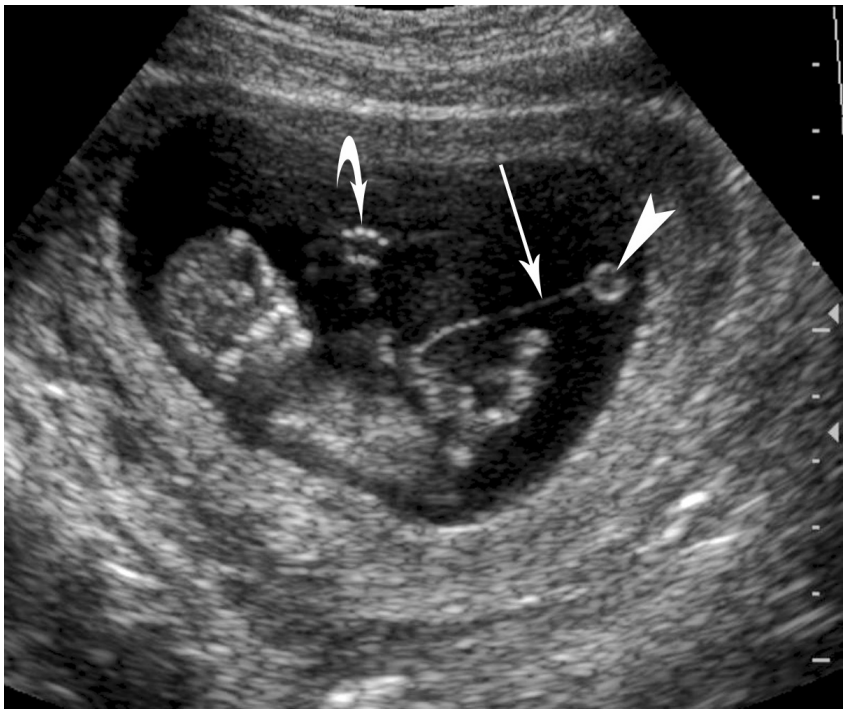


Figure 5: Embryo, yolk sac, vitelline duct
Transabdominal image of a 12 week pregnancy shows a well-formed embryo. The yolk sac (arrowhead) remains present attached to the embryo at the umbilicus by the vitelline duct (straight arrow) (also called the omphalomesenteric duct). The limbs of the embryo are well formed including the hand and fingers (curved arrow). Note the thickening of the decidua posteriorly at the site of the placenta.

8.3 Abnormal early pregnancy

By clinical definition the term 'threatened abortion' refers to bleeding or cramping in the first 20 weeks of pregnancy due to any cause. Threatened abortion affects up to 25 % of all pregnancies. In up to 12 % of these patients the pregnancy will fail resulting in spontaneous or missed abortion. The differential diagnosis of threatened abortion includes the following:

– Spontaneous abortion / miscarriage.
– Embryonic demise including demise of one embryo of a twin pregnancy.
– Anembryonic pregnancy, i.e. no embryo visualized. Also called blighted ovum.
– Retained products of conception.
– Ectopic pregnancy.
– Peri-gestational haemorrhage, i.e. sub-chorionic haemorrhage or implantation bleed.
– Gestational trophoblastic disease, i.e. molar pregnancy.

Spontaneous abortion / miscarriage

Failed pregnancies occur in 10-15 % of all confirmed pregnancies. Most failed pregnancies result in spontaneous abortion, which is defined as the non-induced passage of the products of conception prior to 20 week gestation. Spontaneous abortions are caused by viral infections (e.g. cytomegalovirus, herpes, and rubella), major chromosome anomalies, uterine anomalies, maternal diseases and trauma. Often the cause is unknown. In complete spontaneous abortion ultrasound shows an empty uterus with no foetal components or products of conception.

Embryonic demise and anembryonic pregnancy

Embryonic demise may be confidently diagnosed when a visualized embryo exceeds 7 mm in CRL and no cardiac activity is present. Absence of embryonic or foetal cardiac activity should be documented with M-mode ultrasound (Figure 6). Equally definitive for failure of the pregnancy is the presence of an intrauterine gestational sac exceeding 25 mm in mean sac diameter (MSD) without an embryo being present. This condition has been called an anembryonic pregnancy or blighted ovum. A calcified yolk sac may be visualized.

Findings that indicate likely impending embryonic demise include:
– *Bradycardia*: an embryonic heart rate <85 beats per minute is strong evidence of impending demise of the embryo.
– *Oligohydramnios*: a small size of the gestational sac relative to the size of the embryo is indicative of oligohydramnios in the first trimester. A MSD <5 mm larger than CRL is an indicator of incipient (beginning) embryonic demise and spontaneous abortion.

Abnormal position of the gestational sac correlates with poor prognosis for the pregnancy. The gestational sac should be clearly positioned in the fundus of the uterus. Any other location is abnormal.

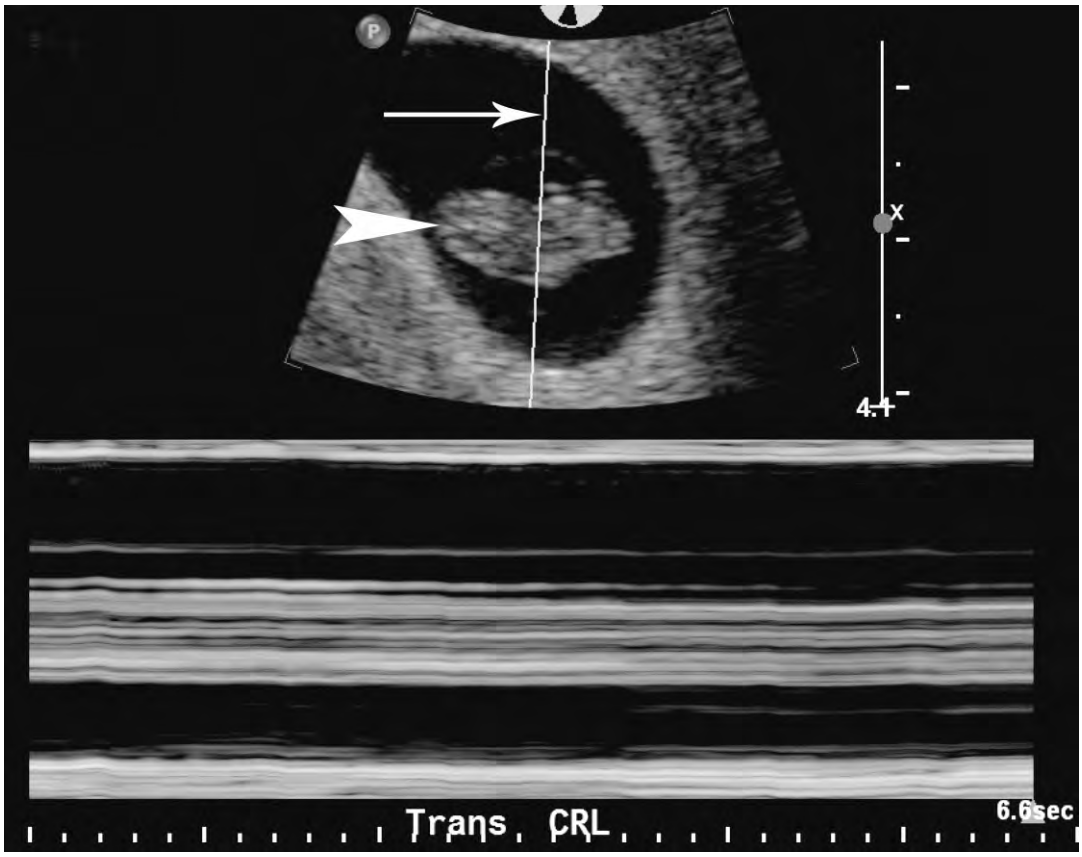


Figure 6: Embryonic demise
M-mode ultrasound is used to document in-utero embryonic demise of a 7.5 week embryo (arrowhead) measuring 12 mm in CRL. The M-mode ultrasound beam (arrow) is positioned to pass through the thorax in the region of the heart. The M-mode trace shows no cardiac activity.

Retained products of conception (RPOC)

Persistence of any placental or foetal tissues within the uterus following spontaneous abortion, delivery, or termination of pregnancy is termed retained products of conception (RPOC). RPOC is associated with risk of continued bleeding, uterine infection, and formation of scar tissue within the uterine cavity. Ultrasound shows a variable quantity of echogenic material within the uterine cavity (Figure 7). RPOC is more echogenic than myometrium. Doppler may show continuing blood flow within the material supporting the diagnosis of RPOC. However, the absence of blood flow does not exclude the diagnosis as RPOC is commonly avascular. Blood clots within the uterine cavity are typically hypoechoic and avascular.

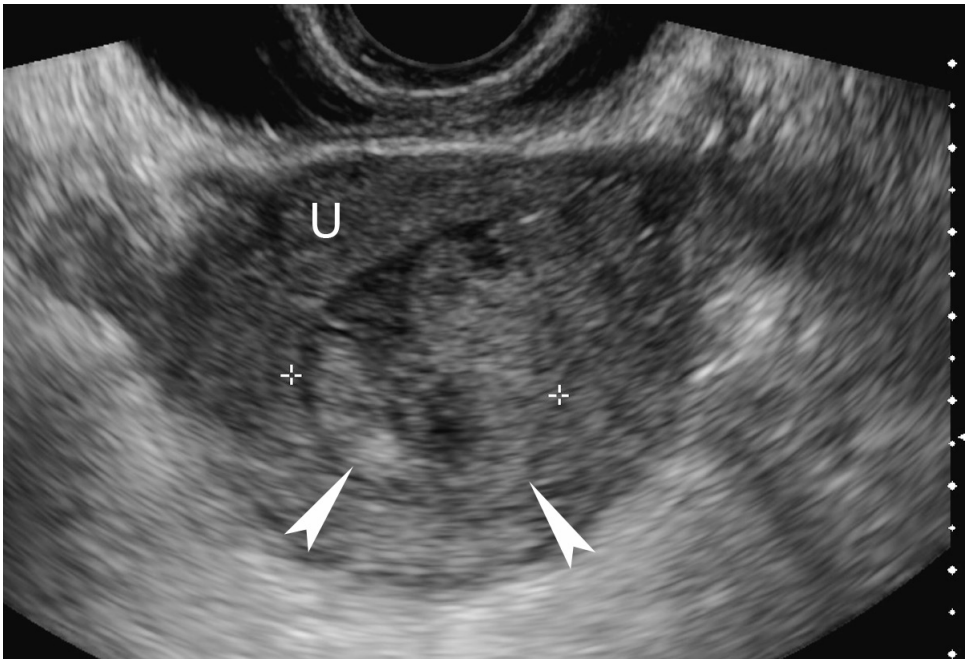
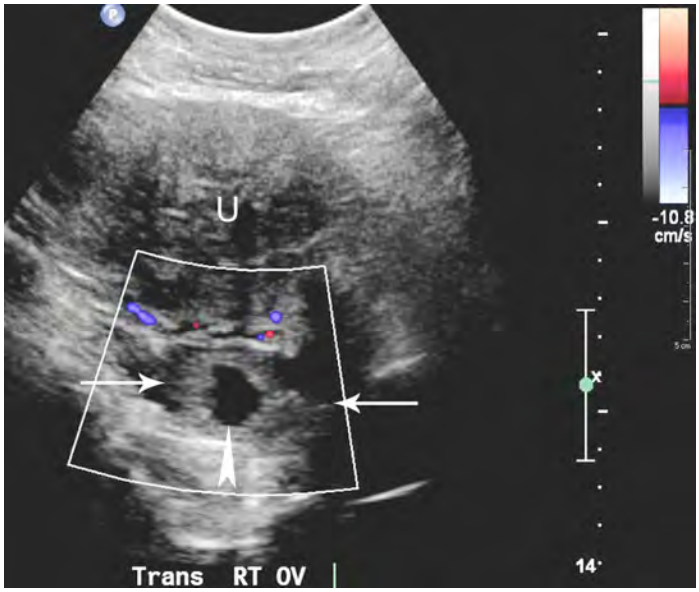
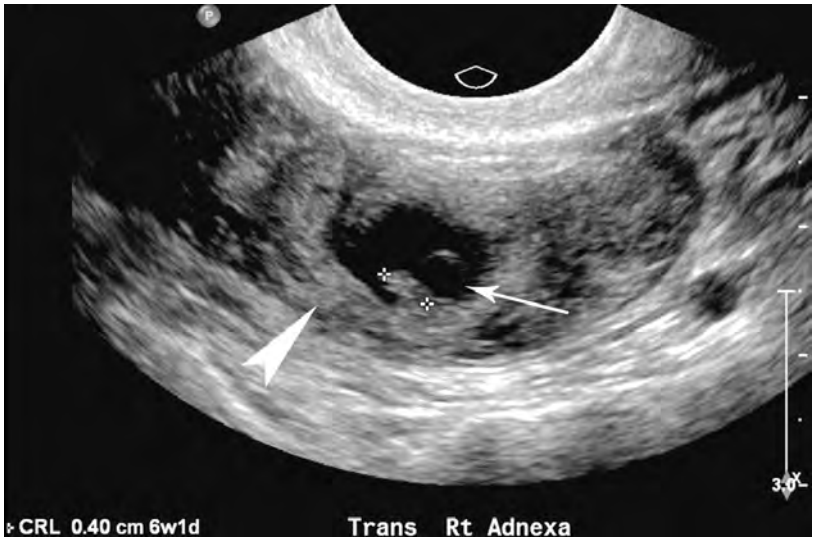


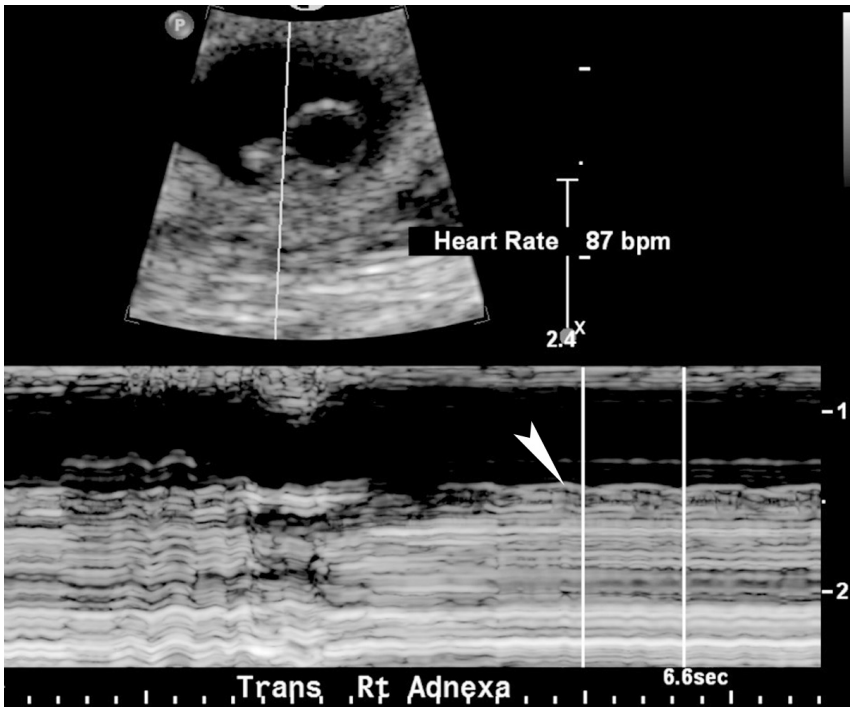
Figure 7: Retained products of conception
In a patient with continued bleeding following delivery transvaginal ultrasound shows the uterus (U) to be filled with echogenic material (arrowheads, between cursors, +), which proved to be retained fragments of placenta. Colour flow ultrasound (not shown) showed blood flow in some portions of the retained placental fragments.

Ectopic pregnancy

An ectopic pregnancy occurs when an embryo implants outside the uterus, most commonly in the fallopian tubes (Figures 8 A, B and C). Undiagnosed, the ectopic pregnancy may rupture, resulting in life threatening haemorrhage. Ectopic pregnancy is the leading cause of maternal death in the first trimester and poses a significant risk in resource-constrained settings. Risk of ectopic pregnancy is increased if the patient has a history of pelvic inflammatory disease, previous ectopic pregnancy, or previous tubal surgery. Both transabdominal and transvaginal ultrasound should be performed. The initial goal of ultrasound is to demonstrate the presence or absence of an intrauterine pregnancy. If an intrauterine pregnancy is present the risk of a simultaneous ectopic pregnancy is minimal estimated at 1 in 30,000. Definitive evidence of ectopic pregnancy is made by demonstration of an extrauterine gestational sac containing either a yolk sac or a live embryo. The presence of a 'tubal ring', appearing as an echogenic, thick-walled, ring-like mass separate from the ovary is about 95 % predictive of an ectopic pregnancy (Figure 9). A complex cystic or solid adnexal mass without distinguishing features is about 85 % predictive of an ectopic pregnancy (Figure 10). The cul-de-sac and even the flanks and upper abdomen should be carefully examined for evidence of free intraperitoneal fluid. Moderate to large volume of intraperitoneal fluid, especially if the fluid contains echogenic particulate debris, or appears solid representing clotted blood, is about 70 % predictive of ectopic pregnancy (Figure 11).

A 

B 



C

Figures 8 A-C: Live ectopic pregnancy
A. Transvaginal colour Doppler ultrasound shows the right ovary
(between arrows) containing a corpus luteum (arrowhead) with no blood flow.
B. Careful right adnexal transvaginal scanning shows a thick-walled cystic mass (arrowhead) separate from the ovary. The appearance of the mass is typical for an extrauterine gestational sac. Within the mass is a visible embryo (between cursors, +) and a yolk sac (arrow). Real-time ultrasound demonstrated embryonic cardiac activity. CRL of 4 mm indicates a gestational age of 6 weeks, 1 day.
C. M-mode ultrasound documents the presence of the cardiac activity at 87 beats per minute.

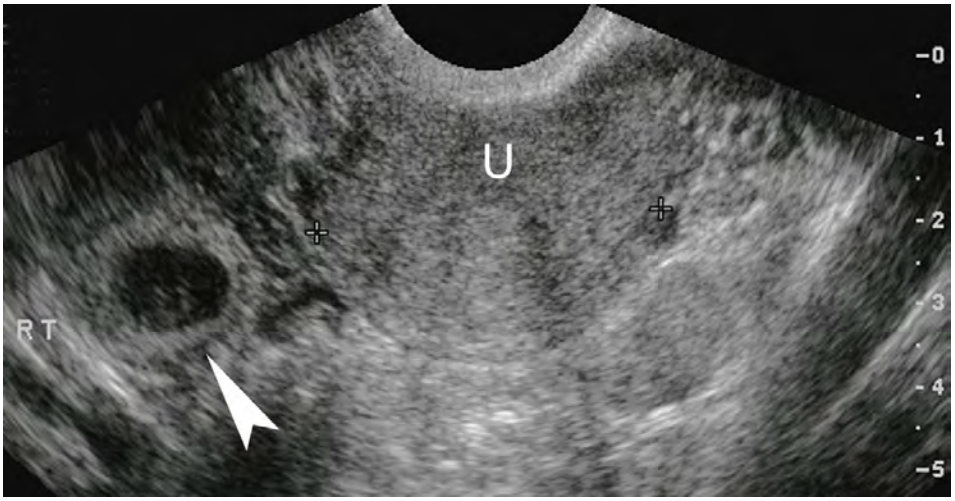


Figure 9: Ectopic pregnancy: Tubal ring sign
Transabdominal ultrasound image shows an empty uterus (U) and a ring-like structure (arrowhead) in the right adnexa. The ring has thick walls and contains amorphous material. Detailed real-time scanning confirmed that this structure was separate from the ovary. Ectopic pregnancy was confirmed with laparoscopic surgery. The tubal ring sign is highly indicative of ectopic pregnancy.

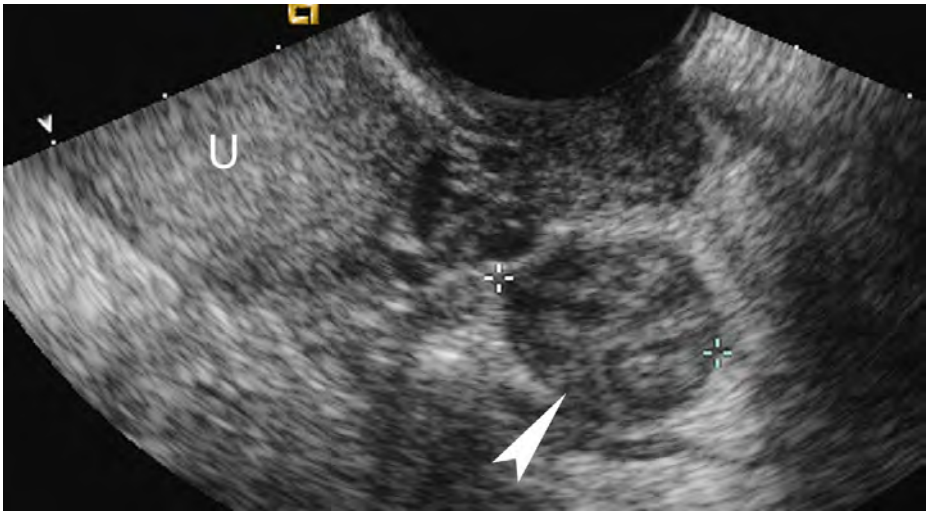


Figure 10: Ectopic pregnancy: Adnexal mass
Transvaginal scan of a pregnant woman with left adnexal pain shows a round solid mass (arrowhead) in the left adnexa. Detailed real-time ultrasound scanning confirmed that the uterus (U) showed no evidence of intrauterine pregnancy and that the left adnexal mass was separate from the left ovary.

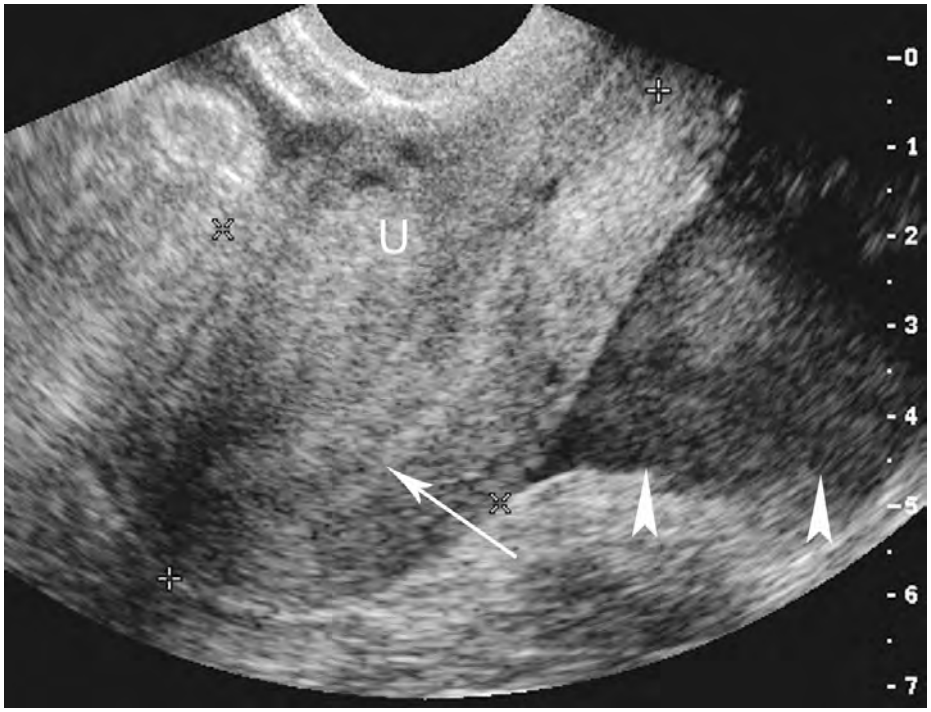


Figure 11: Ectopic pregnancy: Blood clots in cul-de-sac
Longitudinal transvaginal scan shows the uterus (U) with thickened endometrium (arrow) consistent with decidual reaction but no evidence of a gestational sac. Echogenic material in the cul-de-sac (arrowheads) is indicative of blood and clots. A ruptured ectopic pregnancy was found at surgery.

Peri-gestational haemorrhage

Peri-gestational haemorrhage, also called subchorionic haemorrhage or implantation bleeding, is a common cause of bleeding in the first trimester affecting about 20 % of women presenting with threatened abortion. It is a mild form of early placental abruption with separation of the edge of the placenta from the myometrium resulting in venous bleeding. Ultrasound shows the haemorrhage as a crescent-shaped collection between the gestational sac and the uterine wall (Figure 12). The blood may be anechoic, show floating echogenic particles, or be solid appearing if clotted. Large haemorrhages, exceeding 40 % of the size of the gestational sac are associated with spontaneous abortion in 50 % of cases. Small haemorrhages are generally not of clinical significance.

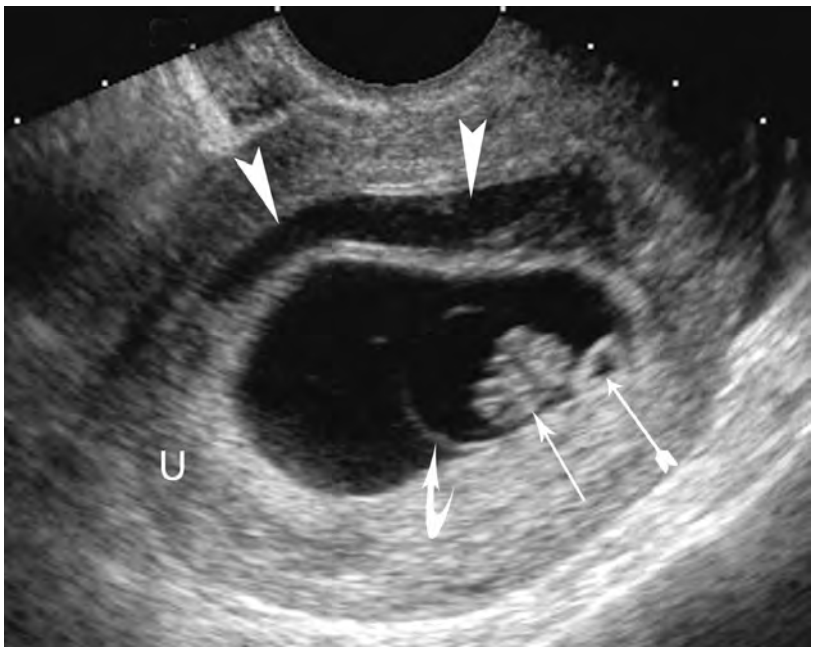


Figure 12: Peri-gestational haemorrhage
Longitudinal transvaginal image of the uterus (U) of an 8-week gestational shows the characteristic crescent shaped collection of a peri-gestational haemorrhage (arrowheads). Floating echodensities within the collection and a small clot confirm the collection as being blood. Also note in this early pregnancy the normal amnion (curved arrow), the embryo (arrow without tail), and the yolk sac (arrow with tail).

Gestational trophoblastic disease – molar pregnancy

Gestational trophoblastic disease (GTD) or molar pregnancy is a proliferation of trophoblastic tissue from the fertilized ovum that ranges from benign and curable to aggressively malignant. Trophoblastic tissue is the functional unit of the placenta. Patients typically present in the first trimester with hyperemesis, bleeding, or toxemia. Quantitative serum beta-human chorionic gonadotropin levels (beta-hCG) are typically substantially elevated serving to confirm the diagnosis. The following forms of GTD are most relevant:

– The complete hydatidiform mole, ‘classic’ mole, is most common accounting for 80 % of cases of GTD (Figure 13). Placental villi develop cystic changes and proliferate excessively. The uterus is larger than expected for dates. In the first trimester the uterine cavity is filled with a highly echogenic granular mass producing a ‘snowstorm’ appearance on ultrasound. The cysts that make up the mole are too small to be discretely visualized. The molar tissue shows prominent vascularity on colour Doppler (Figure 14). By the second trimester the cysts have enlarged and become distinctly visible. The ovaries are often enlarged by the presence of large cysts, e.g. theca lutein cysts. No embryo is present.

– The partial hydatidiform mole has an abnormal foetus present. The karyotype is triploid and the placental tissue shows a lesser degree of cystic change than in the complete mole.
– An invasive mole occurs in 10 % of GTD. The trophoblasts invade the myometrium and may metastasize to other organs.
– Choriocarcinoma is an aggressive malignancy that complicates 2-5 % of molar pregnancies, but may also complicate normal and ectopic pregnancies. The uterus is filled with heterogeneous, haemorrhagic, necrotic material. The tumour commonly metastasizes to lungs, brain, liver, and other organs.

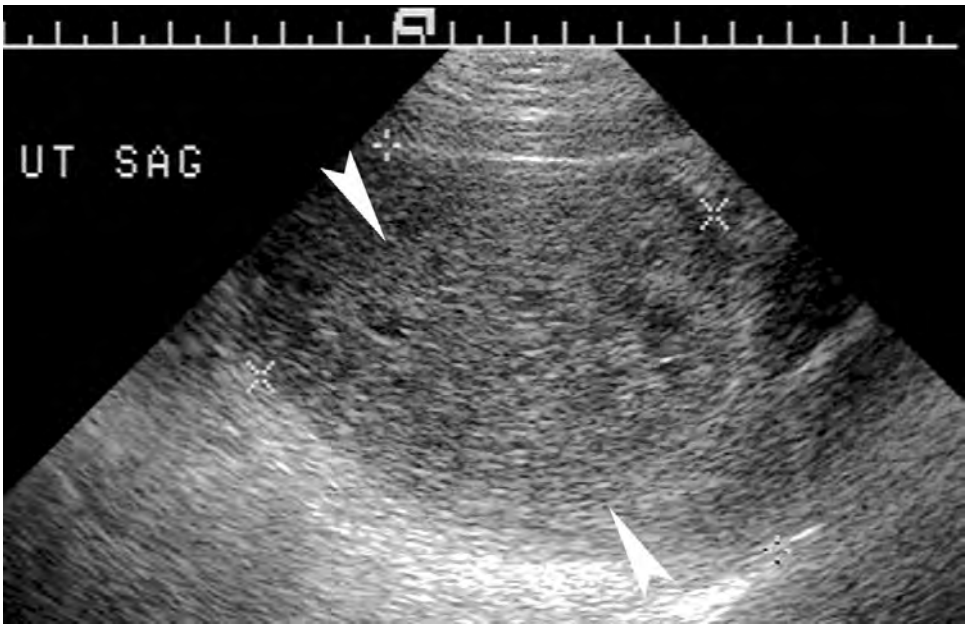


Figure 13: Complete mole
Longitudinal transvaginal image of the uterus (between cursors, +, x) shows the uterine cavity to be filled with echogenic material (between arrowheads). This is the characteristic 'snowstorm' appearance of classic mole in the first trimester.

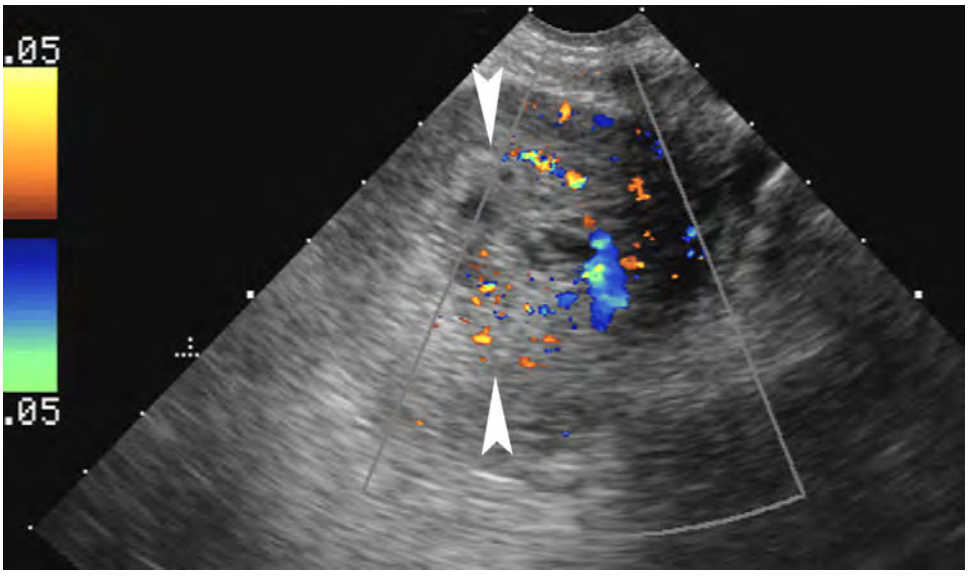


Figure 14: Complete mole – Colour Doppler
Transvaginal colour Doppler image of the same patient as shown above, demonstrates the prominent vascularity of the molar tissue (between arrowheads).

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9. 2nd / 3rd trimester obstetrics ultrasound

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Indications for obstetric ultrasound in the second and third trimesters, especially in women presenting with unknown dates or no previous medical care during pregnancy are: confirmation of viable pregnancy, detection of multiple gestations, estimation of gestational age, evaluation of foetal growth, evaluation of foetal well-being, assessment of amniotic fluid, determination of placental position and detection of foetal anomalies. Detailed review of foetal anomalies is beyond the scope of this manual.

9.1 Scanning technique – 2nd / 3rd trimester

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine.
The patient should ideally have a filled bladder in order to use it as acoustic window.

Scanning steps for transabdominal imaging

1. Select 'OB' from exam type in the drop down menu when entering the patient's details. Include the date of the last menstruation period (LMP) if known.
2. Start in the far right lower pelvic region with the transducer in the transverse position with the marker pointing to the patient's right. Slowly move the transducer towards the patient's head and back. Repeat to cover the entire pelvic region.
3. Rotate the transducer 90 degrees into the longitudinal position with the marker pointing towards the patient's head. Then slowly move the transducer right to left and back. Repeat to cover the entire pelvic region.
   The following basic parameters should to be recorded in a 2nd / 3rd trimester scan:
   - Number of foetuses
   - Presentation
   - Foetal viability
   - Gestational age
   - Quantity amniotic fluid
   - Placental location
   - Length of cervix
4. After the entire pelvic area has been scanned, identify the number of foetus(es), the presentation and confirm foetal viability (see below).
5. Evaluate the placenta (see section placenta below) and the amniotic fluid volume (see section amniotic fluid volume below).
6. Perform measurements to estimate gestational age (see section gestational age below).

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

9.2 Number of foetus(es) / detection of multiple gestations

Twins and other multiple gestations are considered high risk pregnancies. The incidence of virtually all complications of pregnancy are increased when a gestation includes multiple foetuses. Mortality of twins is 15 % higher than mortality of singleton pregnancies. Twins parallel the growth of singletons through the first and second trimesters. The growth of twins tends to diminish in the third trimester. Approximately 25 % of twin pregnancies are affected by intrauterine growth retardation. The risks associated with twin pregnancies are related to the type of twinning. Dizygotic twins have the lowest risk for growth retardation and have dichorionic-diamionitic placentation. The twins may be of different gender and two placentas are present. The presence of a thick membrane, best seen early in pregnancy, indicates dichorionic twins and has the lowest risk for complications of twin pregnancy (Figure 1).

Other types of twinning, e.g. monochorionic-diamniotic and monoamniotic twins (Figure 2), are at increased risk for intrauterine growth retardation, intrauterine demise, and twin-twin transfusion syndrome.

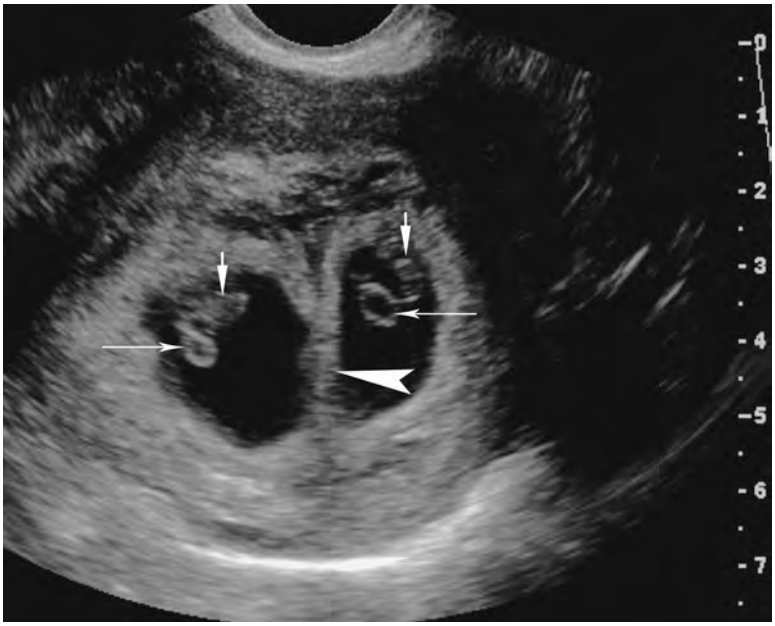

Figure 1: Dichorionic twins at 7 weeks
Transvaginal ultrasound reveals a twin pregnancy at 7 weeks gestational age. The presence of a thick membrane (arrowhead) separating the twins is indicative of dichorionic twinning. Two yolk sacs (long arrows) and two tiny embryos (short arrows) are shown.

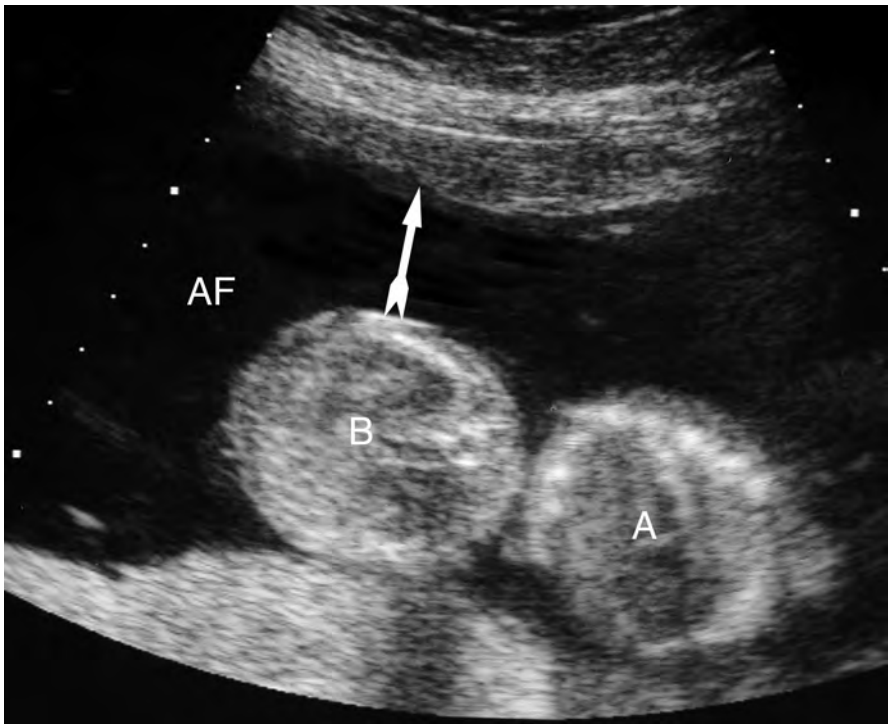

Figure 2: Monoamniotic twins - polyhydramnios
Ultrasound examination of a pregnant woman, clinically large for dates, reveals a twin pregnancy. The twins are labelled A and B. By convention the twin closest to the cervix is labelled Twin A and the twin farthest from the cervix is labelled Twin B. This convention allows identification of each twin on subsequent ultrasound examinations, important for assessment of growth. Gestational age is 18 weeks. Careful ultrasound examination failed to detect a membrane separating the twins. The twins also shared a single placenta. This is indicative of monoamniotic twinning. Though rare, this type of twinning is at highest risk for complications including entanglement of the two umbilical cords. Polyhydramnios is also evident. When the amniotic fluid (AF) volume is normal the trunk of the foetus touches both the anterior and posterior walls of the uterus. When the amniotic fluid volume is increased, as in this case, the foetuses float in the amniotic fluid and there is wide separation of the anterior uterine wall from the foetus (arrow).

9.3 Presentation

Foetal presentation refers to the foetal body part nearest to the internal os of the cervix. The foetus moves throughout pregnancy, so foetal presentation changes frequently. Presentation becomes important in near-term or whenever a woman presents in active labour. Abnormal foetal presentation is associated with an increased incidence of difficult labour, termed dystocia.

Cephalic presentation is head first with the foetal head adjacent to the cervix. Normal foetal presentation is termed **vertex**, **occiput anterior**. The foetal head is adjacent to the cervix with the face directed posteriorly toward the maternal sacrum, with the head flexed, and the chin in contact with the foetal thorax. This presentation is present in 95 % of pregnancies at term, provides the smallest diameter for passage of the foetus through the birth canal, and is associated with the highest rate of normal vaginal delivery.

Abnormal foetal presentations are associated with increased risk of dystocia, birth trauma, and perinatal death. Abnormal presentations may require physical manoeuvres to reposition the foetus, operative vaginal delivery utilizing forceps or a vacuum extractor to facilitate delivery, or abdominal (caesarean) delivery. Ultrasound is utilized to confirm abnormal foetal presentations and other potential complications.

Abnormal foetal presentations include:

– **Occiput posterior**. The foetal face is directed anteriorly and the occiput is directed posteriorly. A larger diameter of the head must pass through the birth canal. This is the most common abnormal presentation.

– **Breech**. The foetal head is identified near the fundus of the uterus with the buttocks near the cervix (Figure 3). Breech is the 2nd most common abnormal presentation.
  • In *frank breech* the hips are flexed and the knees are extended.
  • In *complete breech* the foetus is in a sitting position with both hips and knees flexed.
  • In *single or double footling breech* one or both legs are extended presenting at the cervix before the buttocks.

– **Transverse**. The long axis of the foetal body is oblique or perpendicular to the long axis of the mother's body.

With ultrasound, determine the position of the foetal head: cephalic - head in the pelvis, breech - head in the uterine fundus, or transverse - head in the mid-uterus with foetal body in a transverse plane relative to the mother. Carefully identify the position of the foetal face, body, and extremities relative to the cervix.

Describe the foetal position. Use with the annotation function on the scanner to annotate the image with orientation, as required.

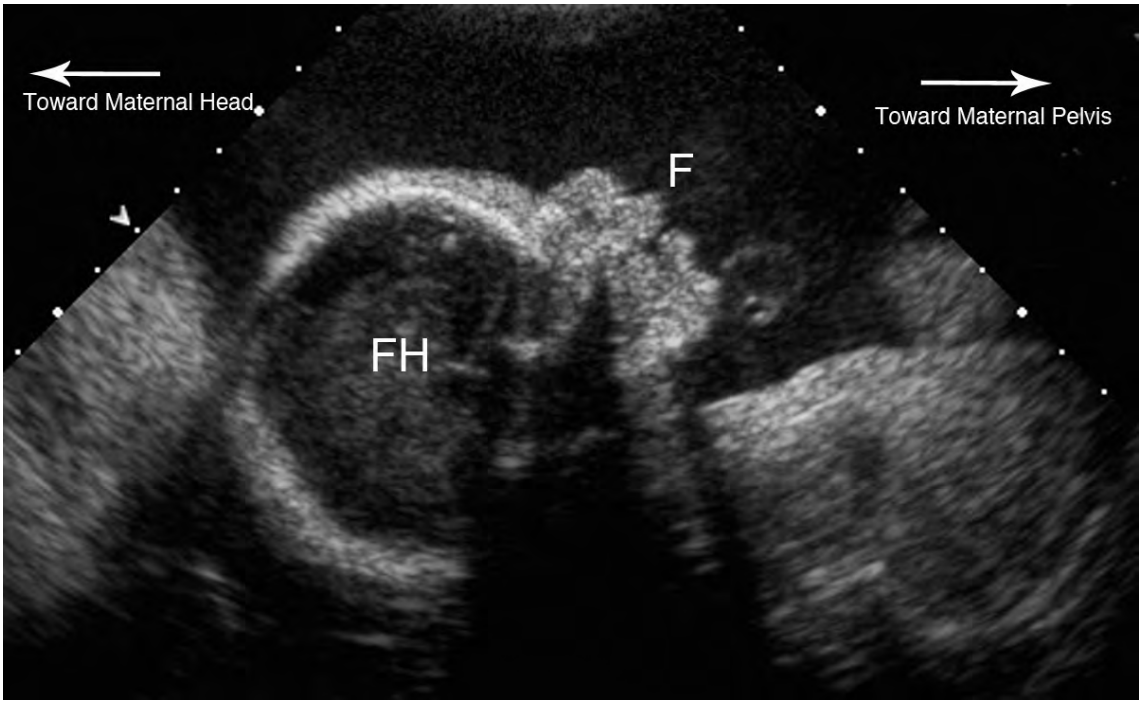

Figure 3: Breech presentation
This ultrasound image is aligned in a longitudinal plane in the long axis of the mother's body with her head toward the left side of the image and her pelvis toward the right side of the image. The foetal head (FH) is positioned in the fundus of the uterus with the foetal face (F) directed anteriorly. This is indicative of a breech presentation. Further ultrasound scanning is needed to determine the position of the foetal arms and legs relative to the foetal buttocks and the maternal cervix.

9.4 Foetal viability

The foetus is identified within the uterus and the foetal heart is located. Real-time ultrasound examination confirms the presence of a beating heart. Cardiac motion and foetal heart rate can be further investigated and documented by M-mode ultrasound as described previously in Chapter 8.1.

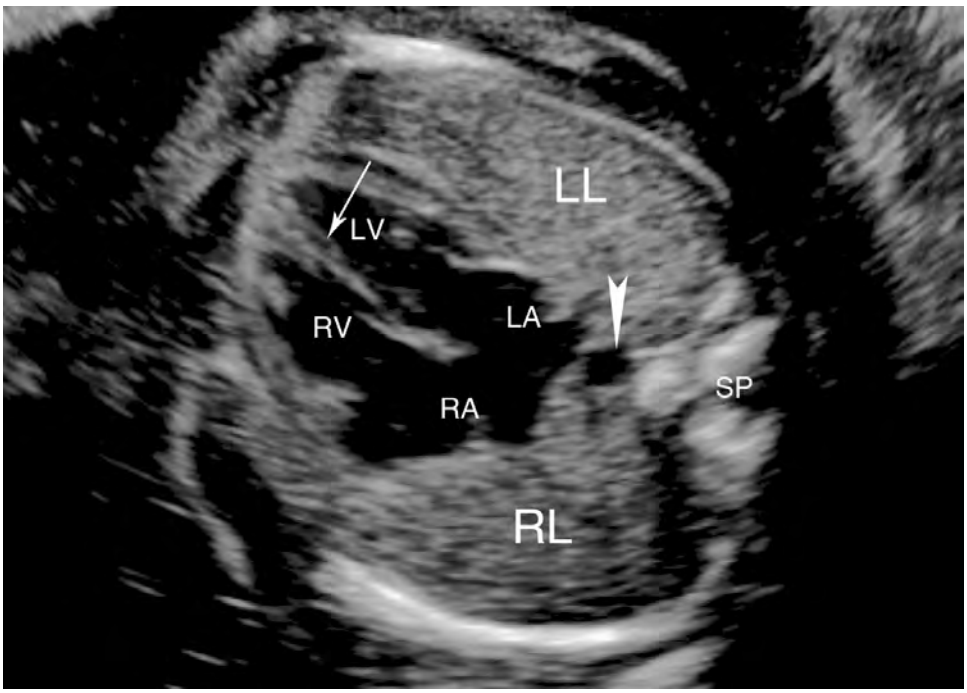

Figure 4: Normal foetal heart
Transverse ultrasound image through the thorax of a 20 week foetus shows the normal appearance of the foetal heart. The four cardiac chambers are well demonstrated: LV – left ventricle, LA – left atrium, RV – right ventricle, RA – right atrium. The foetal spine (SP) is seen posteriorly. The aorta (arrowhead) in transverse plane is evident just anterior to the spine. The axis of the heart as defined by the interventricular septum (arrow) is oriented approximately 45 degrees to the left. The lungs (RL – right lung, LL – left lung) are fluid filled and moderately echogenic. The presence, or absence, of heart beat is obvious on real-time ultrasound examination.

9.5 Gestational age

After 12 weeks the following measurements are used to estimate gestational age: bi-parietal diameter (BPD) (Figure 5), head circumference (HC) (Figure 6), abdominal circumference (AC) (Figure 7), and femur length (FL) (Figure 8).

General scanning notes
- Careful attention must be paid to obtain and select the correct anatomic plane for each of these measurements.
- Select 'OB' as the examination type. Press 'calcs' from the options. Highlight the correct measurement and press 'select'.
- Press the 'freeze' button to pause or resume scanning. Using the touch pad scroll through the last 30-60 seconds to identify the best image for measurements.
- Remember to 'save' measurements once complete.
- Time permitting, it is ideal to make several measurements of each parameter and use the average, to allow for image variability.

Bi-parietal diameter (BPD) and Head circumference (HC)

Scanning steps

1. Obtain a transverse view of the foetal head displaying the thalamus and midline third ventricle.
2. Select 'BPD' and measure the widest diameter, from the outer edge of one side of the skull to the inner edge of the other side, not including the skin.
3. Press 'save'.
4. Use the same image and select 'HC' from the measurements.
5. An ellipse measurement will appear, pressing 'select' toggles between size and position.
6. Move the trace to measure the circumference of the outer skull not <u>including</u> the skin.
7. Press 'save'.

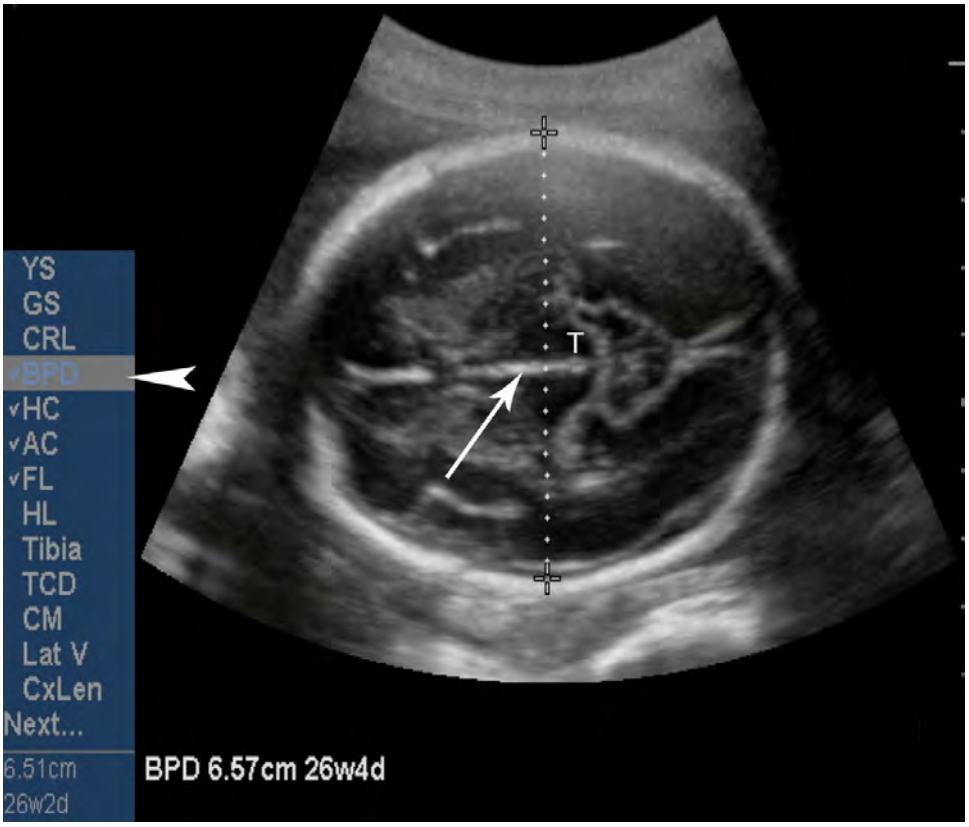

Figure 5: Bi-parietal diameter - BPD
Transabdominal ultrasound through the foetal cranium is obtained positioning the hypoechoic thalamus (T) in the middle of the image. The walls of the third ventricle (arrow) form a bright echogenic line bisecting the thalamus. BPD (arrowhead) is selected from the list of OB measurements. The BPD is measured from the outer aspect of the near skull to the inner aspect of the far skull. In this case the BPD measurement corresponds to a gestational age of 26 weeks, 4 days.

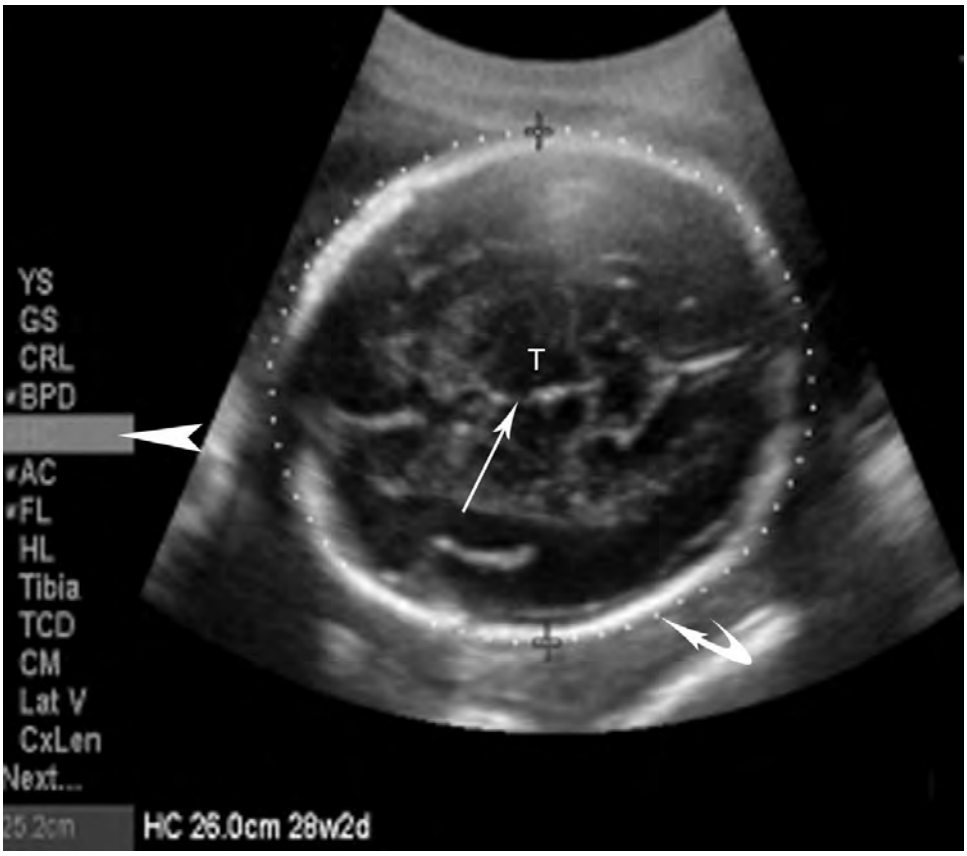

Figure 6: Head circumference - HC
Transabdominal ultrasound through the foetal cranium is obtained positioning the hypoechoic thalamus (T) in the middle of the image. The walls of the third ventricle (arrow) form a bright echogenic line bisecting the thalamus. This is the same anatomic plane used to measure the BPD. HC (arrowhead) is selected from the list of OB measurements. The head circumference is measurement by adjusting the ellipse (curved arrow) to match the outer aspect of the foetal cranium. In this case the HC measurement corresponds to a gestational age of 28 weeks, 2 days.

Abdominal circumference (AC)

Scanning steps

1. Obtain transverse view of foetal abdomen, just under the diaphragm. It must be a true transverse view, with complete ribs on each side, stomach visible, and hepatic portion of umbilical vein.
2. Select 'AC' from the measurements list. Using the same technique for the HC, measure the abdominal circumference including the foetal skin.
3. Press 'save'.

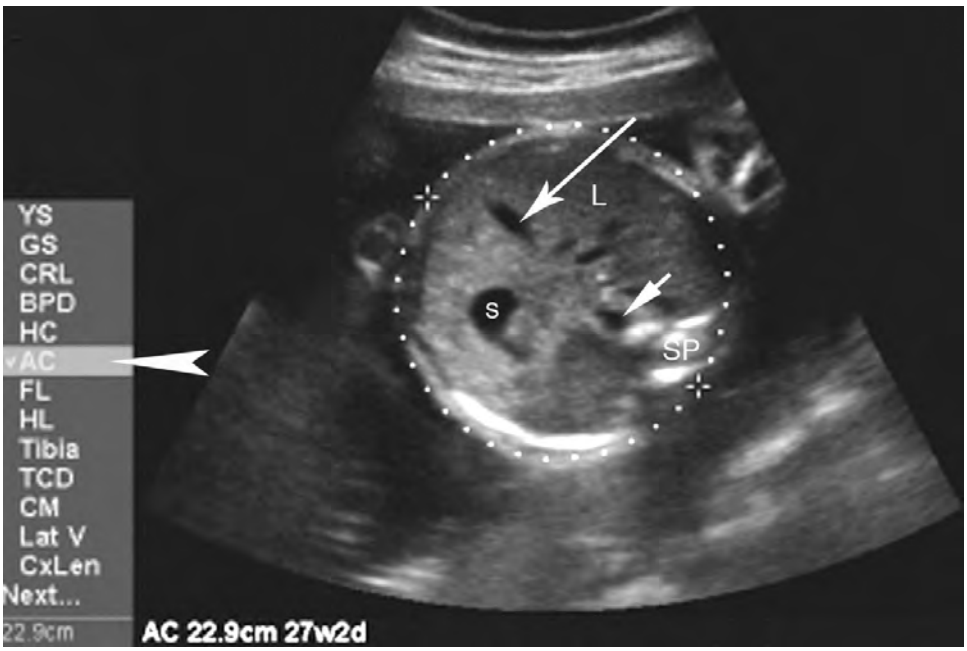

Figure 7: Abdominal Circumference - AC
Transabdominal scanning is used to obtain a transverse image of the foetal abdomen. The anatomic landmarks for the correct image plane are the liver (L) and the intrahepatic portion of the umbilical vein (long arrow) where it joins the left portal vein. Also seen in this image are the fluid-filled stomach (s), the foetal spine (SP) and the aorta (short arrow) just anterior to the spine. The AC (arrowhead) is selected from the list of OB measurements. This selection brings up an ellipse, which is matched to the outer circumference of the foetal abdomen in this anatomic plane. In this case the AC measurement corresponds to 27 weeks, 2 days gestational age.

Femur length (FL)

Scanning steps

1. Obtain a long axis view of the foetal femur. The femur should be horizontal on the screen and demonstrated in its longest dimension.
2. Select 'FL', and measure the entire length of the echogenic portion of the femur excluding the hypoechoic epiphyses.
3. Press 'save'.

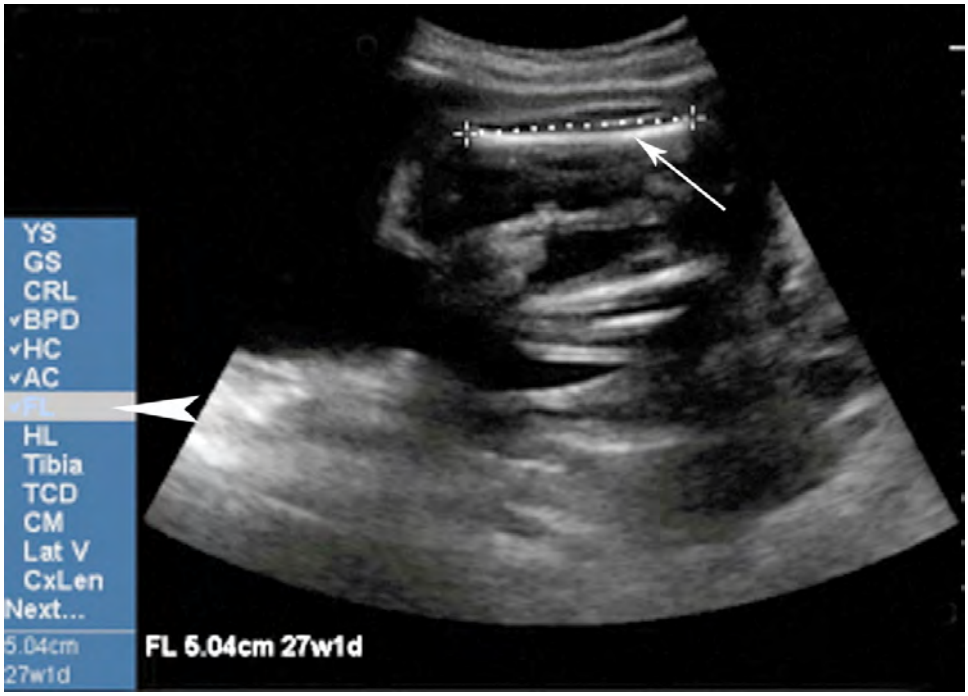

Figure 8: Femur length (FL)
Transabdominal images shows the femur (arrow) in long axis at the maximum length of the echogenic ossified bone. This is the correct image for femur length measurement, which is made of the entire echogenic portion of the bone. The proximal and distal ends of the femur are cartilaginous and hypoechoic at this stage of development. The non-ossified portions of the femur are not included in the FL measurement. The FL (arrowhead) is selected from the list of OB measurements bringing up distance measurement cursors, which are matched to the length of the femur. In this case the FL measurement corresponds to 27 weeks 1 day gestational age.

Gestational age estimation report

Once all measurements are completed and saved, the results can be found in a summary table by clicking 'report'. The table displays the saved measurements and estimated values (Figure 9).
- Gestational Age (GA) by last menstruation period if LMP was entered under patient details.
- Estimated Due Date (EDD) by LMP if LMP was entered under patient details.
- Average Ultrasound Age (AUA).
- Estimated Due Date (EDD) by AUA.
- Estimated Foetal Weight (EFW).
- Saved measurements: e.g. BPD, HC, AC, FL.

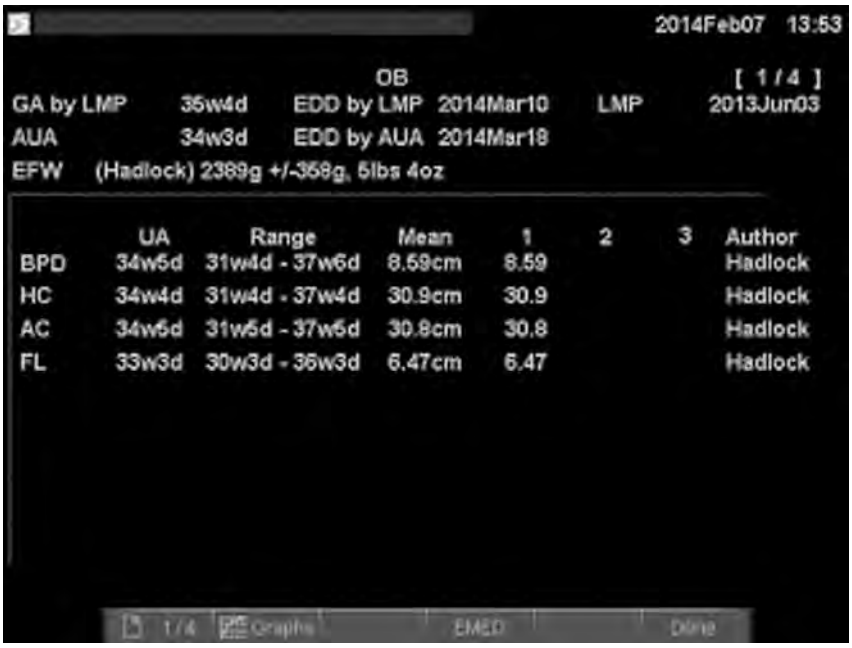

Figure 9: Obstetric measurements report

Estimated foetal weight (EFW)

The EFW is used to identify foetuses that are small for gestational age and potentially growth retarded, as well as foetuses that are large for gestational age and potentially difficult to deliver. EFW is determined by the measurements of BPD and AC, or by measurements of FL and AC. Built into the ultrasound unit computer are charts that automatically include a report of the EFW. Some ultrasound unit computer programs report the weight percentage compared to the gestational age determined by LMP or by ultrasound measurement. Alternatively obstetric ultrasound charts can be consulted for EFW compared to estimated gestational age.

Foetuses below the 10th percentile EFW for gestational age are at risk for intrauterine growth retardation (IUGR). Foetuses below the 5th percentile EFW for gestational age are at very high risk for IUGR.

IUGR is associated with high perinatal morbidity and mortality and risk of impaired neurodevelopment. Mortality for IUGR new-borns is 4-8 times greater than mortality for non-growth retarded new-borns. Risk factors for IUGR include major congenital anomalies, congenital infections (e.g. rubella, cytomegalovirus, toxoplasmosis), exposure to teratogens, maternal illness and malnutrition, smoking, alcohol, and drug abuse, as well as placental insufficiency. Low amniotic fluid volume (oligohydramnios) is commonly found in gestations with IUGR.

The term macrosomia describes foetuses that are large for gestational age. Macrosomic foetuses are at high risk for complications during and after delivery including shoulder dystocia, neurologic damage to the brachial plexus, fractures, perinatal asphyxia, meconium aspiration, and neonatal

hypoglycaemia. Maternal diabetes places the foetus at high risk for macrosomia. Macrosomia is defined as EFW above the 90th percentile for gestational age or EFW above 4000 grams.

Estimation of the gestational age is an interpretation based on clinical history, physical examination, and ultrasound measurements. It is not just a value from the ultrasound report.

9.6 Amniotic fluid

Amniotic fluid protects the foetus from injury, allows for growth and foetal movement, and is essential for normal foetal lung maturation. Normal fluid volume allows for free movement of the foetal limbs. Fluid surrounds the foetus but both the anterior and posterior walls of the uterus are in contact with the foetal abdomen.

Amniotic fluid volume is difficult to measure accurately by ultrasound. There are two main methods for estimating amniotic fluid volume: the 'single deepest pocket' (Figure 10) and 'the amniotic fluid index' (AFI). Neither method is highly accurate, but are attempts at estimating amniotic fluid volume more objectively.

– The 'single deepest pocket' method measures the vertical dimension of the largest visible pocket of fluid. Normal range for the deepest fluid pocket is 2-8 cm.
– The AFI is determined by using the sum of deepest pocket measurement in each of the four quadrants of the uterus. The normal range for AFI is 5-20 cm but varies with gestational age.

Scanning steps

1. Check all four uterine quadrants and identify the largest pocket of free amniotic fluid.
2. With transducer in the longitudinal position (marker pointing towards the patient's head) and perpendicular to the floor, measure the maximum vertical dimension of the fluid pocket using the callipers. Do not include any foetal parts or the umbilical cord in the measurement.
3. Repeat for all quadrants if estimating AFI.
4. In a twin gestation, separate measurements are taken in each gestational sac.

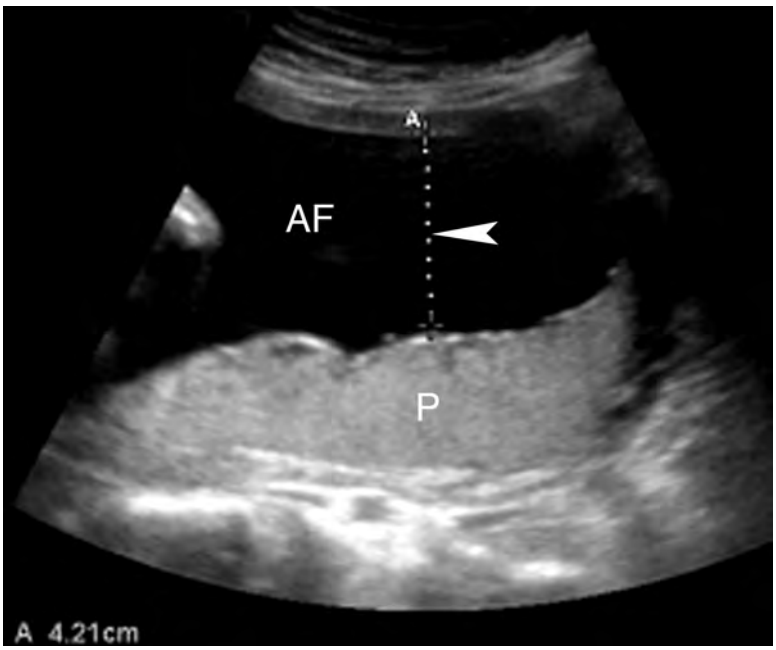

Figure 10: Amniotic fluid measurement
Transabdominal scanning of the entire uterus is used to find the deepest amniotic fluid (AF) pocket. A vertical measurement (arrowhead) is made of the depth of the pocket, in this example from the anterior uterine wall to the surface of the placenta (P). The AFI is measured in a similar fashion in all four quadrants of the uterus.

Pathological findings measuring amniotic fluid:

– **Oligohydramnios**: is an abnormally low volume of amniotic fluid as compared to the gestational age. This can be caused by premature rupturing of the membranes, placental abnormalities, pre-eclampsia or intrauterine growth restrictions. Oligohydramnios is linked with increased birth defects, premature birth, foetal morbidity and mortality. Ultrasound reveals restricted foetal movement with little or no amniotic fluid. The deepest pocket measurement is <2 cm and the AFI is <5 cm.
– **Polyhydraminos**: is an abnormally increased volume of amniotic fluid as compared to the gestational age. This can be caused by foetal defects, infection, multiple pregnancies or diabetes. Many cases are of unknown cause. Polyhydramnios presents with increased uterine size for gestational age, abdominal pain, and breathing difficulties. Polyhydraminos is linked with birth defects and increased foetal morbidity and mortality. Ultrasound reveals the foetus floating in fluid with fluid present anteriorly between the foetal abdomen and anterior uterine wall. The deepest pocket measurement is >8 cm and the AFI is >20 cm.

9.7 Placenta

The placenta is a vital intrauterine organ attached to the wall of the uterus that supplies the foetus with oxygen and nutrients, supports foetal development, and eliminates waste. The placenta develops at the site of implantation of the fertilized ovum and may be located on any portion of the wall of the uterus.

On ultrasound the placenta appears as a disc-shaped structure with a finely granular texture. The surface of the placenta is smooth and sharply defined by the covering chorion. A retroplacental complex of blood vessels is often visualized extending from the placenta into the underlying uterine wall (Figure 11). As the placenta matures hypoechoic vascular lakes, echogenic septations, and calcifications may appear.

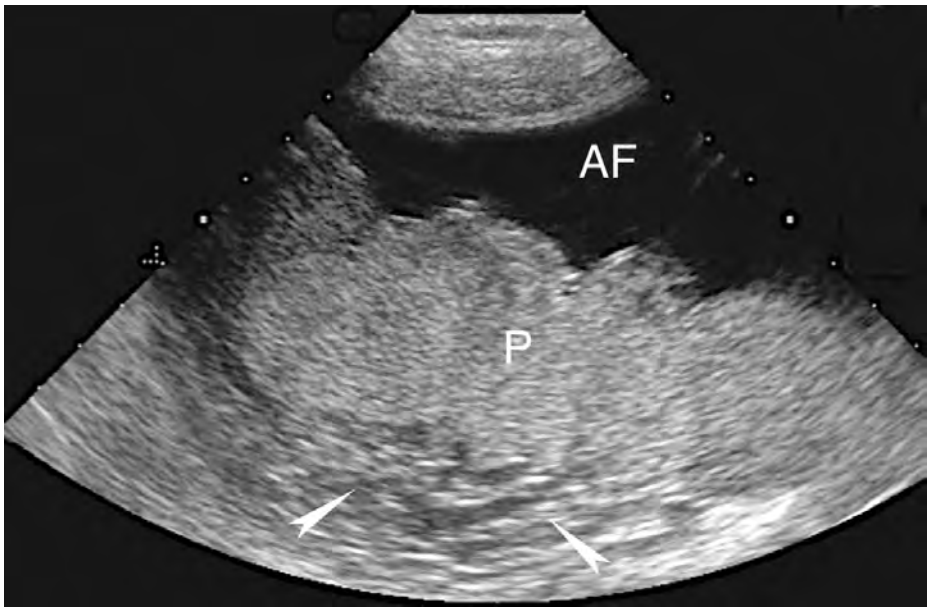

Figure 11: Normal placenta
Transabdominal scan of the normal placenta (P) early in the third trimester. The bulk of the placenta has mid-level granular echogenicity. Its inner surface is lobulated and sharply outlined by amniotic fluid (AF). The retroplacental complex of blood vessels (arrowheads) is prominent.

Position of placenta

The position of the placenta and its relationship to the cervix in later stages of pregnancy is of vital importance.

Placenta previa refers to low implantation of the placenta that covers all, or a portion of the internal os of the cervix. Complications of placenta previa are potentially fatal maternal haemorrhage, premature delivery, intrauterine growth retardation, and perinatal death. Patients often present in the third trimester with painless vaginal bleeding. Placenta previa is rare, affecting only about 0.5 % of pregnancies in the third trimester. However, ultrasound examination in the first and second trimester may demonstrate a low-lying placenta near the cervical os in up to 45 % of pregnancies. The lower uterine segment continues to elongate during gestation moving the placenta away from the cervix in most cases. Patients in whom the placenta covers part of or the entire cervix in the third trimester typically require surgical intervention and delivery via caesarean section.

Risk factors for placenta previa include previous caesarean section, previous placenta previa, multiparity, and maternal age over 35 years. After one caesarean section the risk of placenta previa is 2 %. After 2 caesarean sections, the risk increases to 5-6 %.

Scanning steps

Diagnosis of placenta previa in the third trimester by transabdominal scanning is often difficult. Translabial or transvaginally scanning are most accurate for a confident diagnosis. However, a safe abdominal scan should be performed first for an estimation of the placental location.

Transabdominal

1. The patient's bladder should be moderately full but not over distended as bladder over distension compresses and elongates the lower uterine segment.
2. With the transducer in the transverse and longitudinal positions examine the uterus transabdominally and identify the location of the placenta and its relationship to the cervix.
3. Establish whether the placenta is located anteriorly, i.e. at the top of the screen, or posteriorly, i.e. at the bottom of the screen.
4. Identify the lowest edge of the placenta and measure the distance from it to the internal cervical os.
5. If the edge is less than 3 cm from the cervix further assessment with translabial or transvaginal ultrasound is recommended.

Transvaginal

Ultrasound examination is generally safe as long as the cervix is closed.

Ensure a private space is properly prepared, consent obtained and bladder emptied, see section on transvaginal imaging Chapter 6.3.2.

1. Place a generous amount of coupling gel on the transvaginal ultrasound transducer and cover with a condom, removing any air bubbles. Additional gel should be placed on the outside of the transducer to ease insertion into the vagina. The operator must take great care to ensure the condom remains in place.
2. The transducer marker should be pointing to the ceiling, i.e. 12 o'clock position, as it is initially inserted.
3. Be sure to move and rotate the transducer slowly and gently.
4. The transducer can be rotated 90 degrees counter clockwise, with the marker on the patient's right, to further evaluate.
5. Identify the lowest edge of the placenta and measure the distance from it to the internal cervical os.

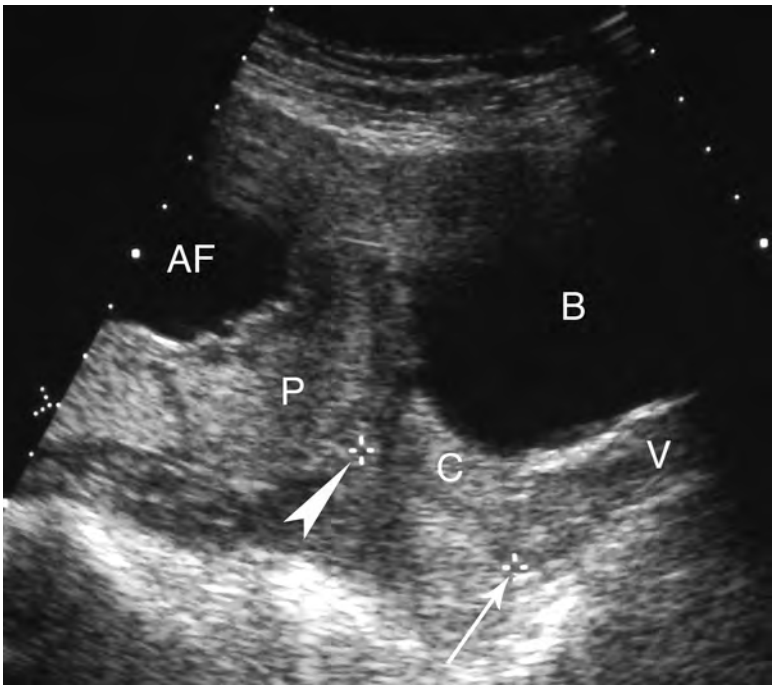

Figure 12: Placenta previa – transabdominal scan
Sagittal plane transabdominal scan of the lower uterus shows the placenta (P) entirely covering the internal os (arrowhead, cursor) of the cervix (C). Amniotic fluid (AF) outlines the surface of the placenta. The bladder (B) is partially distended. The vagina (V) appears as a muscular tube. The intersection of the plane of the long axis of the cervix and the long axis of the vagina is the landmark for the location of the external os (arrow, cursor) of the cervix.

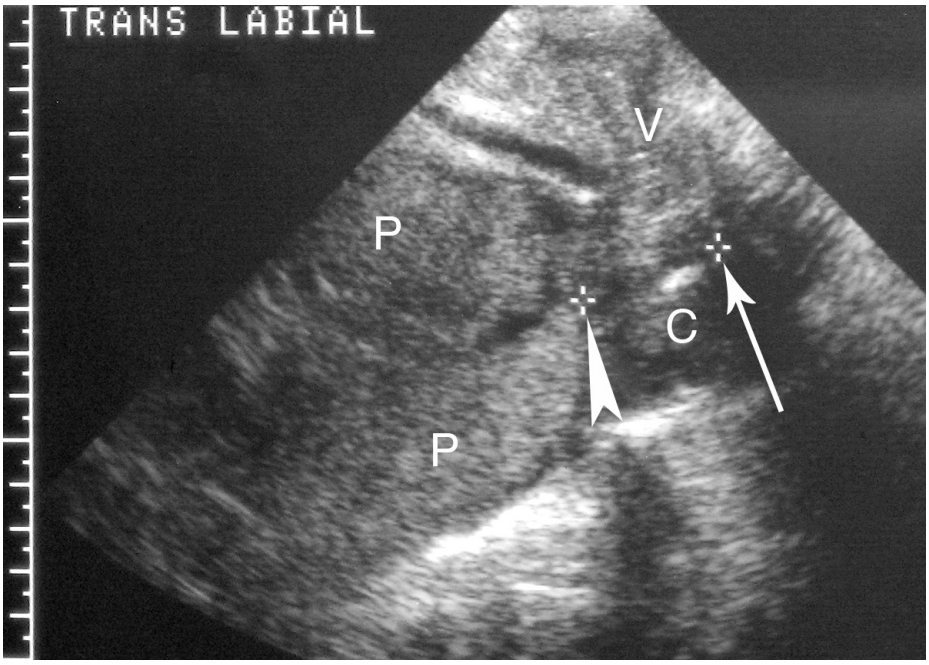

Figure 13: Placenta previa – translabial scan
With the transducer placed on the labia, the view is down the long axis of the vagina (V) and is perpendicular to the long axis (between cursors, +) of the cervix (C), making translabial scanning the optimal technique for evaluating the cervix and lower uterine segment. The placenta (P) clearly covers the internal os (arrowhead, cursor) of the cervix allowing a certain diagnosis of the placenta previa. The external cervical os (arrow) is marked by the second cursor.

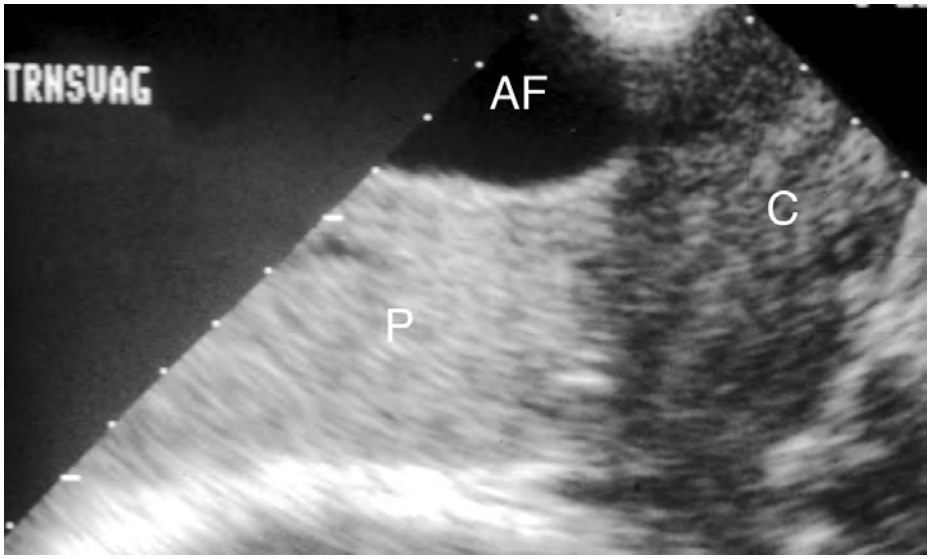

Figure 14: Placenta previa – transvaginal scan
Transvaginal image shows the placenta (P) covering the cervix (C). If placenta previa is suspected clinically, transvaginal scanning carries the risk of inducing or increasing vaginal bleeding by injuring the placenta if the cervix is open. AF = amniotic fluid.

Translabial

Translabial examination is safer than the transvaginal exam as there is no risk of injuring the placenta. It can be carried out when no transvaginal transducer is available and the user is experienced in this technique. See Annex 6 for a scanning protocol.

Placental abruption

Placental abruption is a serious complication of late pregnancy defined as premature separation of the placenta from the myometrium. Complications include precipitous delivery, prematurity, maternal and foetal coagulopathy, and foetal death. Arterial bleeding occurs between the placenta and the uterine wall. The placenta may infarct causing foetal hypoxia and death. Amniotic fluid may leak into the maternal bloodstream causing consumption coagulopathy. Ultrasound reveals a retroplacental haematoma that may be hypoechoic or echogenic. The retroplacental complex of blood vessels is disrupted. The surface of the placenta may bulge inward.

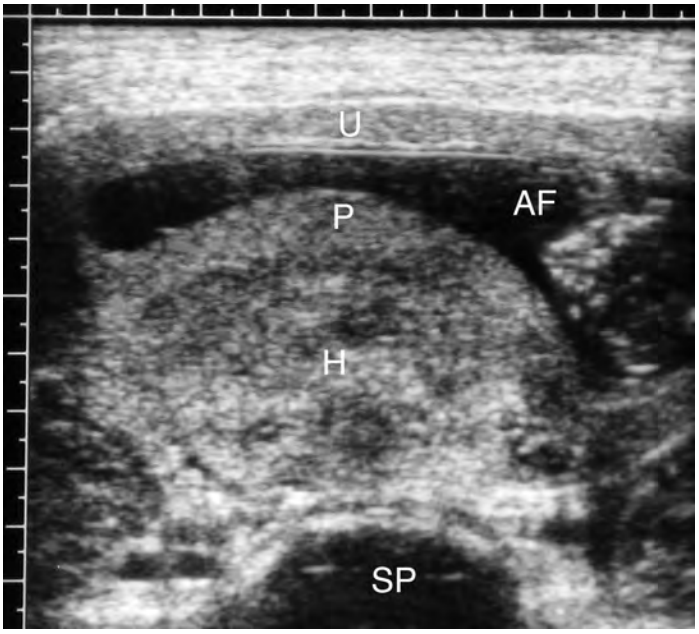

Figure 15: Placental abruption
Transabdominal scan of a pregnant patient with severe abdominal pain reveals a large haematoma (H) uplifting the placenta (P). Note the anterior bulge of the placental surface and the thinning of the placenta caused by the mass effect of the haematoma. The haematoma is heterogeneously echogenic. The maternal spine (SP) is seen at the bottom of the image. AF = amniotic fluid, U = anterior wall of the uterus.

Placenta creta

Placenta creta refers to abnormal placental invasion of the myometrium resulting in abnormal attachment and bleeding during the third trimester and during and after labour and delivery. The placenta may penetrate the uterine wall and invade the bladder resulting in haemorrhage into the bladder. Risk factors are similar to those for placenta previa, which is often present. Ultrasound findings include thinning of the myometrium deep to the placenta, obliteration of visualization of the retroplacental blood vessels, and irregularity of the bladder wall.

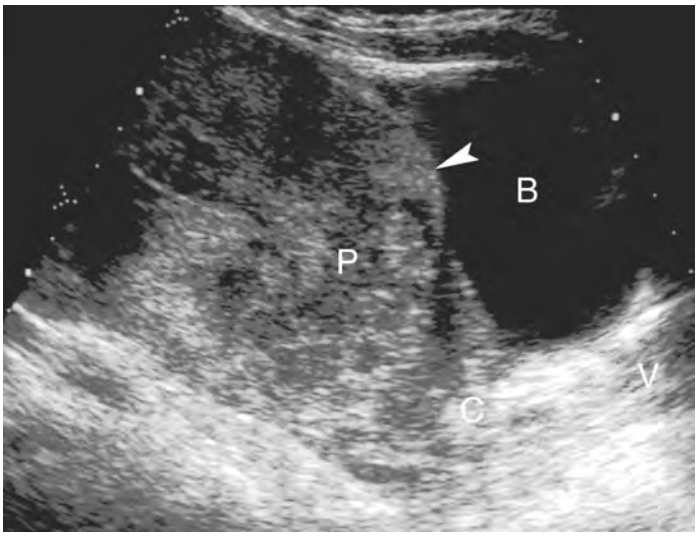

Figure 16: Placenta creta
Transabdominal scan in sagittal plane through the distended bladder (B) shows complete placenta previa with the placenta (P) completely covering the region of the cervix (C). The cervix is poorly defined in this image. The uterine wall abutting the bladder and the bladder wall (arrowhead) appear markedly thinned and ill-defined. These findings suggest placenta creta, abnormal invasion and adherence of the placenta to the uterine wall. (V) Vagina.

9.8 Cervix

Normal cervix

The normal cervix remains closed during pregnancy to physically retain the foetus in utero and to prevent ascending infection of the uterus.

The normal cervix appears as a hypoechoic cylinder continuous with the myometrium. The cervical canal appears as an echogenic, or hypoechoic, line extending through the middle of the cervix. The internal os is defined by the point where the amniotic sac meets the cervical canal. The external os is interpreted as the point at which the cervical canal is no longer defined. The normal length of the cervical canal in pregnancy is 2.5-4.0 cm.

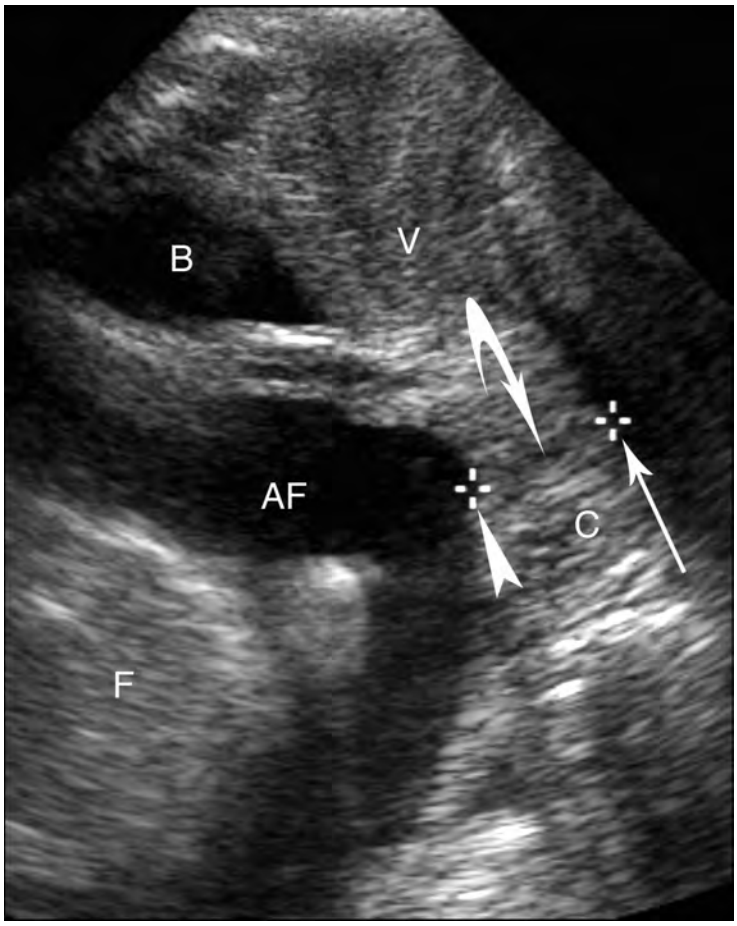

Figure 17: Normal cervix
Translabial scan shows the normal appearance of the cervix (C) in pregnancy. Image through the long axis of the vagina (V) is perpendicular to the cervix showing the internal os (arrowhead, cursor) abutting amniotic fluid (AF), the cervical canal (curved arrow, between cursors) and the external of (long arrow, cursor). The bladder (B) is partially distended.
A portion of the third trimester foetus (F) is evident.

Incompetent cervix

Cervical incompetence is responsible for approximately 16 % of premature deliveries and is defined as painless cervical dilatation and effacement after the first trimester without uterine contractions. A shortened cervix is predictive of cervical incompetence and preterm labour. On ultrasound the cervix is considered to be abnormally short when the closed endocervical canal measures <2.5 cm. Cervical length >3 cm effectively excludes imminent pre-term delivery. Fluid within the endocervical canal indicates dilatation of the cervix. Bulging of membranes into or through the canal is indicative of inevitable delivery.

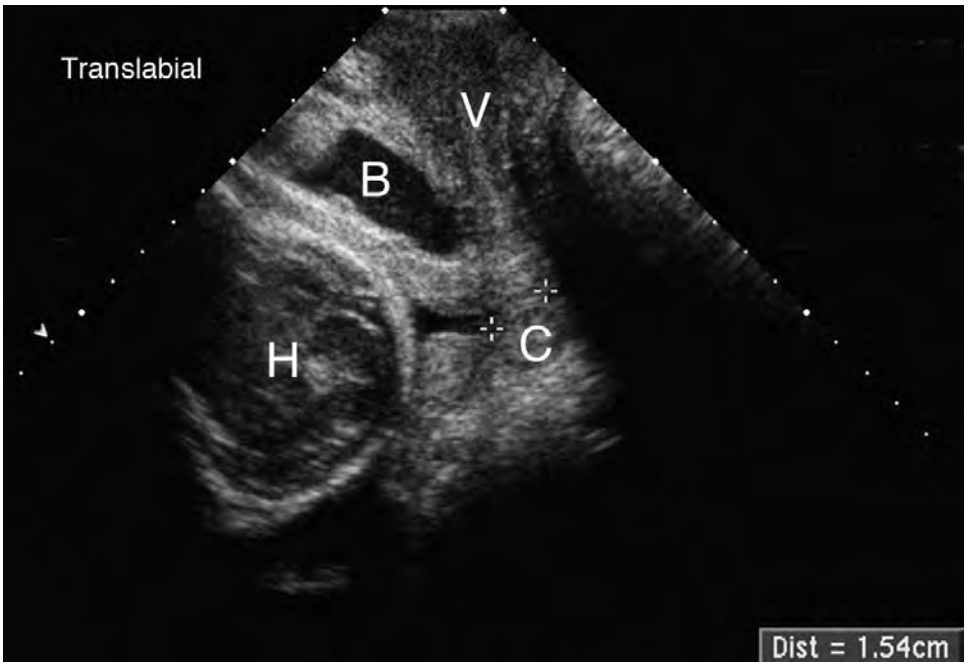

Figure 18: Shortened cervix
A translabial scan through the long axis of the vagina (V) reveals a short cervix (C) measuring 1.5 cm in length (between cursors, +) predictive of preterm delivery. The foetal (H) is in cephalic presentation. The bladder (B) is partially distended.

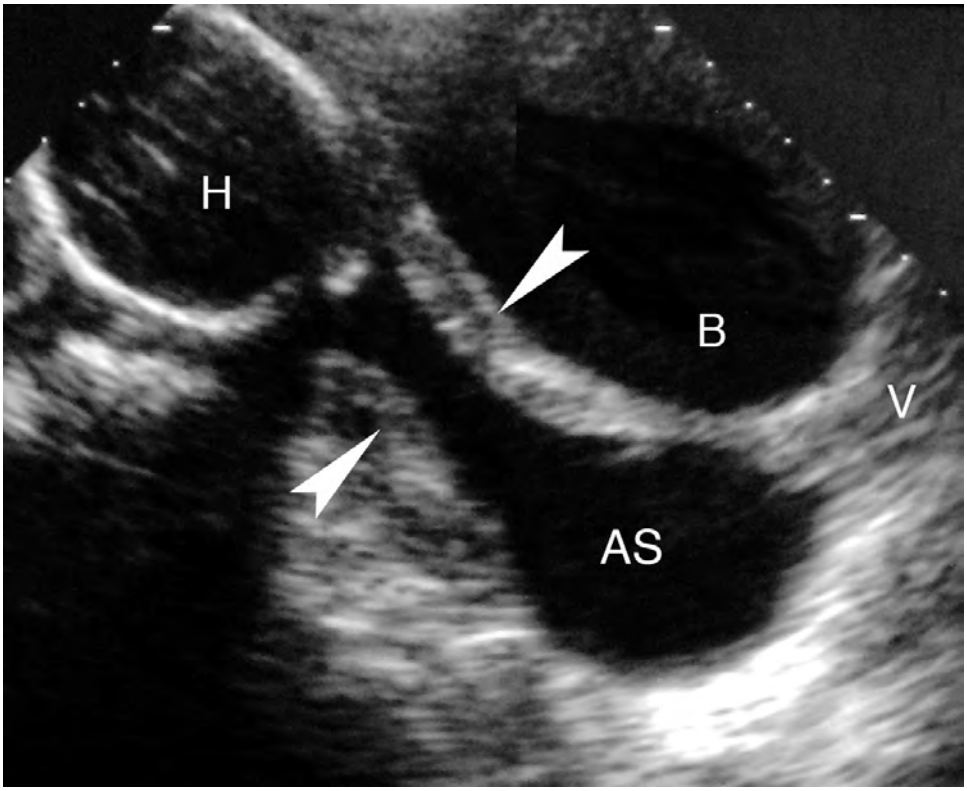

Figure 19: Bulging membranes
Transabdominal scan through the distended bladder (B) reveals a widely dilated cervix (between arrowheads) with the amniotic sac (AS) bulging through the cervix and into the vagina (V). The foetal head (H) is in cephalic presentation. Delivery is imminent and inevitable.

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10. Ultrasound in emergencies – the extended 'FAST' scan

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Focused Assessment with Sonography in Trauma (FAST) is a screening technique that is aimed at detecting free fluid in the peritoneal cavity as an indirect sign of acute intraperitoneal haemorrhage and injury to visceral organs.

FAST can be extended to include detection of pleural and pericardial effusions. In addition, air in the pleural space indicating a pneumothorax can be detected.

FAST scanning relies on the principle that free fluid collects in certain anatomical areas of the abdomen when the patient is supine. As a screening examination and depending on the skill of the examiner FAST, may be false negative, or in the presence of pre-existing ascites false positive.

Indications for FAST are:

– Blunt abdominal trauma
  FAST can identify intraperitoneal bleeding, e.g. from the injured liver, spleen, or other organs who may need an emergent laparotomy. A FAST scan can be used as a screening for early recognition of intraperitoneal blood.
  It is safe, rapid, and can and should be repeated, especially if the patient's status changes.
– Chest trauma
  • Pleural fluid: Ultrasound is sensitive for detecting pleural fluid and can identify as little as 20 mL in the pleural space. In the initial minutes of the trauma evaluation, an ultrasound examination of the lower thorax can be used to determine if an urgent chest drain is necessary as it is faster than taking a chest X-ray.
  • Pleural air: Ultrasound examination of the thorax can also be undertaken to identify pleural air. A pneumothorax is common after trauma. A small pneumothorax can be missed on an AP (anteroposterior) supine chest X-ray. However, identifying pleural air with ultrasound is a much more difficult examination than determining the presence of pleural fluid. In addition, it is not possible to determine the size of the pneumothorax by ultrasound. Ultrasound can be used to determine the need for an urgent chest X-ray (if available). If the scan shows no pleural fluid and no evidence for a pneumothorax, the chest X-ray still should be done, but is less urgent.

Notes:
– Clinical skills / assessment remain crucial.
– A negative FAST exam does not rule out intraabdominal injury.
– If the clinical suspicion for injury is high, consider repeating the FAST scan.
– Not all abdominal injuries produce free fluid, e.g. bowel injury.
– Free fluid may not always be blood, consider ascites or other causes.

10.1 Scanning technique - FAST

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

A 13-6 MHz linear array vascular transducer such as the HFL38x is preferred for the extended anterior thoracic view/pneumothorax study.

Apply gel to the transducer face and/or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Scanning steps - Basic 4 views of the FAST exam

1. Right upper quadrant (RUQ) view is used to asses for free fluid in the space between the liver and the right kidney (hepatorenal space - Morrison's pouch) (Figure 1 and Figure 2) and to investigate the right pleural space. The liver serves as an acoustic window to the hepatorenal space. Scanning cephalad, i.e. towards the head, through the liver allows imaging of the right pleural space for pleural fluid. Scanning caudally, i.e. towards the tail bone, allows for imaging of the lower pole of the right kidney and the right paracolic gutter for free intraperitoneal fluid.
2. Left upper quadrant (LUQ) view is used to asses for fluid in the subphrenic and splenorenal space and to investigate for a left pleural effusion. The spleen serves as a sonographic window to the splenorenal recess and the perisplenic spaces between the diaphragm and spleen. Scanning cephalad through the spleen allows assessment of the left pleural space. Scanning caudally allows assessment of the left paracolic gutter for fluid and of the lower pole of the left kidney.
3. The pericardial view or subxiphoid view is used to asses for pericardial fluid and cardiac motion. The left lobe of the liver is used as a sonographic window to the heart. The heart is imaged in sagittal plane and in angled transverse 4-chamber views. Fluid in the pericardial space is seen between the myocardium and the pericardial membrane.
4. The pelvis view is used to assess for free pelvic fluid. The pelvis is the most dependent space of the peritoneum where free intraperitoneal fluid may accumulate. Free fluid may be seen posterior or superior to the bladder or uterus. The entire bladder region is scanned in transverse and sagittal planes.

The extended FAST scan may include:

– Both paracolic gutters, i.e. right and left lower quadrants, to reveal free fluid surrounding the bowel. The flanks are scanned in longitudinal plane laterally or anteriorly.
– The anterior thoracic view is used to diagnose a pneumothorax. With respiration the normal visceral pleura slides back and forth beneath the parietal pleural. The pleural space is imaged just below the intercostal muscles with the transducer placed in an anterior intercostal space. Absence of visualization of the sliding visceral pleura is evidence of a pneumothorax. Higher frequency transducers provide the best visualization of the pleural space.

10.2 Right upper quadrant (RUQ) view

Four areas should be examined for free fluid: the pleural space, sub-diaphragmatic space, Morrison's pouch, inferior pole of the kidney/paracolic gutter.

Scanning steps and technique

1. Place the transducer with the marker pointing towards the patients head in the right midaxillary line, at approximately the 8^{th} to 11^{th} intercostal space. It may need to be adjusted up, i.e. toward the head, or down, i.e. towards the feet, depending on each patient's characteristics.

Placing the patient in Trendelenburg position, i.e. feet raised higher than the head by 15-30 degrees, has been demonstrated to increase the sensitivity for detecting fluid in the upper abdomen.

2. It is important to visualise the inferior pole of the kidney as a small volume of peritoneal fluid may first collect there. Slide the transducer inferiorly along axillary line to locate the inferior pole.
3. Rib shadows can be minimised by rotating the transducer very slightly counter clockwise, so the marker is pointed toward the posterior axilla.
4. Slide the transducer cephalad, i.e. towards the head, to obtain a view of the diaphragm and look for pleural fluid.

Scanning notes for the RUQ view

– Morrison's pouch is the space between the Glisson's capsule of the liver and Gerota's fascia of the right kidney. Normally the kidney and liver are nearly (juxtaposed) next to one another (Figure 1). Retroperitoneal fat appears as a bright hyperechoic (white) line separating the two organs. When abdominal free fluid is present a hypoechoic, i.e. dark, stripe may be seen between the liver and the kidney (Figure 2).

– Pleural fluid will appear as a black triangle just superior to the diaphragm, instead of the usual 'mirror artefact', i.e. the reflection of the liver parenchyma at the pleural level (Figure 3 and Figure 4).

– *Note*: Fluid in the duodenum, the gallbladder, and the inferior vena cava may be mistaken for free fluid.

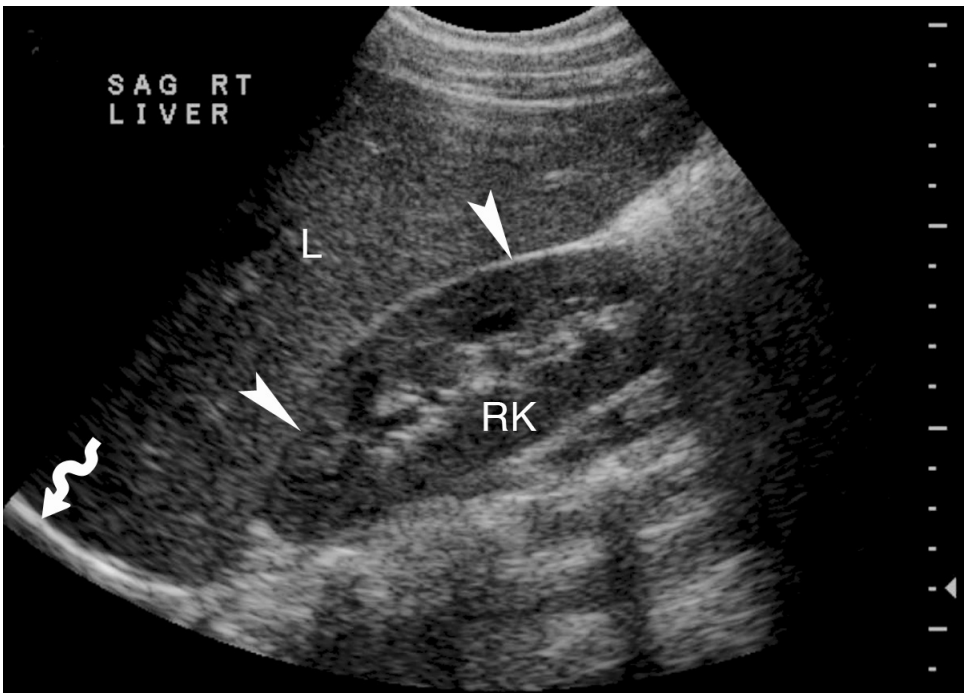

Figure 1: Normal hepatorenal space
Longitudinal view of the right upper quadrant shows the right lobe of the liver (L) and the right kidney (RK). The potential space between them (arrowheads), known as Morrison's pouch or the hepatorenal space appears as an echogenic line in the normal patient. The diaphragm (squiggly arrow) is shown as a thick smoothly curving echogenic line.

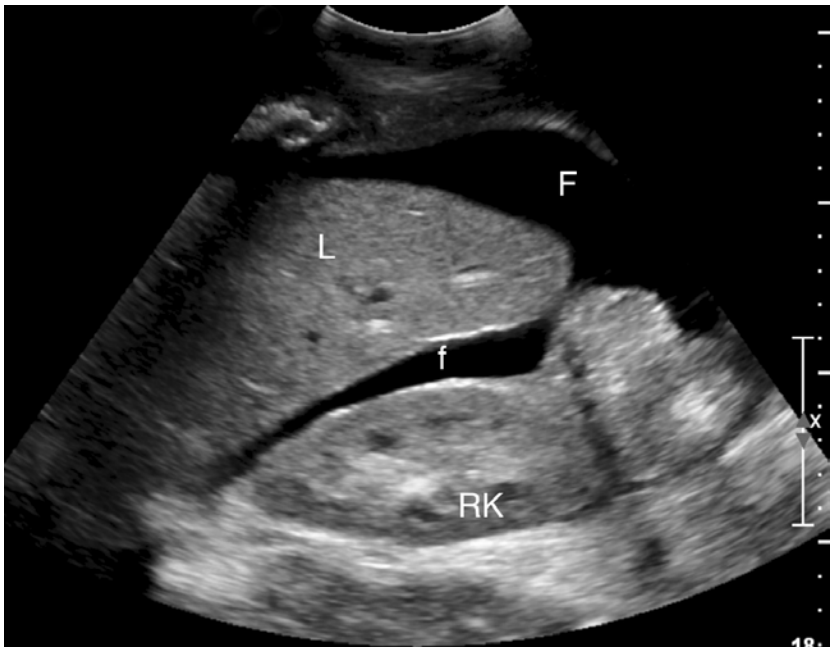

Figure 2: Perihepatic fluid
Longitudinal right upper quadrant image in a supine patient reveals fluid as an anechoic space in Morrison's Pouch (f) between the liver (L) and the right kidney (RK) with additional fluid (F) surrounding the liver tip. In the setting of trauma this finding would indicate hematoperitoneum. The fluid may be anechoic or may contain particulate matter.

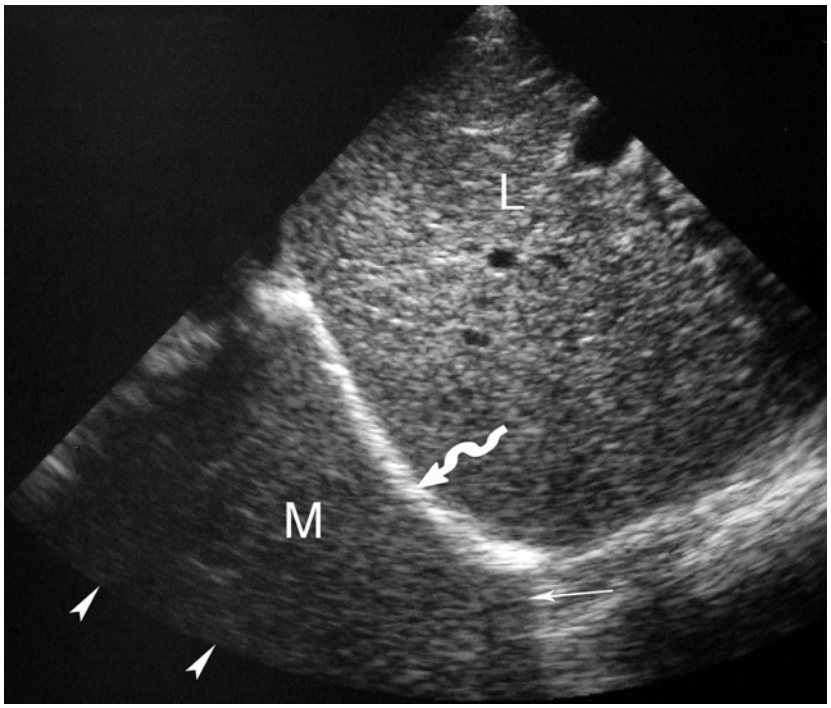

Figure 3: Normal pleural space
A right upper quadrant ultrasound image using the liver (L) as a sonographic window shows the normal appearance of the right pleural space. The diaphragm (squiggly arrow) appears as a thick bright curving echogenic line. The air filled lung above the diaphragm produces a 'mirror-image' ultrasound artefact that reproduces the texture and appearance of the liver parenchyma above the diaphragm (M). This well recognized artefact is evidence of normal air-filled lung without a pleural effusion present. Compare to Figure 4 showing a pleural effusion. Note the absence of rib shadows deep to the mirror-image artefact (arrowheads). Air in the lung has blocked transmission of the ultrasound beam beyond the diaphragm. A rib shadow (straight arrow) is seen where the ultrasound beam has passed through the liver.

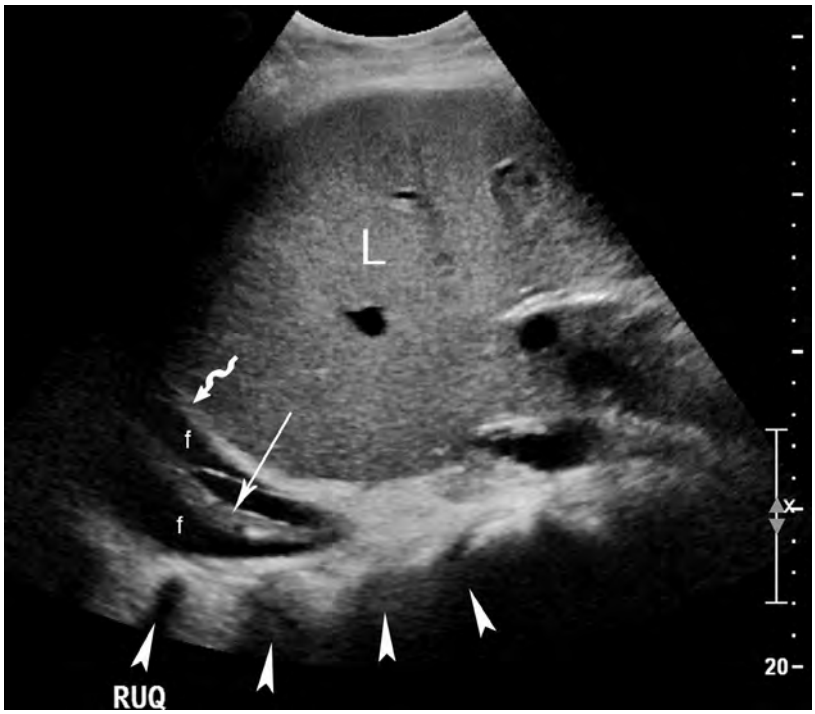

Figure 4: Right pleural effusion
Right upper quadrant ultrasound image in a different patient shows the characteristic appearance of a right pleural effusion. Again the liver (L) is used as a sonographic window to the right pleural space. The diaphragm (squiggly arrow) is again seen as a curving echogenic line. Pleural fluid (f) appears as an anechoic band above the diaphragm. Pleural effusions are always associated with some degree of lung atelectasis. In this case the partially collapsed right lower lobe of the lung (straight arrow) appears as a sharply marginated band of tissue similar in echogenicity to the liver parenchyma. The arrowheads indicate acoustic shadows cast by the ribs. These are important sonographic landmarks that confirm the presence of pleural effusion when seen above the level of the diaphragm. Since fluid has displaced air-filled lung the ultrasound beam passing through the liver can penetrate the pleural fluid and image the ribs from the inside out. The rib shadows should be visualized to confirm the presence of pleural fluid.

10.3 Left upper quadrant (LUQ) view

Four areas should be examined for free fluid: the pleural space, sub-diaphragmatic space, splenorenal recess, and the inferior pole of the kidney.

Scanning steps and technique

1. Orient the transducer with the marker pointing toward the patient's head.
2. The transducer is placed at the posterior axillary line at approximately the 9th to 10th intercostal space. Adjust posteriorly and superiorly in order to get the best image as the left kidney is more posterior and superior than right kidney (Figure 5).
3. Slide the transducer towards the head and rotate it very slightly clockwise in order to remove rib shadows and obtain a suitable view of the spleen and diaphragm.

Scanning notes for the LUQ view

– The spleen has homogenous parenchyma with a smoothly rounded sharply defined capsule. Vessels enter and exit at the splenic hilum.
– Free fluid accumulates superiorly between the spleen and the diaphragm; and posteriorly around the inferior tip of the spleen (Figure 6). Less frequently, only when there is a lot of fluid, will fluid accumulate between the kidney and the spleen.

– A pleural effusion will appear as a black stripe or triangle just superior to the diaphragm, as similarly demonstrated in the RUQ view (Figure 4).
– A fluid filled stomach can mimic free fluid, as can loops of bowel. Bowel loops can be distinguished from free fluid because they are round and demonstrate peristalsis.

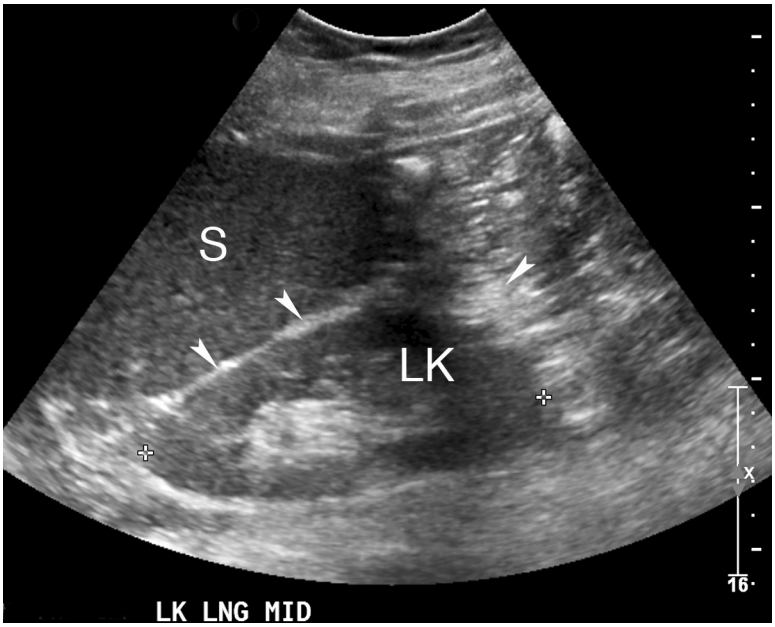

Figure 5: Normal spleen and left kidney
Longitudinal left upper quadrant image shows the echogenicity of the spleen (S) and the left kidney (LK, between cursors, +) to be approximately equal. The perisplenic spaces (arrowheads) are echogenic indicating the absence of perisplenic fluid.

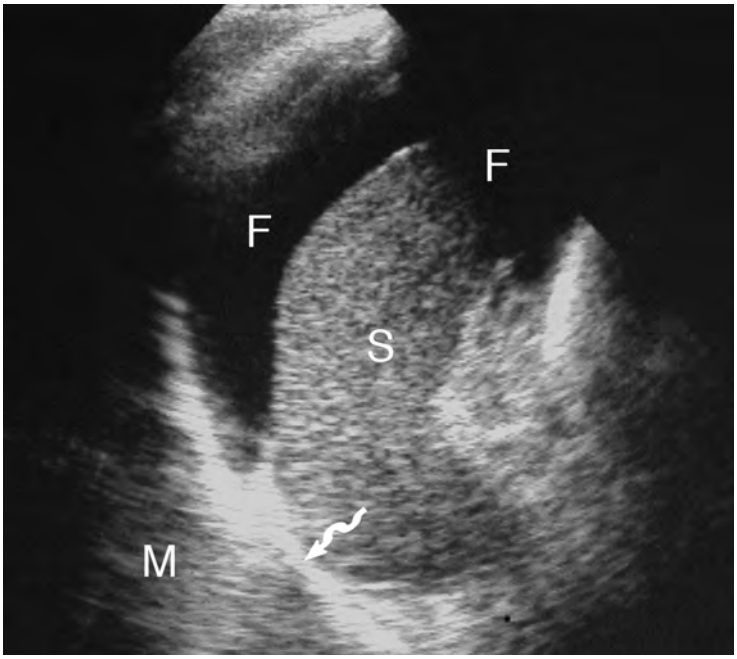

Figure 6: Fluid around the spleen
Longitudinal left upper quadrant image reveals anechoic fluid (F) around the spleen (S) and between the spleen and the diaphragm (squiggly arrow). Air-filled left lung produces a mirror-image artefact (M).

10.4 Pericardial / subxiphoid view

The pericardial view is a transverse view angled upward from the subxiphoid region to image the heart and to diagnose pericardial effusion.

Scanning steps and technique

1. Place the transducer in transverse orientation in the subxiphoid area with the marker directed toward the patient's left shoulder and the transducer angled upward toward the heart.
2. Pressure on the transducer is required. Ensure it is almost parallel to the skin of the torso. If the patient can bend the knees this can help relax the abdominal wall muscles. If the patient is able to cooperate, ask her/him to take a breath in and hold it.
3. Slide the transducer superiorly until the moving heart is evaluated.
4. Use the liver as an 'acoustic window' allowing for direct penetration of the beam to the heart while avoiding the lungs and ribs. Solid organs can be used as 'acoustic windows' allowing the ultrasound beam to penetrate without interference from lung or bowel gas.
5. Increase the depth of the image if needed to include the pericardium and chambers of the heart.

Scanning notes for the pericardial view

– The immediate goal of the examination is to diagnose or exclude a pericardial effusion.
– A normal pericardium is seen as a hyperechoic, i.e. white, line surrounding the heart. The right ventricle is immediately adjacent to the left lobe of the liver. Look at the interface between the right ventricle and the liver to identify pericardial fluid. A hypoechoic, i.e. black band between the rim of the liver and the heart wall represents fluid in the pericardial sac (Figure 7). Circumferential pericardial fluid with or without right ventricle or right atrium collapse is concerning for tamponade.
– Injuries to left lobe of the liver may also be identified in this view.
– A focal posterior effusion, seen on the parasternal long axis view, may be a left pleural effusion rather than a pericardial effusion.
– The hypoechoic stripe of a pericardial effusion usually wraps around the apex of the heart.
– Sometimes a stomach full of air can block the ultrasound beam before it reaches the heart. If this is a problem, slide the transducer to the right and scan through the liver.
– The subxiphoid view can be limited by: obesity, pneumoperitoneum, pneumothorax, gas in bowel, abdominal tenderness, or protruding abdomen. The subxiphoid view may be supplemented by the parasternal long axis view.

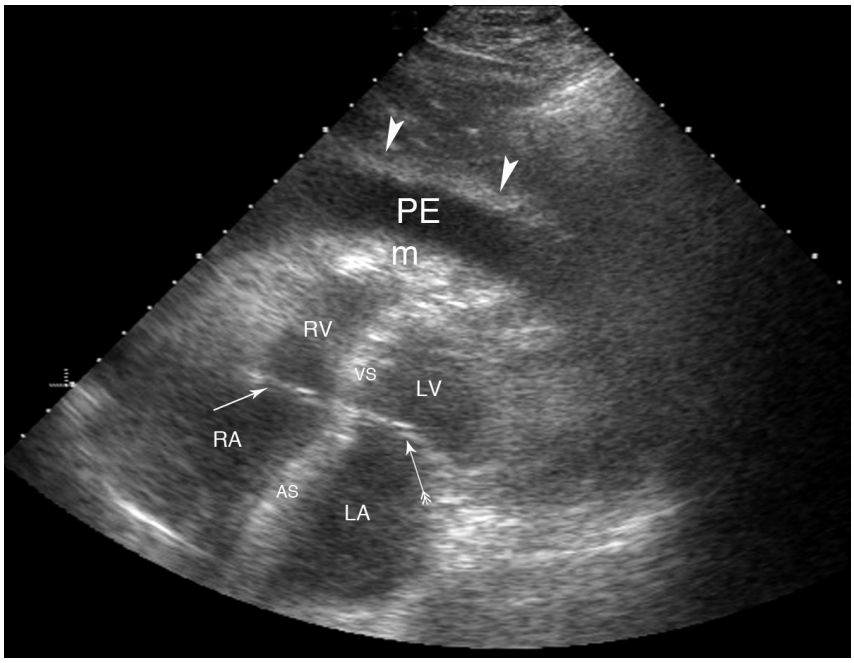

Figure 7: Pericardial effusion
Transverse upward-angled subxiphoid view reveals a pericardial effusion (PE) as a hypoechoic band between the chest wall (arrowheads) and the myocardium (m). The heart is shown in 4-chamber view from the cardiac apex. Anterior and to the right is the right ventricle (RV), just to the left is the left ventricle (LV) separated from the right ventricle by the ventricular septum (VS). In this patient both the right atrium (RA) and the left atrium (LA) are dilated. The atrial septum (AS) separated the enlarged atria. The tricuspid valve (arrow without tail) and the mitral valve (arrow with tail) are both closed in this phase of the cardiac cycle (early ventricular systole).

10.5 Pelvic view

The pelvic view examines for the presence of free fluid around the bladder. Transverse and longitudinal views of the suprapubic region are obtained to depict the urinary bladder and rectouterine/retrovesical pouch, a recess formed by a fold of the peritoneum descending between the rectum and uterus in women or the rectum and bladder in men.

This scan should be performed on a patient with full bladder if possible. The bladder should not be overfilled. A very full bladder will displace fluid out of the cul-de-sac and possibly result in a false negative examination.

Scanning steps and technique – transverse view

1. Place the transducer just superior to the symphysis pubis in the midline of the abdomen.
2. Ensure the marker points toward the patient's right side.
3. Angle the transducer inferiorly (toward the patient's feet) to visualize the urine-filled bladder
4. Scan side to side to identify pockets of free fluid between bowel loops.
5. Fluid collections may be seen lateral or posterior to the bladder or uterus.
6. Sliding the transducer right and left on the symphysis pubis provides full evaluation of the pelvis.

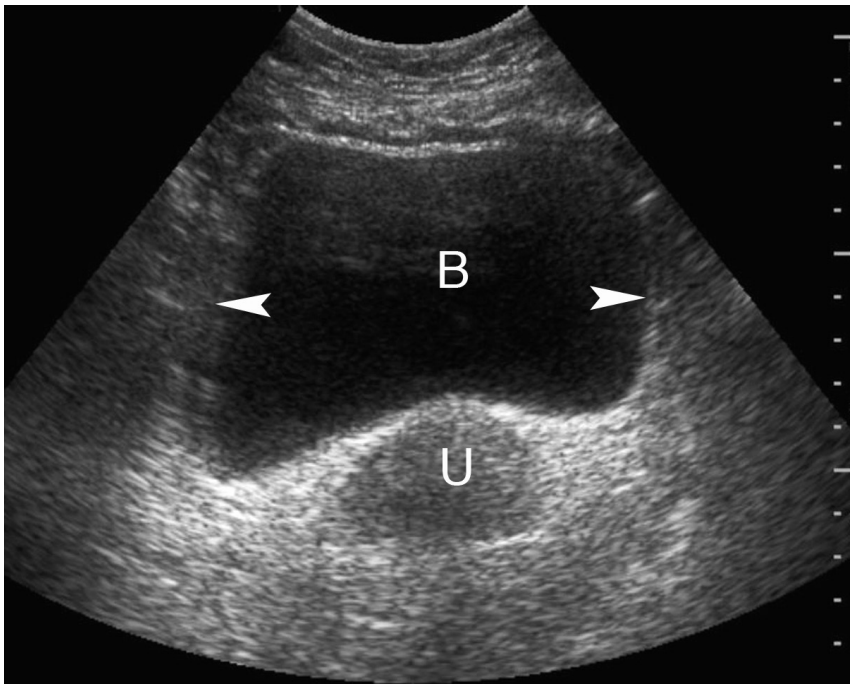

Figure 8: Normal pelvic view – Transverse
Transverse suprapubic view shows the full bladder (B) and a portion of the uterus. Note that the full bladder extends to the pelvic side wall (arrowheads) without intervening free pelvic fluid. The recesses surrounding the uterus (U) remain echogenic indicating the absence of free pelvic fluid.

Scanning steps and technique – longitudinal view

1. Place the transducer in the same location but rotated with the marker pointing toward the patient's head.
2. Sweep and angle the transducer right and left to scan the entire pelvis.
3. Fluid collections may be seen cephalad or posterior to the bladder or uterus.

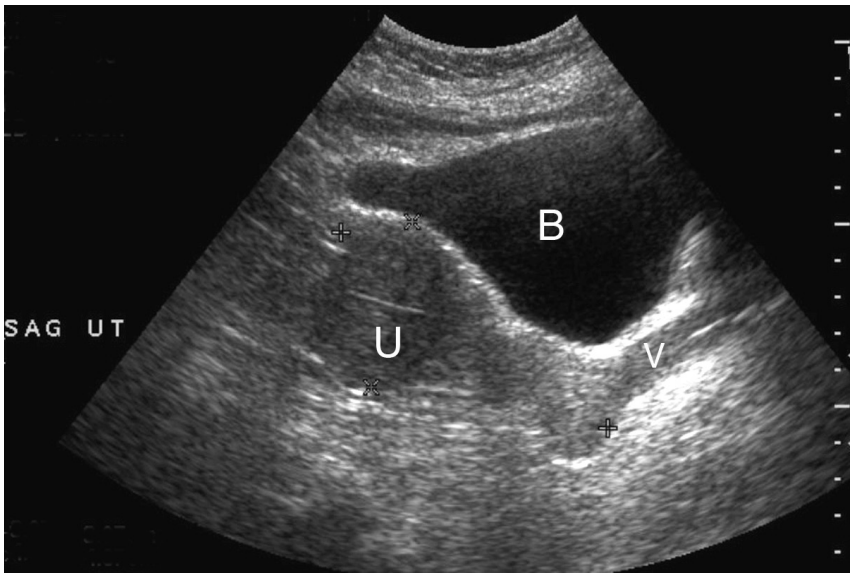

Figure 9: Normal pelvic view – Longitudinal
Longitudinal suprapubic view in the midline shows optimal filling of the bladder (B) and normal appearance of the uterus (U) and vagina (V). Again note that the peritoneal recesses between the bladder and uterus and posterior to the uterus remain echogenic indicating the absence of free intraperitoneal fluid in the pelvis.

Scanning notes for the pelvic view

- Free fluid is anechoic, i.e. dark, and found in the rectovesicular pouch in men and rectouterine pouch, i.e. pouch of Douglas, in women. This view requires that the bladder be moderately full to allow detection of small fluid collections. Failure to adequately fill the bladder may result in false negative or indeterminate results.
- 30-40 % of women of reproductive age have fluid collections of up to 50 mL in the pouch of Douglas. These are considered physiologic when related to recent ovulation. However, more than trace fluid should be regarded as pathologic as well as any free fluid anterior to the uterus suggests haemoperitoneum. Pathologic free fluid may also be seen completely surrounding the edges of the uterus.
- Free fluid will be seen along the intraperitoneal portion of the posterior wall of the bladder in males.
- The most common reason for difficulties in visualising the bladder is a transducer position that is too superior. Remember that the bladder is a pelvic organ and only emerges from above the symphysis pubis as it becomes distended.

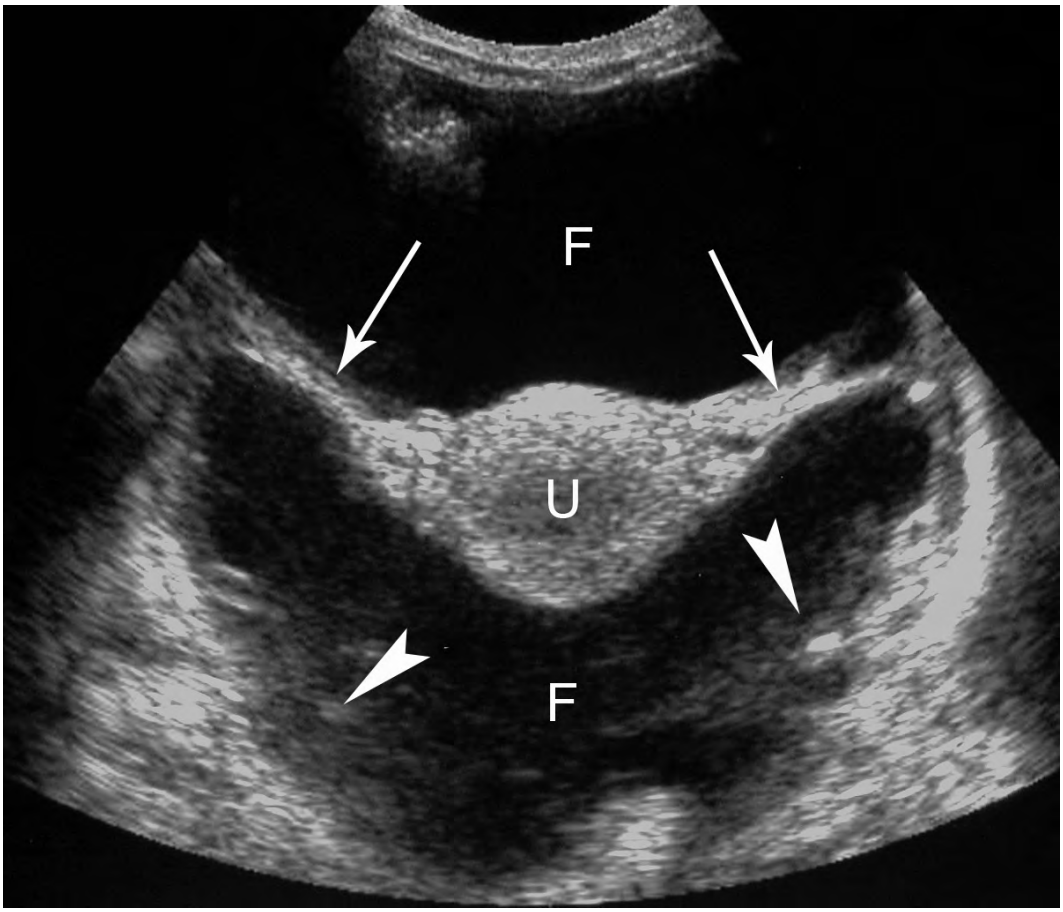

Figure 10: Free pelvic fluid – Transverse
Transverse suprapubic view shows a large haemoperitoneum associated with a shattered spleen. The uterus (U) is suspended in free intraperitoneal fluid (F) by the broad ligaments (arrows). Blood clots (arrowheads) in the pouch of Douglas appear as ill-defined echogenic masses.

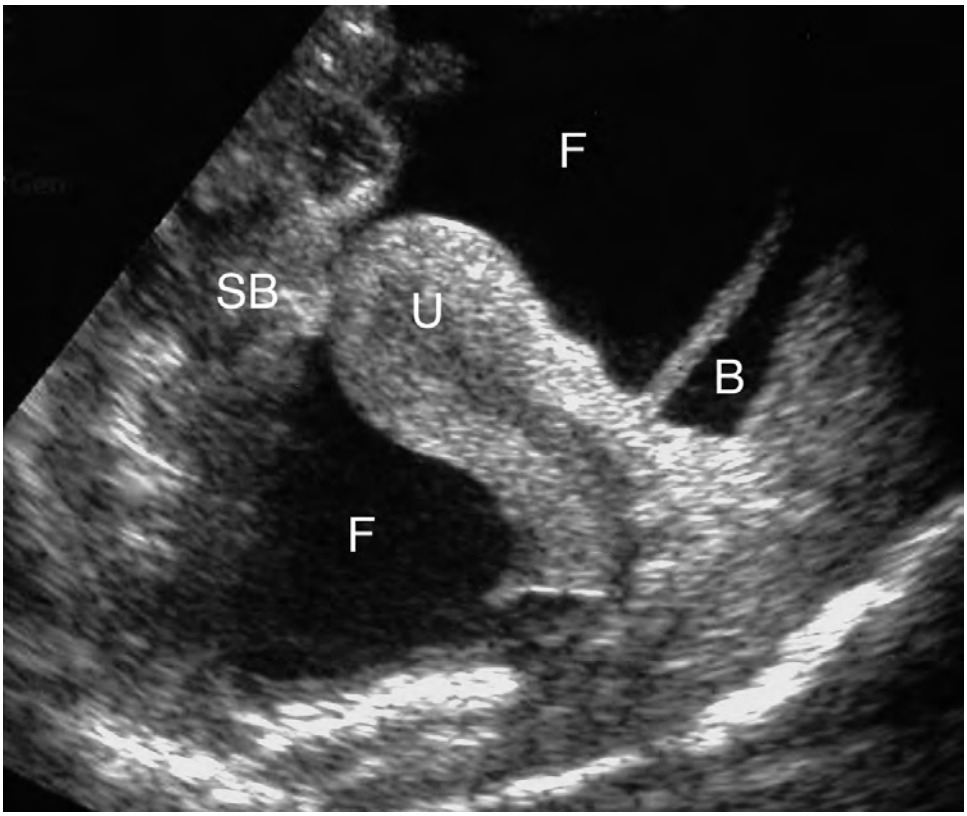

Figure 11: Free pelvic fluid – Longitudinal
Longitudinal suprapubic view in the midline in the same patient with the shattered spleen shows large volume free intraperitoneal fluid (F) anterior and posterior to the uterus (U). The bladder (B) is only partially filled. Multiple loops of small bowel (SB) are seen superior to the uterus.

10.6 Anterior thoracic view / pneumothorax study

This view is used to identify a pneumothorax.

A linear array transducer, e.g. HFL38x, is best for examinations of the chest for pneumothorax. However, the C60x abdominal transducer can be used if no linear transducer is available.

Scanning steps and technique – anterior thoracic view

1. The transducer is initially placed longitudinally on the anterior chest at the 3rd and 4th intercostal space in the mid clavicular line with the marker pointing towards the patient's head.
2. Decrease the depth setting so that the ultrasound image shows a maximum depth of 4 cm.
3. Adjust the transducer until the ribs can be seen. The ribs appear as a sharply defined curving echogenic focus followed by a dark acoustic shadow deeper in the image (Figure 12 and Figure 13).
4. Identify the pleural line, i.e. hyperechoic line between and below the two ribs.
5. Asses for a 'sliding sign'. The 'sliding sign' describes movement of the echogenic line representing the visceral pleura and surface of the air-filled lung as it slides back and forth beneath the parietal pleura with inspiration and expiration. The presence of the 'sliding sign' excludes the presence of a pneumothorax in the area of the thorax being examined.
   An ultrasound is positive for pneumothorax when the sliding sign is absent.
   The extent of the pneumothorax can be approximated by moving the transducer laterally or inferiorly until the sliding sign is again seen, indicating that aerated lung parenchyma is in contact with the parietal pleura.

6. Asses for 'B-lines' referred to as 'comment tail artefact'. B-lines or comment tail artefact are generated from normal lung tissue. They appear as bright well defined lines that arise from the pleural line and extend to the bottom of the screen without fading.
   The presence of 1 or 2 B-lines is normal and rules out a pneumothorax.
7. Repeat, and systematically examine intercostal spaces from cranial to caudal, i.e. head to feet, to evaluate the entire chest on each side. The more intercostal spaces examined the more sensitive is ultrasound examination for pneumothorax.

Scanning notes for the anterior thoracic view

– Hold the transducer still when assessing for the 'sliding sign', as any movement of the transducer may simulate moving pleura and give you a false negative study.
– Chest ultrasound can only detect a pneumothorax which is located directly under the transducer.
– The extent of the pneumothorax can be approximated by moving the transducer laterally or inferiorly until the sliding sign is again seen, indicating that aerated lung parenchyma is in contact with the parietal pleura.
– Lack of pleural sliding may also be seen with poor ventilation or previous pleural disease with adhesions binding the visceral and parietal pleura.
– If available, a chest radiograph is still indicated when a pneumothorax is suspected and the ultrasound pneumothorax study negative.

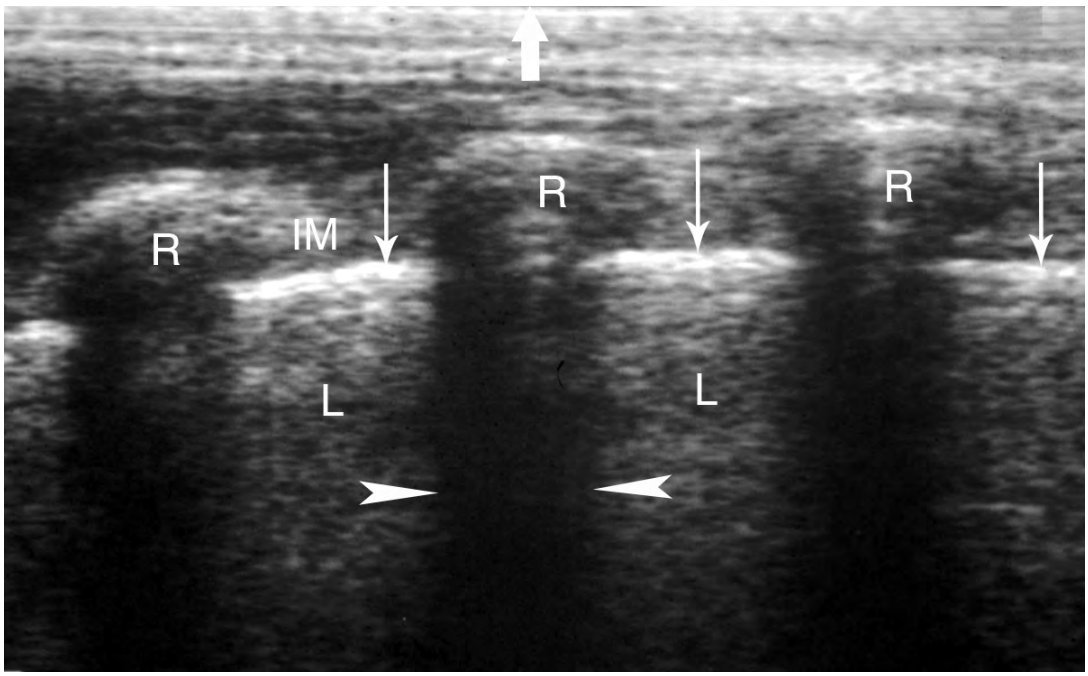

Figure 12: Pleural space – Longitudinal
Ultrasound image of the pleural space was obtained by placing a linear array transducer directly on the upper anterior chest wall in a longitudinal orientation. The ribs (R) and the acoustic shadows they produce (dark band between arrowheads) serve as anatomic landmarks. The interface (thin arrows) between the visceral pleura covering the lung and the parietal pleura lining the chest is approximately 1 cm deep to the near surface of the ribs, and 2-3 cm deep to the skin surface (thick arrow). Intercostal muscle (IM) between the ribs serves as an acoustic window to the thorax. When no pneumothorax is present and the lung (L) is normal and air-filled the US beam is totally reflected at the lung surface. With real-time imaging the lung surface (thin arrows) slides back and forth with inspiration and expiration (the 'sliding sign'). When a pneumothorax is present with air in the pleural space the static appearance is exactly the same, however the sliding sign is absent. In either case repeated reflection of the ultrasound beam between the transducer face and the soft tissue-air interface produces an artefact of granular echoes (L) deeper in the image.

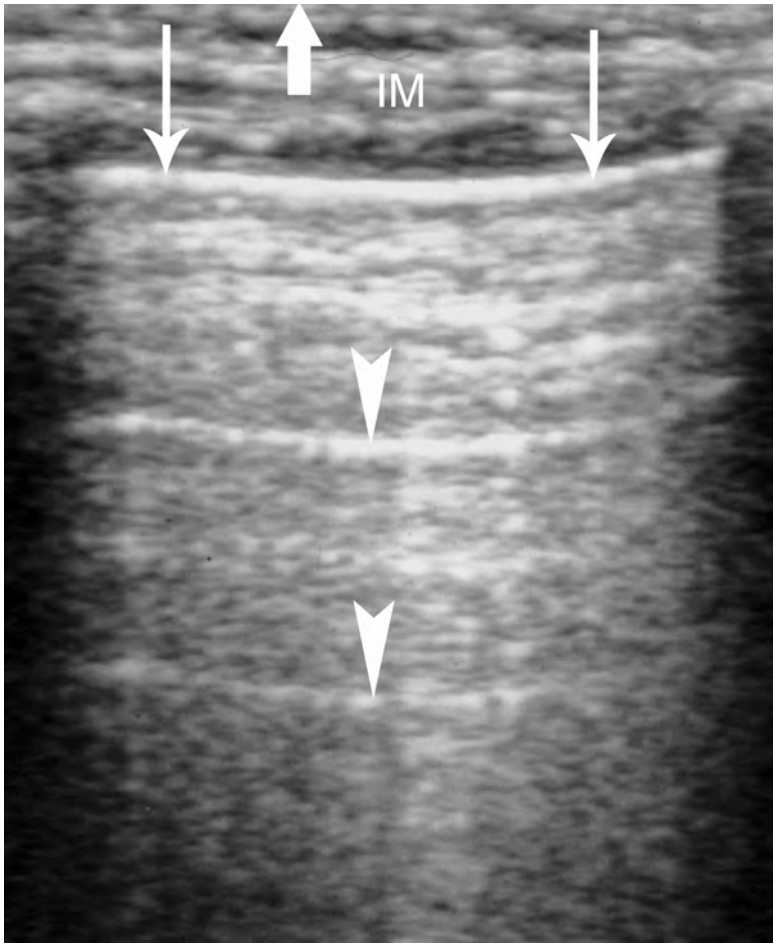

Figure 13: Pleural space – Transverse
The transverse view aligned with an intercostal space provides the best image of the pleural space and lung. Sound waves are transmitted through the intercostal muscles (IM) to the pleural space. The interface between soft tissue (intercostal muscle) and air, whether the air is in the lung or in the pleural space, produces a highly echogenic line (thin arrows) about 2-3 cm deep to the skin surface (thick arrow). Because the interface between soft tissue and air causes total reflection of the ultrasound beam the pattern of echoes deep to this interface is completely artefactual and does not demonstrate discrete anatomic information. The ultrasound beam is repeatedly reflected between the soft tissue-air interface and the skin/surface of the transducer (thick arrow). This repeated reflection produces a 'reverberation artefact' seen in the image as a series of echogenic lines (arrowheads) mirroring the appearance of the soft tissue-air interface. These lines are shown in the image at equal distance from each other. The lines diminish in intensity as they are projected deeper in the image. The static image has the same appearance whether the soft tissue-air interface is produced by air in the lung or air in the pleural space. Air in the lung moves back and forth with respiration as the visceral pleura slides adjacent to the parietal pleura, while air in the pleural space does not move. Absence of the 'sliding sign' is the critical finding for the ultrasound diagnosis of pneumothorax.

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11. Cardiac

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Adult and paediatric cardiac ultrasound should be used early and liberally when a patient presents in a low-resourced setting with suspected cardiac pathologies, since the majority of the population lacks access to primary care, sufficient laboratory testing, X-ray and CT imaging modalities. This lack of access often contributes to a delay in diagnosis, with patients presenting in extremis with complex cardiac complications from congenital illness, smouldering infections, cardiomyopathies, untreated hypertension and other acute or chronic diseases.

Consider performing cardiac ultrasound for patients presenting with the following:
– Clinical signs: hypotension, tachycardia, altered mental status, diaphoresis, heart murmur, and oedema.
– Symptoms: chest discomfort, shortness of breath, fatigue, persistent cough, and dizziness.

Basic cardiac scanning techniques are outlined below and common pathologies to look for include:
– Pericardial effusion
– Cardiac tamponade
– Heart failure
– Right heart strain
– Volume status

11.1 Scanning technique - cardiac

Transducer

The 5-1 MHz (low-frequency) phased array transducer such as the P21x which is compatible with the MSF standard M-Turbo is recommended.

A 5-10 MHz (high-frequency) linear transducer such as the HFL38x is recommended for evaluation of the lungs.

Alternatively, a 5-2 MHz, curvilinear abdominal transducer such as the C60X, can be used, but may be suboptimal.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine, or be placed in the left lateral decubitus position.

Scanning steps and technique – four primary cardiac views

The examiner should evaluate the heart using four primary cardiac views one of the inferior vena cava (IVC):

1. Parasternal long axis view
   - Place the transducer on the left chest near the sternum with the indicator probe pointed to the patient's left hip. Starting at the level of the nipples / areola, slide the probe down along the left border of the sternum to find the best acoustic window. Minor rotation (either clockwise or counter clockwise) will allow for a clear view.
   - The parasternal long axis view should demonstrate the right ventricle at the top (near field) of the screen followed by the interventricular septum, then left ventricle and ventricular outflow tract (aortic valve), then the mitral valve as well as left atrium. A bright line seen at the very bottom (far field) of the image indicates the pericardium (Figure 1).
   - The primary valve observed and evaluated in the parasternal long axis view is the mitral valve, with visualization of the anterior and posterior leaflets.

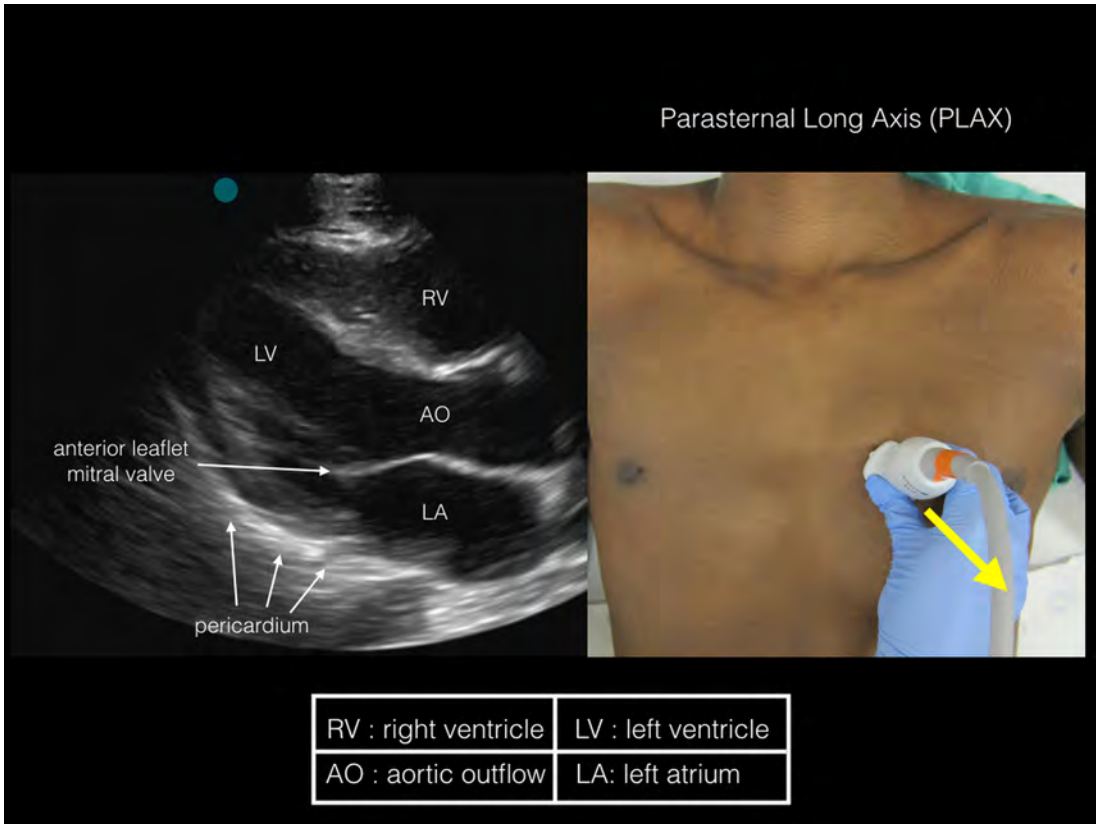


Figure 1: Parasternal long axis probe position and normal anatomy
The image on the left is a parasternal long axis view, showing the normal appearance of the right ventricle (RV) and left ventricle (LV), aortic outflow (AO), left atrium (LA), mitral valve (MV), and pericardium (P).
The image on the right is the corresponding position of the transducer on the patient with the yellow arrow indicating the direction of the probe marker.

2. Parasternal short axis view
   - After the parasternal long axis is obtained, rotate the probe 90 degrees in a counter clockwise direction until the probe indicator points to the patient's left shoulder. Subtle cephalad / caudal (towards the head / towards the feet) movements of the transducer will allow for the best acoustic window (Figure 2).
   - A parasternal short axis (a cross-sectional slice through the middle part of the heart) demonstrates the left ventricle at the level of the mitral valve. The left ventricle is surrounded

by the crescent-shaped right ventricle. The myocardium between the left ventricle and right ventricle is the interventricular septum. The bright line at the very bottom (far field) of the image is the pericardium. In this view, assess the morphology of the mitral valve and symmetric 'squeeze' of the left ventricle.

- In the parasternal short axis view, the mitral valve is observed. In diastole the valve has a 'fish-mouth' view. The anterior leaflet is on the top, closer to the right ventricle, and the posterior leaflet is closer to the bottom of the screen.

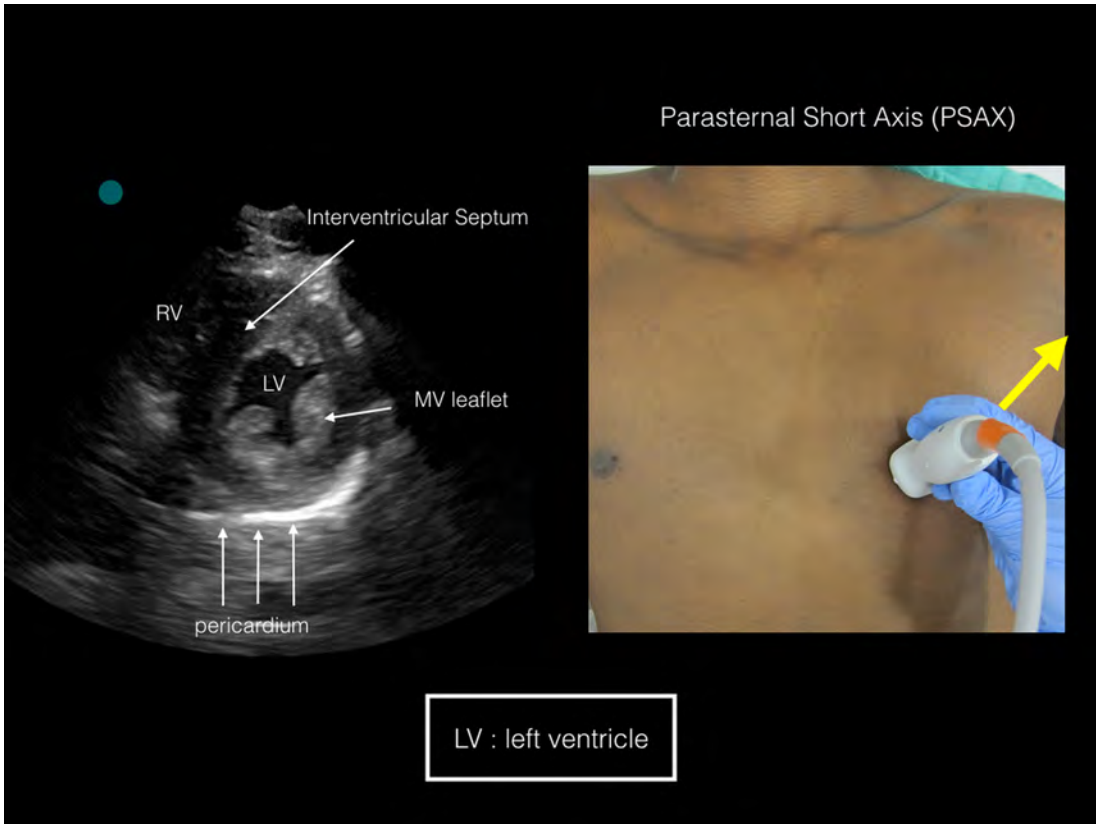


Figure 2: Parasternal short axis probe position and normal anatomy
The image on the left shows a parasternal short axis view (representing a cross-section of the heart) demonstrating the normal appearance of the left ventricle (LV) and mitral valve (MV), with anterior and posterior leaflets.
The interventricular septum is to the left followed by right ventricle.
The bright line at the very bottom (far field) of the image is the pericardium.
The image on the right is the corresponding position of the transducer on the patient with the yellow arrow indicating the direction of the probe marker.

3. Apical four-chamber view
   - From the position of the parasternal long / short slide the transducer laterally along the axis of the heart toward the apex. From this location, angle the beam toward the right scapula (with the probe marker toward the right hip). The goal is to have the transducer footprint at the cardiac apex with the beam directed through both ventricles and atria (the ultrasound view will ideally have the intraventricular septum oriented vertically in the centre of the screen). Once again, make subtle movements for the best acoustic window. This is often the most difficult view to obtain, and generally requires the patient be positioned in the left lateral decubitus position (Figure 3).
   - An apical four-chamber view demonstrates all four chambers of the heart simultaneously as well as the tricuspid and mitral valves. The right ventricular size is normally approximately 3/4th the size of the left ventricle. The bright line at the very bottom (far field) of the image is the pericardium.

- In this view, the mitral valve (right of screen) and tricuspid valve (left of screen) are easily evaluated.

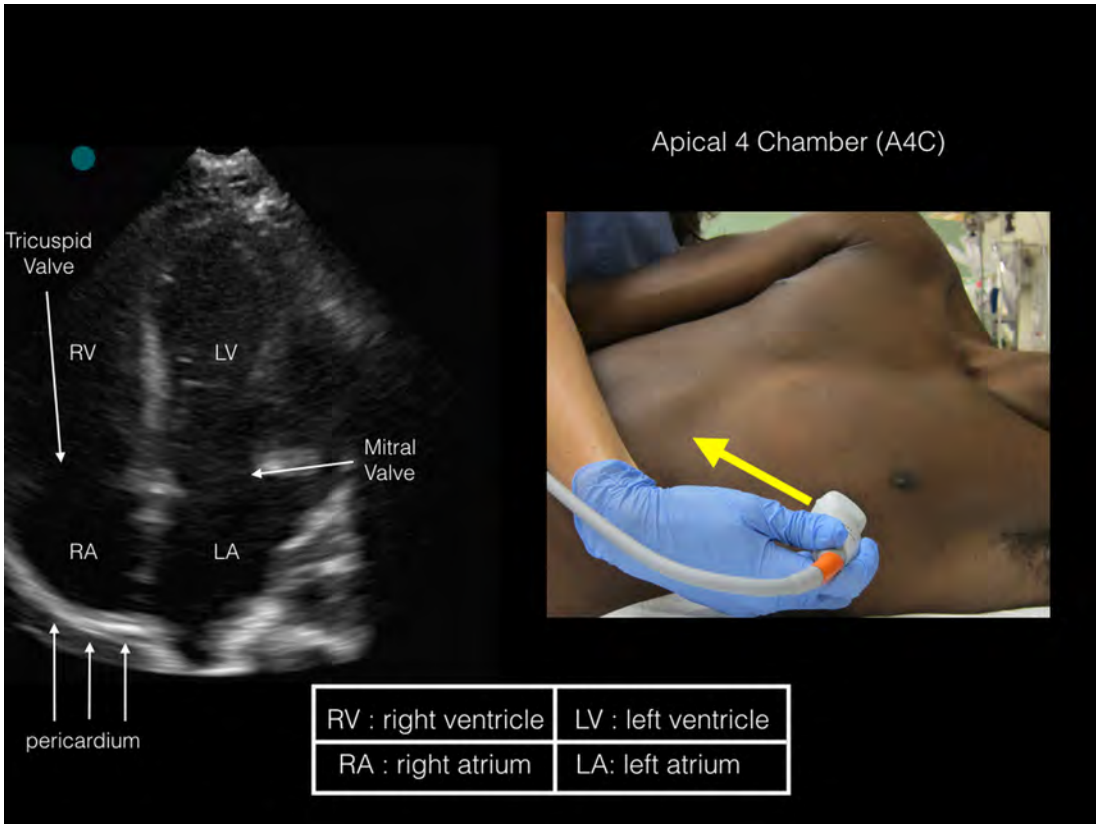


Figure 3: Apical four-chamber view probe position and normal anatomy
The image on the left shows an apical four-chamber view demonstrating the normal appearance of all four chambers of the heart (left ventricle (LV), right ventricle (RV), left atrium (LA) and right atrium (RA) simultaneously
as well as the tricuspid valve (TV), and mitral valve (MV).
The bright line at the very bottom (far field) of the image is the pericardium.
The image on the right is the corresponding position of the transducer on the patient with the yellow arrow indicating the direction of the probe marker.

4. Subxyphoid view & Inferior vena cava (IVC)
   - Heart: The probe is positioned at the centre of the epigastrium with the ultrasound beam to the patient's right shoulder. The left lobe of the liver is used as an acoustic window in the near field. In this view, the liver is in the upper region of the image with the right ventricle, right atrium and left ventricle and left atrium visualized (Figure 4). In patients with hyperinflated lungs from pulmonary pathology, (e.g. COPD, severe asthma), this four-chamber view is often ideal.
   - In the subxyphoid view, the mitral valve is observed. Slight tilting of the transducer can result in observation of the aortic valve.
   - IVC: The probe is positioned longitudinally subxiphoid just to the right of midline and rocked caudally to visualize the right atria if possible. Fan the probe to the patient's left to identify the aorta, and then back to the patient's right to confirm the IVC. The IVC is differentiated from the aorta by observing its confluence with the hepatic vein and the right atrium (Figure 5).
     Note: the IVC has thin walls when compared to the aorta. Once the IVC is identified, the examiner assesses the collapsibility during inspiration, focusing approximately 2-3 cm caudal to the confluence of the hepatic vein (Figure 5).

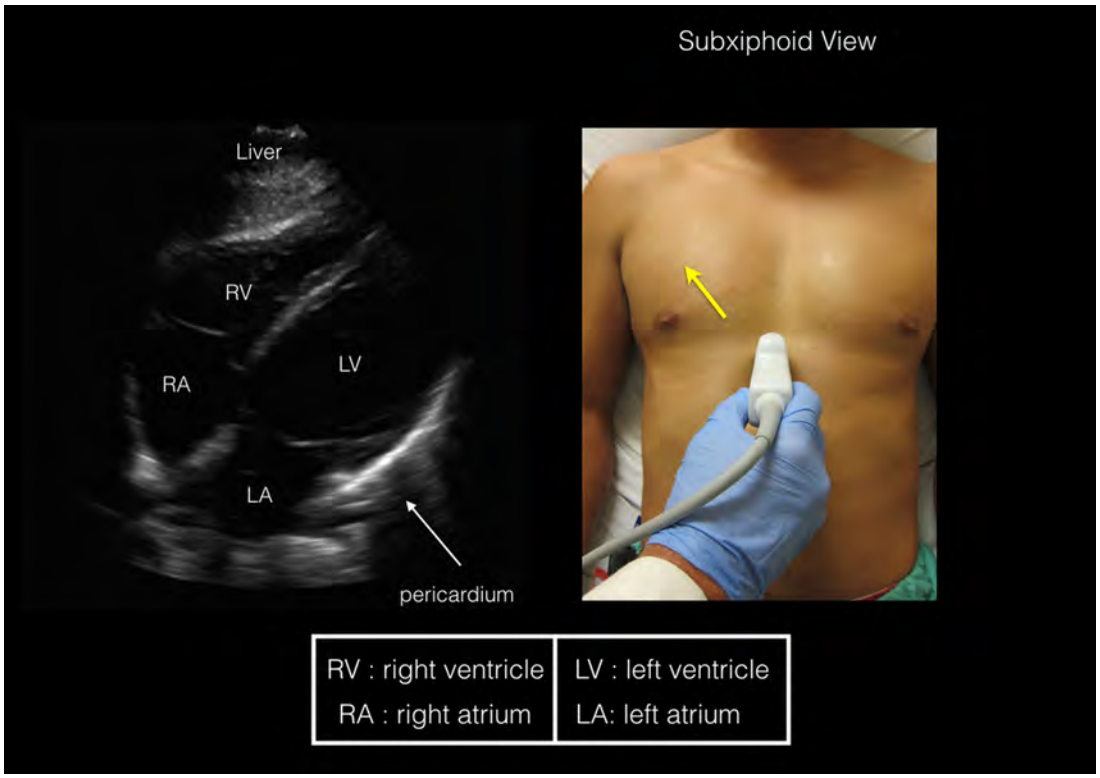


Figure 4: Subxiphoid cardiac view probe position and normal anatomy
The image on the left demonstrates the normal appearance of all four chambers of the heart [left ventricle (LV), right ventricle (RV), left atrium (LA) and right atrium (RA)] simultaneously. The bright line at the very bottom (far field) of the image is the pericardium.
The image on the right is the corresponding position of the transducer on the patient with the yellow arrow indicating the direction of the probe marker.

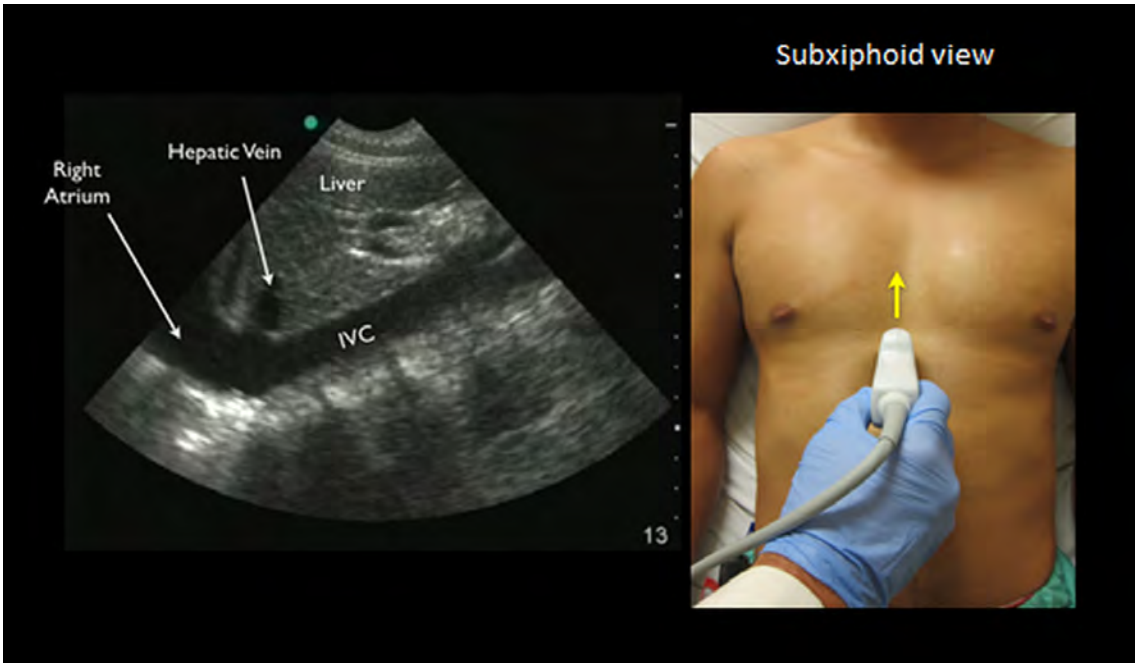


Figure 5: Subxiphoid IVC view probe position for and normal anatomy.
The left image is the long axis view of the IVC demonstrating the hepatic vein confluence with the IVC and entry into the right atrium, the liver is seen in the near field.
The image on the right is the corresponding position of the transducer on the patient with the yellow arrow indicating the direction of the probe marker.

Scanning notes for the four primary cardiac views

– Additional more advanced scanning includes identification of valvular abnormalities, structural congenital abnormalities, aortic root dilatation during dissection and ejection fraction estimates. These advanced techniques are not discussed here but can be found at online resources in Chapter 27, Reference resources for ultrasound'.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

11.2 Normal cardiac anatomy

Adults

In general, the normal heart lies within the mediastinum along an axis from the right mid-humerus to the left elbow. The cardiac apex points inferior, anterior and approximately 60 degrees to the left. The four heart chambers are hypoechoic with echogenic walls similar to that of other muscular tissue. The heart valves are hyperechoic when compared to the heart walls as is the pericardium (also called shimmering). The pericardium is visualised as a ribbon of tissue surrounding the heart. Normal anatomy of the heart in the standard cardiac views is described above (Figures 1- 4).

Paediatric

The normal paediatric heart is similar to the adult in lie and axis. However, you may need to move the probe closer to the sternum in babies and use a higher frequency linear probe (such as the HFL38x) given the shorter depth. Ultrasound is mostly used for identification of cardiac standstill (asystole) and pericardial effusion in paediatrics. While recognition of structural abnormalities can aid providers in detecting congenital heart disease, it is often difficult to identify specific abnormalities and beyond the scope of this manual. Normal appearing anatomy on bedside exam will still require comprehensive echocardiography to effectively rule out disease if available. We suggest you work to recognize 'normal' from 'abnormal' using the chapter's basic principles.

11.3 Pathology

11.3.1 Pericardial effusion

Pericardial effusion is the accumulation of fluid within the pericardium. A pericardial effusion is easiest seen in the parasternal long and short axis views but may be viewed in the other views. Steps to evaluate for pericardial effusion include:

1. Identify the heart in the parasternal long view (see Scanning Techniques section).
2. Observe the dependent space between the descending thoracic aorta (DTA) and myocardium. The DTA appears as a cylinder posterior to the mitral valve and left atrium. A pericardial effusion will appear as an anechoic stripe surrounding the heart (Figure 6).
3. To ensure accuracy, pericardial effusions should always be confirmed in more than one view if possible.

Small effusions can be confused with pericardial fat pads, which will appear anteriorly as isolated dark areas with bright speckles. Moderate to large effusions are circumferential, and can be seen in the near and far field in the long and short axis views (Figure 7).

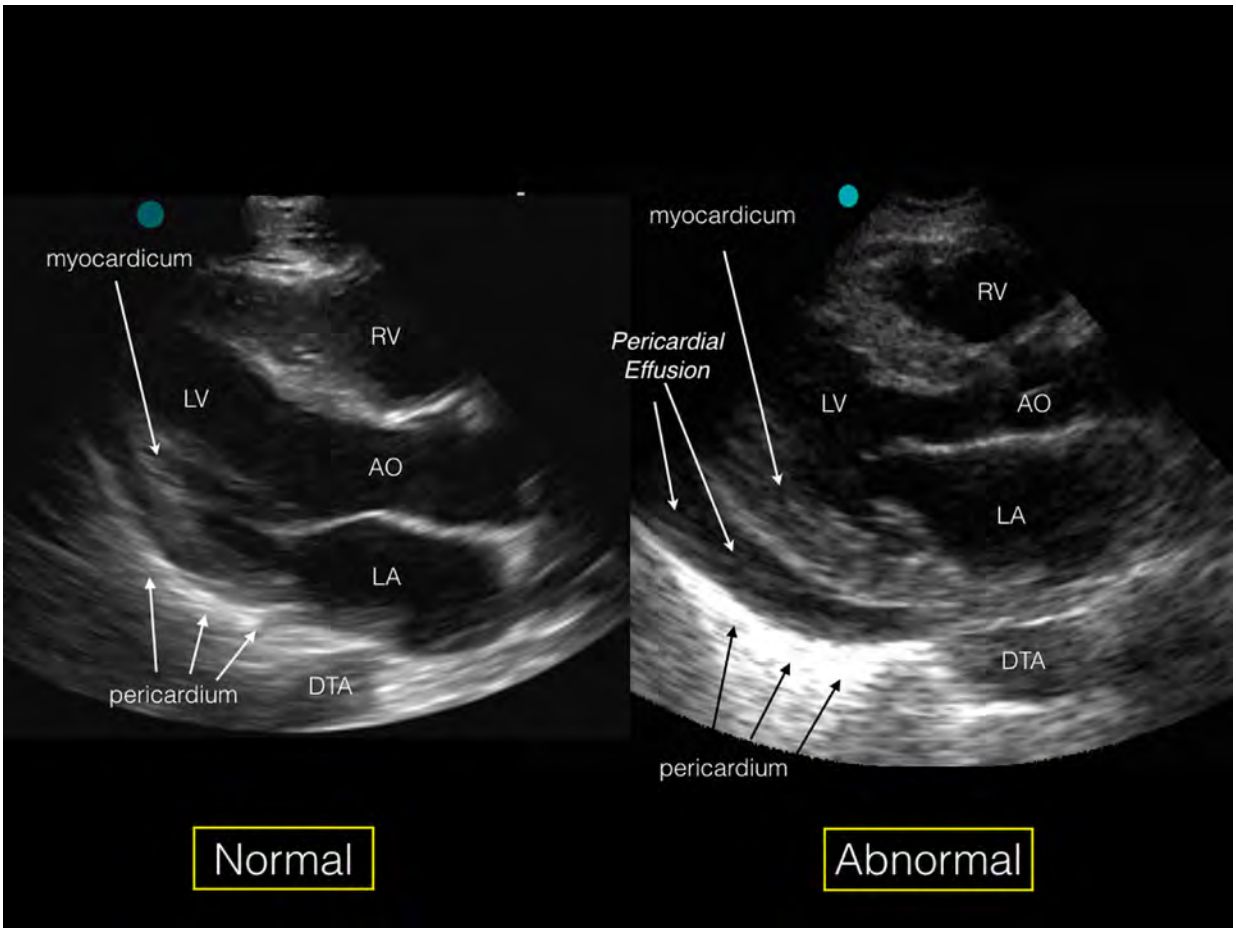


Figure 6: Normal parasternal long view compared with a moderate pericardial effusion
The image on the left shows no effusion in the dependent position between the descending thoracic aorta (DTA) and myocardium. Compare this to the image on the right where there is a hypoechoic strip between the left ventricular wall nd the pericardium indicative of a mild / moderate pericardial effusion.
Left ventricle (LV), right ventricle (RV), left atrium (LA), aorta (AO).

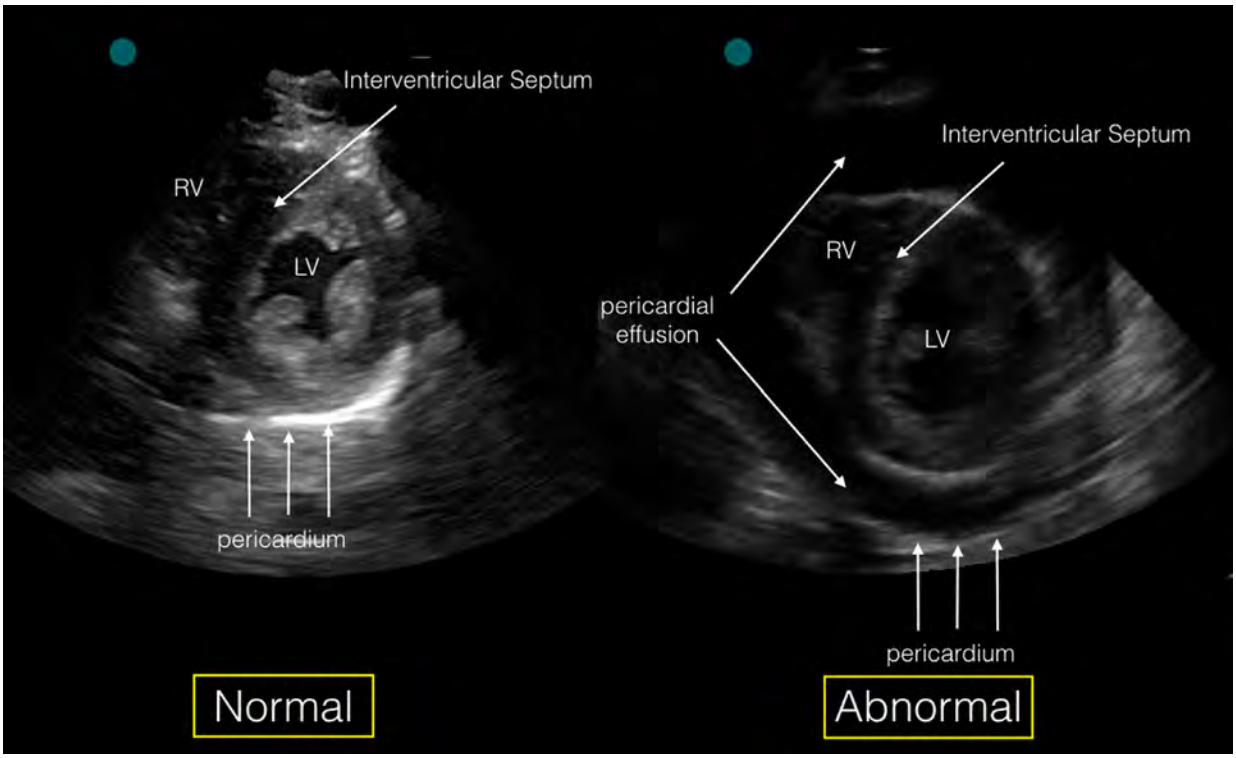


Figure 7: Normal parasternal short axis view compared with a large pericardial effusion
The image on the left shows normal anatomy, left ventricle (LV)
and right ventricle (RV) pericardium and no effusion.
Compare this to the image on the right, where the large pericardial effusion is located
around the heart and is mainly noted inferior to the left ventricle.

11.3.2 Tamponade

Cardiac tamponade is defined as a condition in which fluid in the pericardial space impinges on the myocardium which decreases cardiac output resulting in hemodynamic instability. Cardiac tamponade is a clinical diagnosis, with echocardiography aiding in supplying objective hemodynamic information. Echocardiographic evidence of cardiac tamponade can be characterized by multiple methods including:

1. Diastolic collapse of the right atrium and the right ventricle free wall,
2. Exaggerated respiratory variations of transmitral and transtricuspid Doppler inflow velocities, and
3. Inferior vena cava (IVC) plethora (lack of inspiratory collapse (see Volume Status section below).

The pathologic pressure from the pericardial effusion causes diastolic collapse of the cardiac chambers, particularly the right ventricle, inhibiting normal cardiac filling. This collapse is the most commonly cited criteria for echocardiographic confirmation of tamponade physiology and is discussed below (Figures 8 and 9).

Steps to evaluate for cardiac tamponade:

1. Identify the heart in the parasternal long view (see Scanning Techniques section).
2. Evaluate for an anechoic stripe surrounding the heart between the descending thoracic aorta and the myocardium (pericardial effusion).
3. If tamponade is present, the thin walls of the right ventricle or right atrium collapse during diastole (seen as the opening of the mitral valve) due to the increased pressure of the pericardial effusion.
4. Identify the heart in the parasternal short view (see Scanning Techniques section).
5. Observe the collapse of the right ventricle or right atrium during diastole.

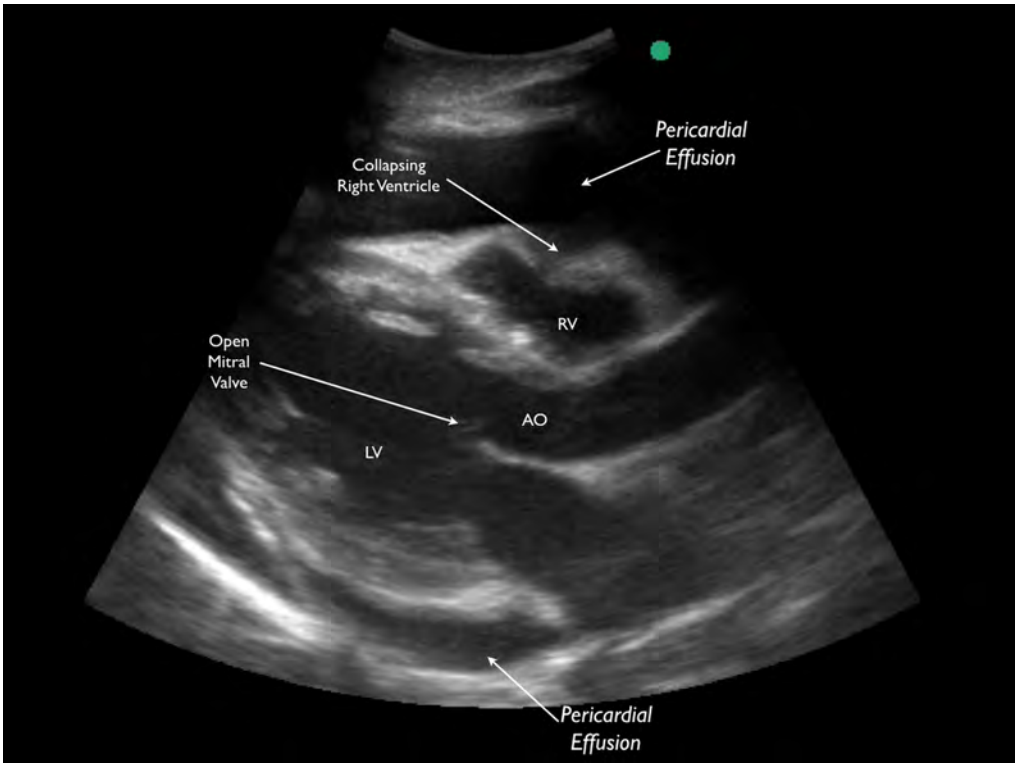


Figure 8: Parasternal long view of right ventricular collapse during tamponade
Right ventricle (RV) wall collapse (collapsing right ventricle) is demonstrated during diastole, when the mitral valve opens (open mitral value). In this view, also visualize the aortic outflow (AO), left ventricle (LV) and the large pericardial effusion, seen both posterior (bottom of screen) and anterior (top of screen).

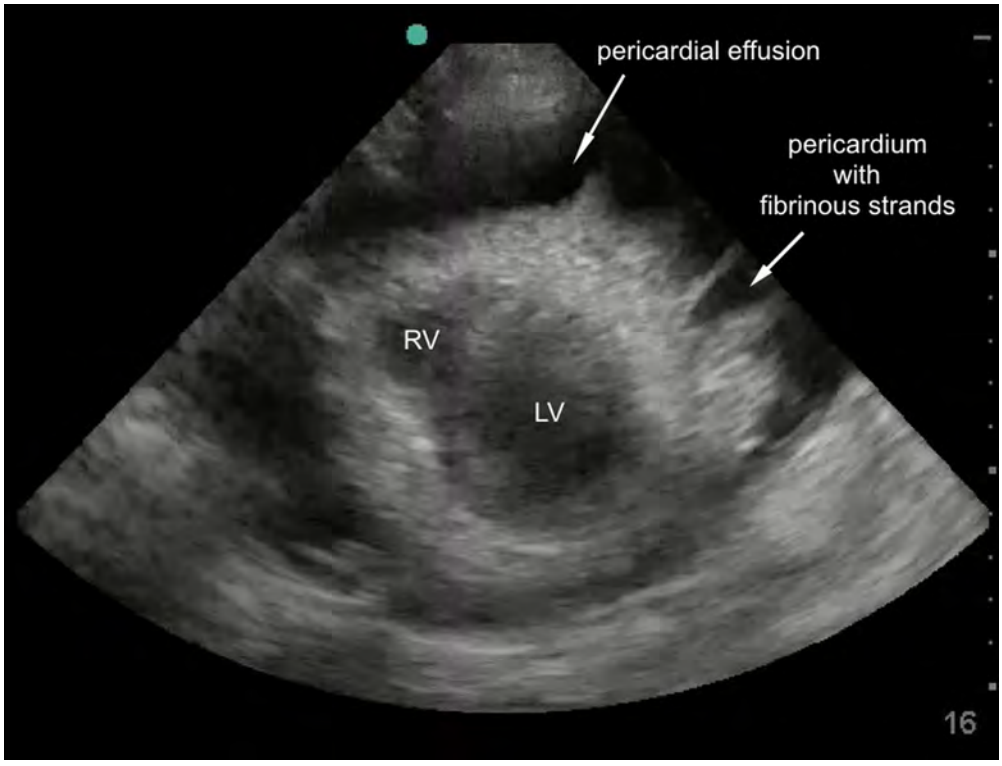


Figure 9: Parasternal short view of left ventricle during tamponade
The thin wall of the right ventricle (RV) collapses during diastole from increased pressure of the pericardial effusion. Note the large amount of fibrinous stranding on the pericardium which is often seen in patients with disseminated tuberculosis.

11.3.3 Heart failure

Heart failure is defined as the inability of the heart to contract appropriately enough to ensure adequate circulation of blood or appropriate cardiac output. There are various types of heart failure which include left-sided diastolic and systolic as well as right-sided, but we will focus on left-sided heart failure in this edition because it is more clinically relevant. In congestive heart failure the cardiac silhouette is often enlarged and may not fit into one single image screen. Contractility is poor and is best appreciated during real time scanning / video and not in a single still image. It should be noted that ultrasound evaluation for heart failure includes the parasternal long view, a lung assessment for pulmonary oedema, and IVC ultrasound for a more sensitive diagnosis. Steps to evaluate for heart failure include:

1. Identify the heart in the parasternal long view (see Scanning Techniques section).
2. Observe the motion of the left ventricular wall. The contraction of the wall during systole normally causes a partial obliteration of the ventricular cavity. A diminished contraction is indicative of poor cardiac squeeze.
3. Find the mitral valve. The anterior leaflet of the mitral valve should brush up against the interventricular septum during systole, a phenomena often called the 'mitral slap'. The valve leaflet appears to stop midway before touching the interventricular septum in heart failure when the squeeze is poor (Figure 10).

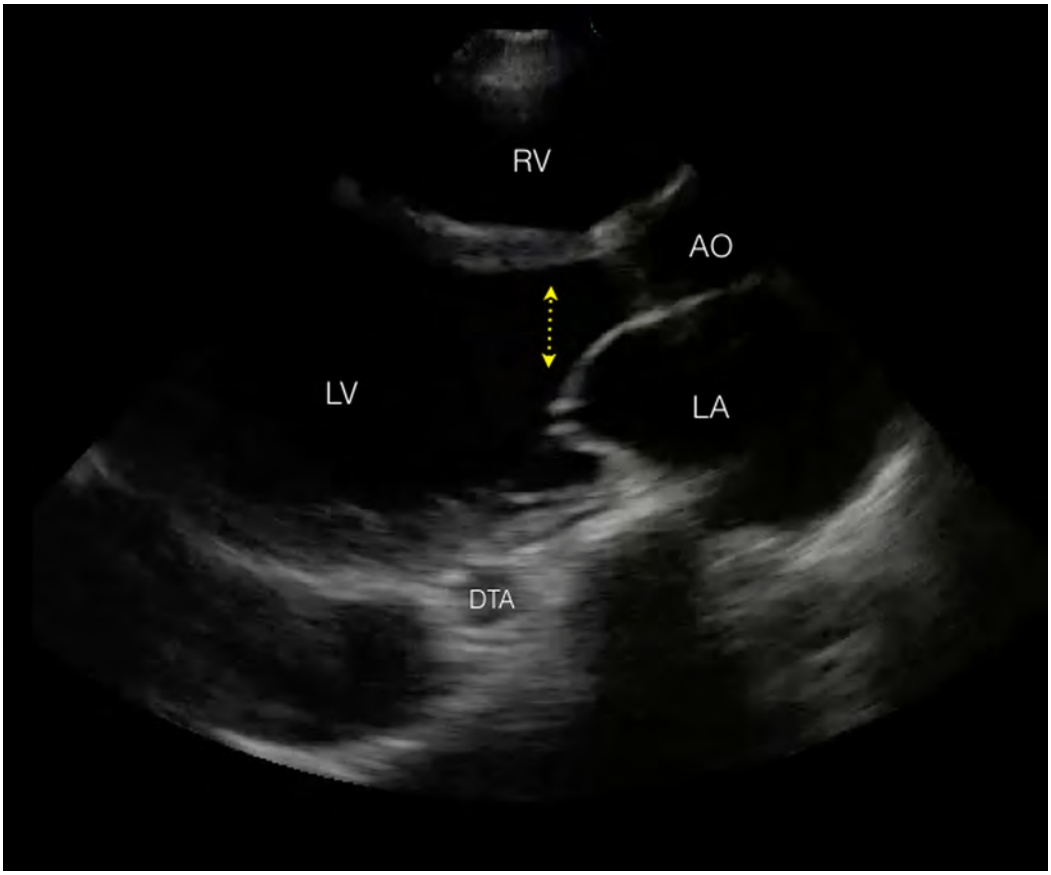


Figure 10: Congestive Heart Failure
Parasternal long view demonstrates the right ventricle (RV), left ventricle (LV), left atrium (LA), aortic outflow (AO) and descending thoracic aorta (DTA).
In congestive heart failure the cardiac silhouette is enlarged, often does not fit into the image and there is poor contractility. This is best observed during real time scanning, but is demonstrated here, during late systole where the mitral value and the interventricular septum do not meet (double arrow).

4. Evaluate the lungs.

   Steps to evaluate the lungs:

   - The 5-10 MHz (high-frequency) transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is recommended.
   - Place the patient in a semi-recumbent position.
   - Place the transducer in between the ribs from the second to the fourth intercostal space between the midclavicular and axillary lines with the marker pointing towards the patient's head.
   - In between the two ribs dark shadows of the rib is the 'pleural line', a hyper echogenic line which is the interface between the chest wall and the lung.
   - Observe for 'B-lines' which many represent evidence of interstitial fluid and volume overload (Figure 11).
     - B-lines are a type of comet-tail artefact arising from the pleural line to the bottom of the screen without fading. This is described in detail in Chapter 23, Paediatric chest.
       - The lines are hyperechoic reverberations that move with the respiration cycle and can be indicative of pulmonary oedema. This must be taken in clinical context given pneumonia and lung masses and pleural effusions are also common causes of B lines.
       - Up to two B lines can be considered normal, but three or more are considered pathological. Your index of suspicion should be high when two or more are noted.

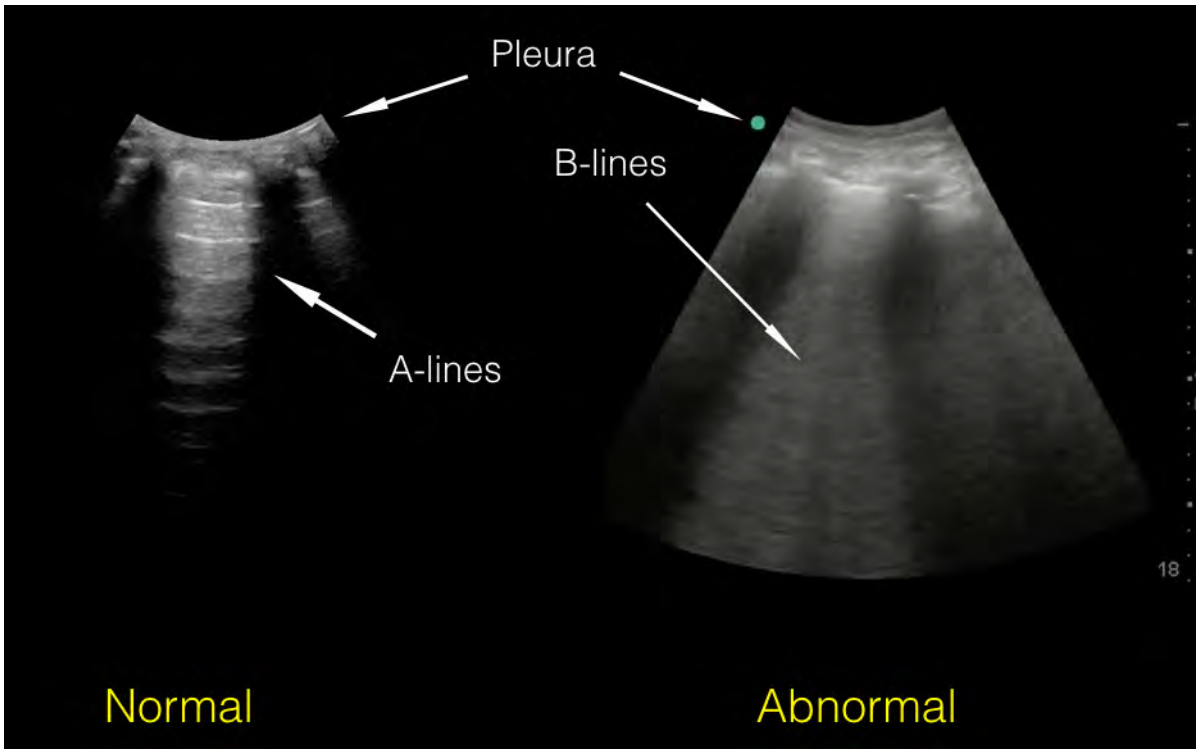


Figure 11: Normal lung with ribs and pleural line compared to lung with B-lines indicating volume overload.
The images show the transthoracic view of normal and abnormal lung with the pleura; a hyperechoic line at the top of the screen. Under normal conditions such as on the left, A lines are present, as horizontal, regularly spaced sharp lines which are reverberations of the pleural line and comet tails are largely absent. Pulmonary oedema is present on the right with B- lines or comet tails as rays spreading away from the transducer towards the bottom of the screen which synchronously move with lung respiration.

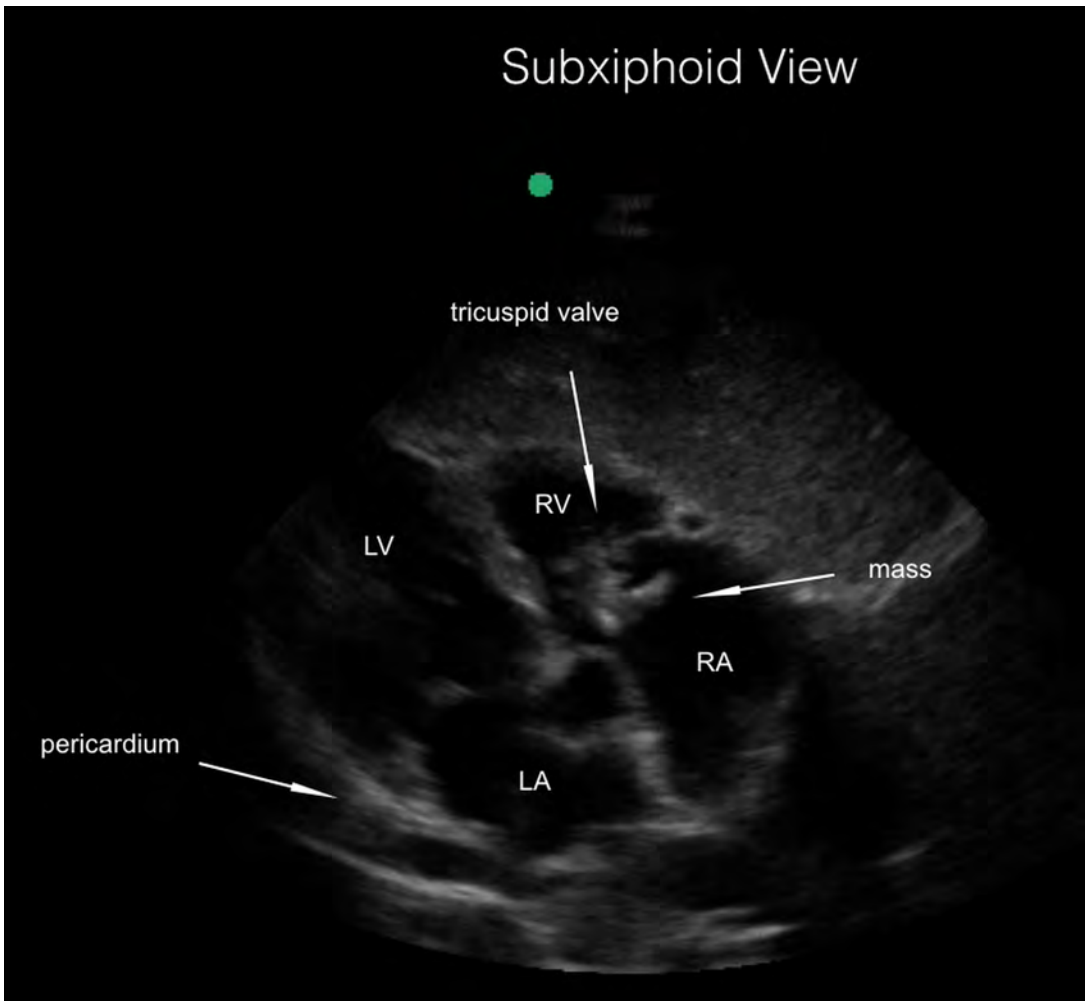
5. Evaluate the IVC (see Scanning Techniques section & 11.3.6). A dilated IVC without respiratory cycle variability is a sign of high preload pressures and impaired cardiac function.

11.3.4 Infective endocarditis

Infective endocarditis (IE), an infection of the inner lining of the heart, is a serious condition that requires prompt recognition and early treatment. Clinical findings that prompt evaluation of this disease include fever, murmur and evidence of peripheral emboli. Bedside ultrasound may demonstrate cardiac valvular vegetations (i.e. abnormal out growths of the valve). Vegetations as small as six millimetres may be seen in the parasternal long and short axis and subxiphoid views. Steps to evaluate for infective endocarditis:

1. Visualize the mitral valve in the parasternal long axis view (see Scanning Techniques section).
2. Visualize the mitral valve and the tricuspid valve in the apical four chamber view (see Scanning Techniques section).
3. Evaluate the valves in the above mentioned views for vegetations (abnormal outgrowths of the valve) (Figure 12).

Valvular incompetence causing regurgitation (e.g. tricuspid regurgitation) in the setting of clinical suspicion of IE should prompt further investigation (blood cultures, comprehensive echocardiographic studies or empiric treatment depending on availability).



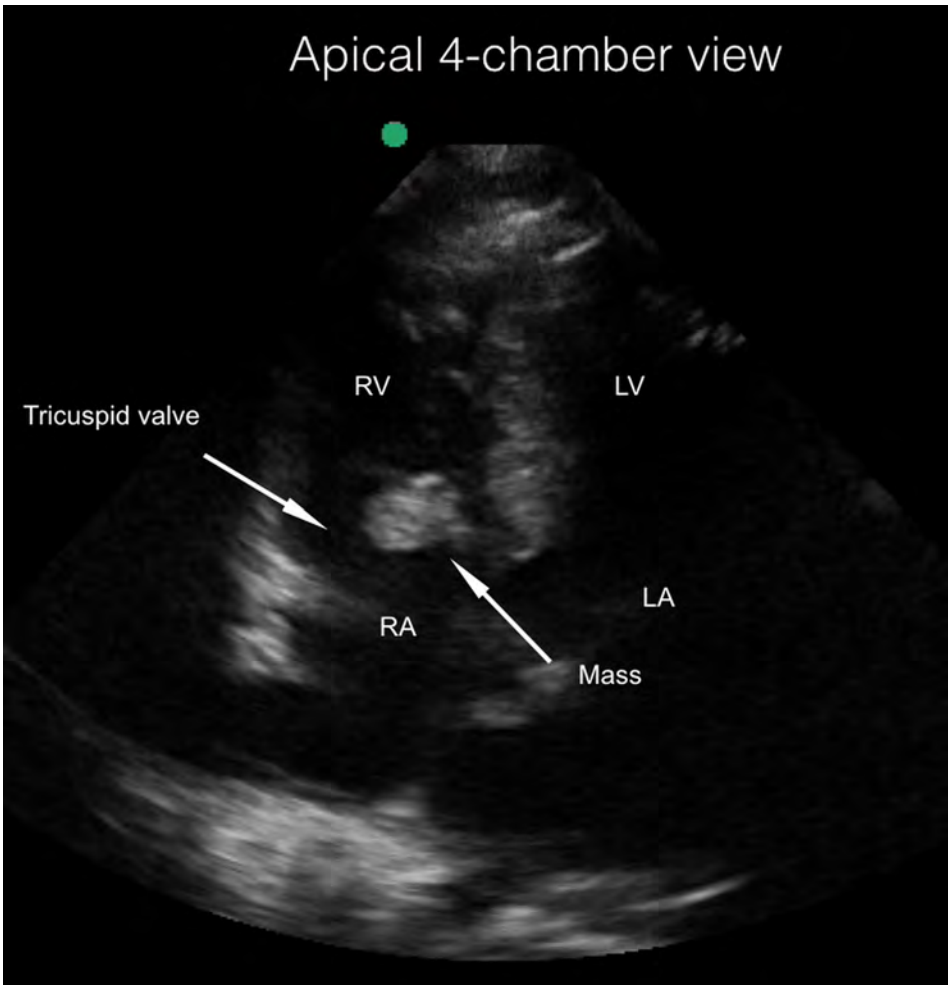


Figure 12: Infective endocarditis
The picture on the top is the subxiphoid axis. The four chambers of the heart: left ventricle (LV), right ventricle (RV), right atrium (RA) and left atrium (LA) are visualised, with the pericardium. A small hyperechoic mass (mass with arrow) is demonstrated on the tricuspid valve.
The figure on the bottom is an apical four-chamber view in a different patient. The four chambers of the heart: left ventricle (LV), right ventricle (RV), right atrium (RA) and left atrium (LA) are visualised, with the pericardium. The hyperechoic mass (mass with arrow) is again demonstrated on the tricuspid valve. In the appropriate clinical setting this is indicative of endocarditis.

11.3.5 Right heart strain

Right heart strain is associated with increased pulmonary artery pressures. Common causes include pulmonary hypertension, mitral stenosis, pulmonary embolism, chronic lung disease and congenital heart disease. Observing right heart strain in association with pulmonary embolism is a predictor of pending shock.

Steps to evaluate for right heart strain:

1. Identify the heart in the apical four-chamber view (see Scanning Techniques section).
2. The left ventricle (LV) is generally about twice the size of the right ventricle (RV). An RV that exceeds this ratio or is even larger than the LV is consistent with right heart strain (Figure 13).
3. Identify the heart in the parasternal short axis view (see Scanning Techniques section).
4. Watch for paradoxical septal wall motion. The septum will be seen to ‘bow’ into the left ventricle in patients with right heart strain. This is often described as a ‘D-shaped’ LV.

5. Observe for McConnell's sign. This sign is akinesia (i.e. loss of movement) of the mid free wall of the RV and normal contractile motion of the apex. During right ventricular contraction, there is no movement of the mid-free wall ('stiff free wall') and normal apical contraction. Finding McConnell's sign has been associated with submassive and massive pulmonary embolism when clinical suspicion exists.
6. Observe for lack of respiratory variation of the IVC (see section on IVC in volume status), indicative of right heart strain.

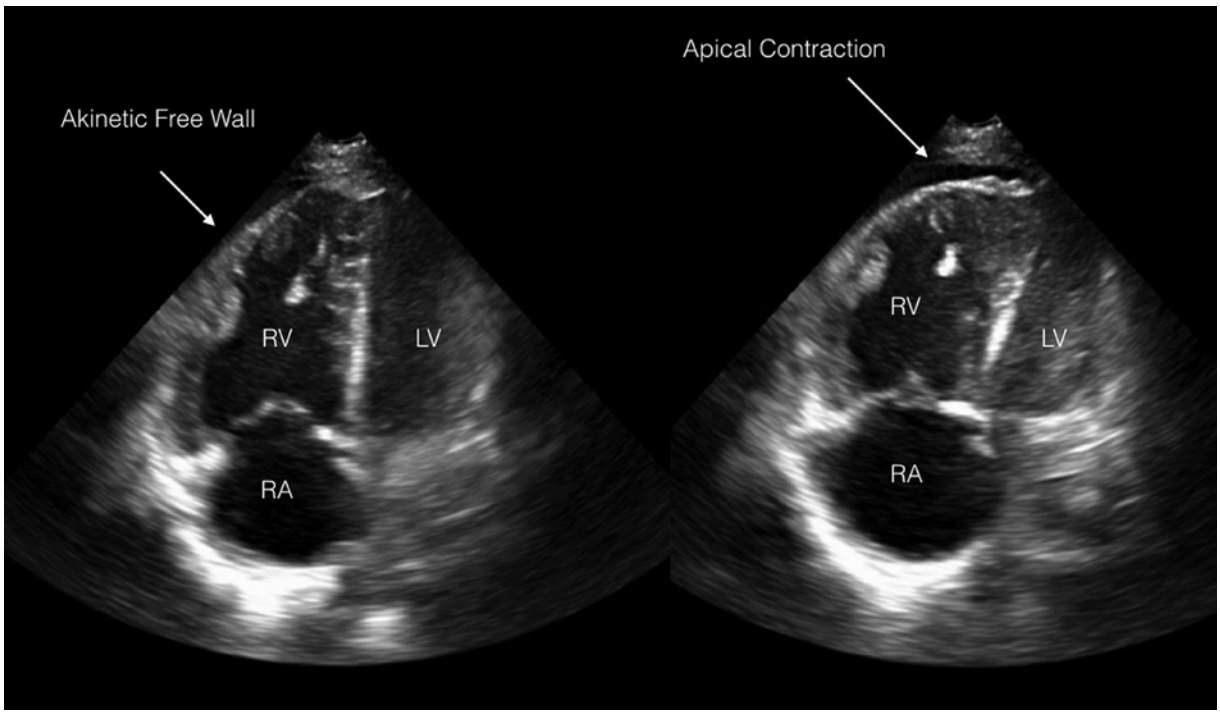


Figure 13: Right heart strain
In this apical four-chamber view, the right ventricle (RV) is larger than the left ventricle (LV) indicative of right heart strain of pulmonary embolism or pulmonary hypertension. McConnell's sign is best observed during real time scanning, but it is demonstrated on the left image by the loss of movement in the mid free wall marked 'akinetic free wall' and on the right image by the normal 'apical contraction' of the apex of the heart. Right atrium (RA).

11.3.6 Volume status

In the hemodynamically unstable patient, a reliable assessment of volume status can be useful in guiding management. The ability for the patient to tolerate a fluid challenge (referred to as fluid tolerance) can be rapidly assessed with point-of-care ultrasound by evaluation of the IVC variability.

Ultrasound assessment of the IVC for volume status is explained in more detail in Chapter 12. During a rapid assessment, the clinician's measurements of the IVC diameter are not required, but rather an overall evaluation of gross variability during respiration may be used as a method to determine if the patient can tolerate an intravenous fluid bolus.

1. Identify the IVC in the subxiphoid view (see Scanning Techniques section).
2. The examiner should focus on the variability of the IVC 2-3 cm distal to the right atrium, approximately at the confluence of the hepatic vein during inspiration and expiration (Figure 14).
3. Ultrasonographic visualization of the IVC can correlate with right atrial pressure and may aide a clinician in the initial resuscitation of the critically ill patient. In conjunction with the clinical exam and an echocardiographic evaluation for gross ejection fraction, the IVC can be a useful

tool in the undifferentiated critically ill patient.

4. A greater than 40% collapsible IVC with normal respiration suggests to the clinician that the patient is fluid tolerant.
   - In severe cases of volume depletion (e.g. dehydration), the IVC may be very difficult to visualize other than at the diaphragmatic border.
   - Conversely, a large, non-collapsible IVC suggests elevated right-sided atrial pressures which can occur with acute decompensated heart failure, chronic pulmonary hypertension, a pulmonary embolus, cardiac valvulopathies (most commonly tricuspid regurgitation and mitral stenosis), cardiac tamponade, and right sided myocardial infarction.

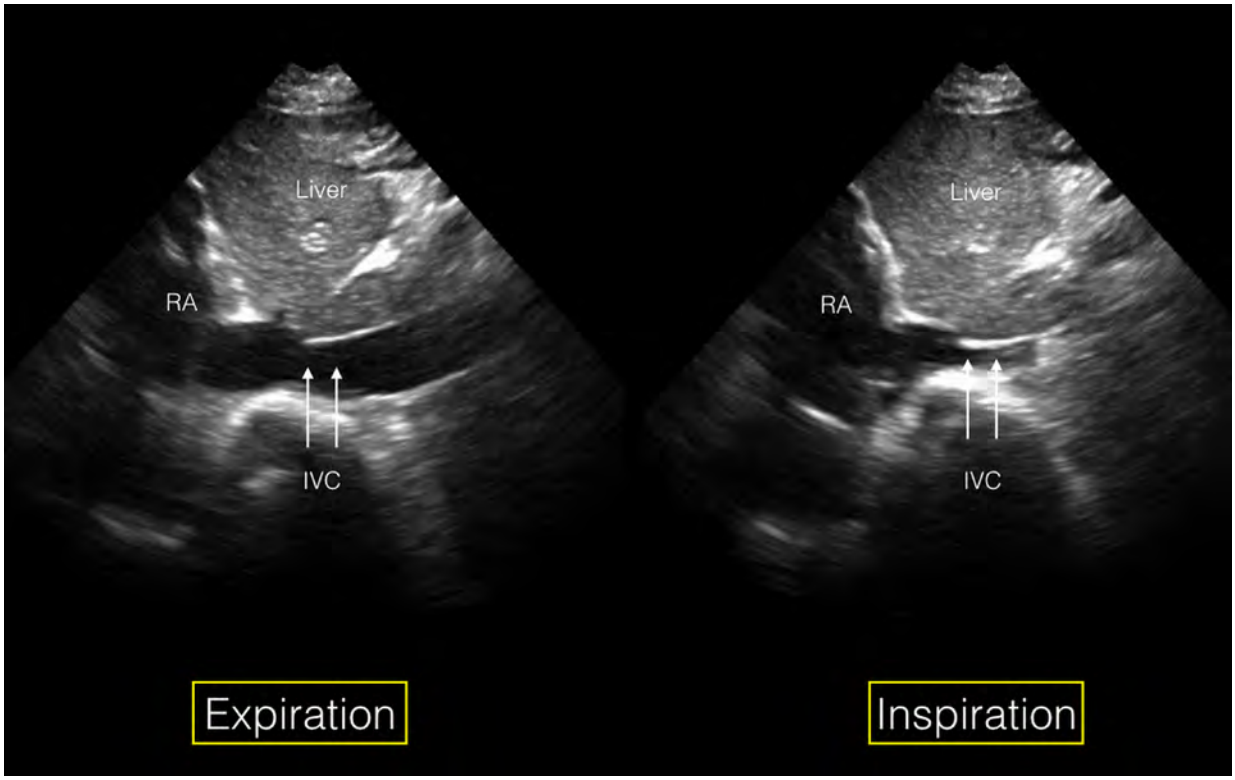


Figure 14: IVC during expiration and inspiration
The figure on the left demonstrates the inferior vena cava (IVC) during the expiratory portion of the respiratory cycle draining into the right atrium (RA).
The figure on the right shows the IVC during the inspiratory cycle with a collapse greater than 50% indicative of volume depletion.

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12. Ultrasound assessment of the inferior vena cava for volume status

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Ultrasound of the inferior vena cava (IVC) is a non-invasive tool that can quickly help determine the aetiology of hypotension and the fluid responsiveness of a patient (defined as increase in cardiac output with fluid loading). It is fast, cheap and without any known complications, so it can be repeated as often as necessary to monitor the resuscitation of the patient and determine how much fluid should be given or when fluids should be stopped.

This chapter will focus primarily on the use of IVC ultrasound in *spontaneously breathing adult patients*.

There are alternate resources for using IVC ultrasound in an intubated patient. IVC collapsibility has been studied, but is not reliable in paediatric patients.

Anatomy and physiology

The IVC sits just anterior to the spine and is the main vein which delivers blood from the middle and lower part of the body back to the heart (Figure 1). Ultrasound of the IVC evaluates the size and collapsibility of the intrahepatic portion of the IVC within the abdomen, during a respiratory cycle.

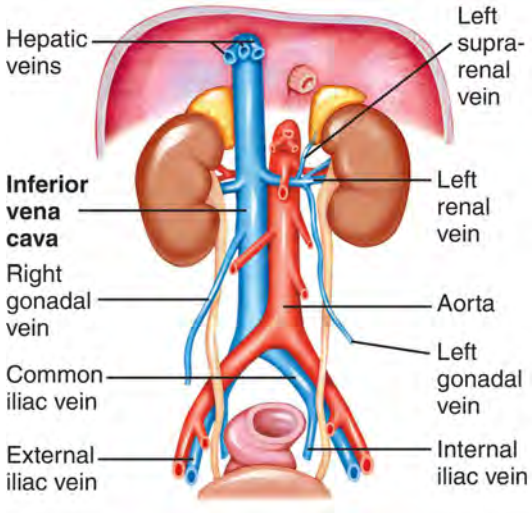

Figure 1: Intra-abdominal IVC anatomy
Image sourced from: http://medical-dictionary.thefreedictionary.com/Posterior+vena+cava

The IVC will collapse anytime the pressure within the IVC drops below the pressure outside the IVC (intra-abdominal pressure). The pressure within the IVC is determined by the blood volume, cardiac function and intrathoracic pressure. During spontaneous inspiration the intrathoracic pressure drops which increases venous return from the IVC into the heart. This drop in thoracic pressure pulls blood volume from the abdominal IVC into the thorax. This lowers the pressure within the abdominal IVC and the IVC collapses.

In volume overloaded conditions, however, inspiration will not result in significant collapse of the IVC because the normally compliant right atrium cannot further stretch to accommodate blood volume that would otherwise be pulled from the IVC into the thorax. Therefore, blood volume is not shifted from the abdominal IVC into the thorax and the pressure within the IVC does not drop.

> In general, in a patient with volume depletion, the IVC collapses.
> In a patient with volume overload, the IVC does not collapse significantly.

Utility

The IVC's collapsibility can be thought of as a way to see how 'full' a patient's 'tank' is. That is to say the IVC collapsibility is most useful to assess the intravascular volume status to help identify fluid responders and the aetiology of hypotension in shocked, adult patients.

For example:
- Patients with hypovolemic or haemorrhagic shock would be expected to have an extremely collapsed or 'empty' IVC because the drop in blood volume lowers the pressure within the IVC.
- Patients with cardiogenic failure would be expected to have a distended, non-collapsible IVC because the impairment of forward cardiac flow results in a back pressure that raises the IVC pressure.

These examples illustrate the intuitive nature of IVC ultrasound to manage shocked patients. However, the use of IVC ultrasound to determine the aetiology of shock is typically part of a larger protocol that incorporates lung and cardiac ultrasound and is outside the scope of this chapter.

Once the cause of shock is determined, IVC ultrasound can be very helpful to guide fluid resuscitation. **However, it cannot be overstated that using IVC ultrasound in isolation without any clinical context is likely to lead to poor decision making**. For example: a collapsing IVC could be seen in a patient with severe dehydration from an acute diarrheal illness and another patient with severe hypoxemia from pneumonia. Fluid loading both patients may help the patient with diarrhoea but potentially harm the severely hypoxemic, pneumonia patient.

> A collapsing IVC may suggest a patient would respond to fluids,
> but it doesn't determine **if fluids should be given**.

12.1 Scanning Technique – IVC assessment

Transducer

A 5-1 MHz phased array transducer such as the P21x which is compatible with the MSF standard M-Turbo is recommended. The smaller footprint of the phased array it easier to obtain an image in a patient with significant bowel gas and/or otherwise smaller scanning window.

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is also suitable.

Apply gel to the transducer face and/or patient. If no gel is available, use water. Never use oil or alcohol based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid the spread of infection.

Patient position

Ideally the patient should be positioned lying on their back, i.e. supine.

If the patient is unable to lay completely supine measurements may be made with a patient on their back but with the head of bed elevated.

If the IVC is difficult to visualize in the supine position sometimes placing the patient's right arm behind their head can improve views.

Patient position and scanning steps

1. Start the scan in the midline under the xiphoid process, or in the right xiphocostal angle (Figure 2). It is very important to place the transducer as close to the xiphoid process as feasible. Position the transducer in the transverse position. If using the curved array transducer (C60X) the marker should be placed to the patient's right (9 o'clock). If using the phased array transducer (P21x) the marker should be placed to the patient's left (3 o'clock).

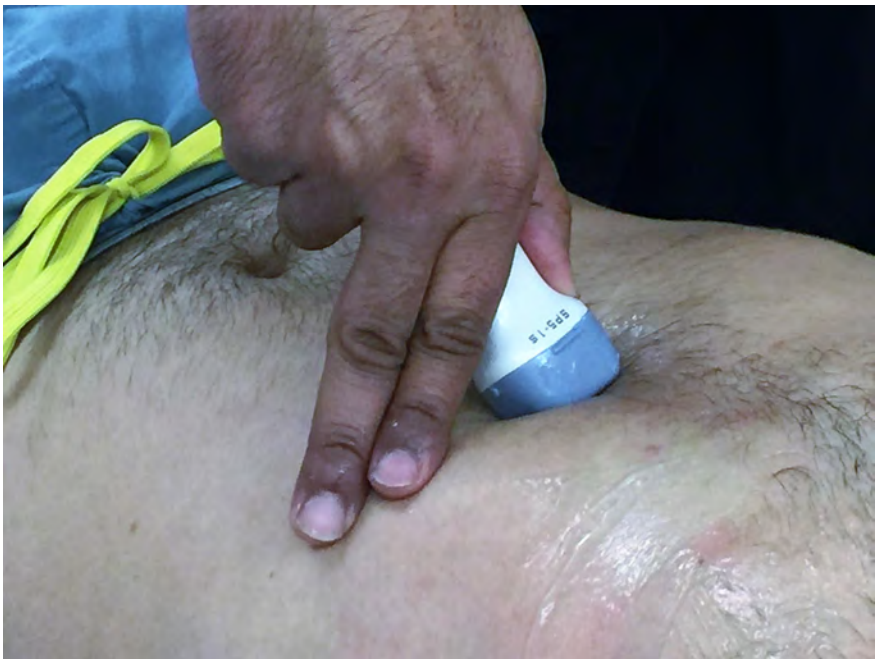

Figure 2: Transducer position for IVC ultrasound in short axis, in this case using a phased array transducer.

2. Identify the IVC. In this initial position the liver should be your acoustic window. The depth should be sufficient to see the spine. Just anterior to the spine this scan should show paired circular anechoic structures. The structure directly adjacent to the liver is the IVC. At this level the IVC typically appears thin walled, and is circular or ellipsoid (Figure 3).

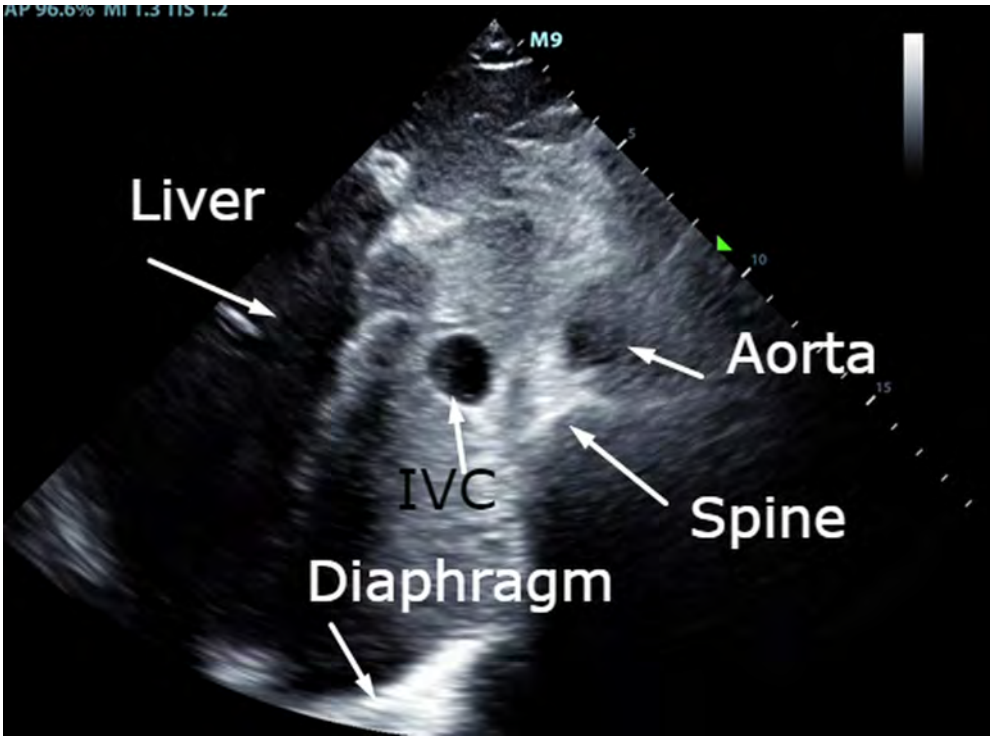

Figure 3: The IVC is seen in short axis (transverse) view in the near field.
The liver is used as an acoustic window. The paired anechoic structures (IVC and aorta) are positioned just anterior to the spine, with the IVC adjacent to the liver.

3. Rock the transducer left and right so that the IVC is in the middle of the screen, and fan the transducer superiorly (towards the head). The IVC should be visualized through its intrahepatic course. The hepatic veins should be seen entering the IVC as an additional confirmation that the visualized structure is the IVC (Figure 4).

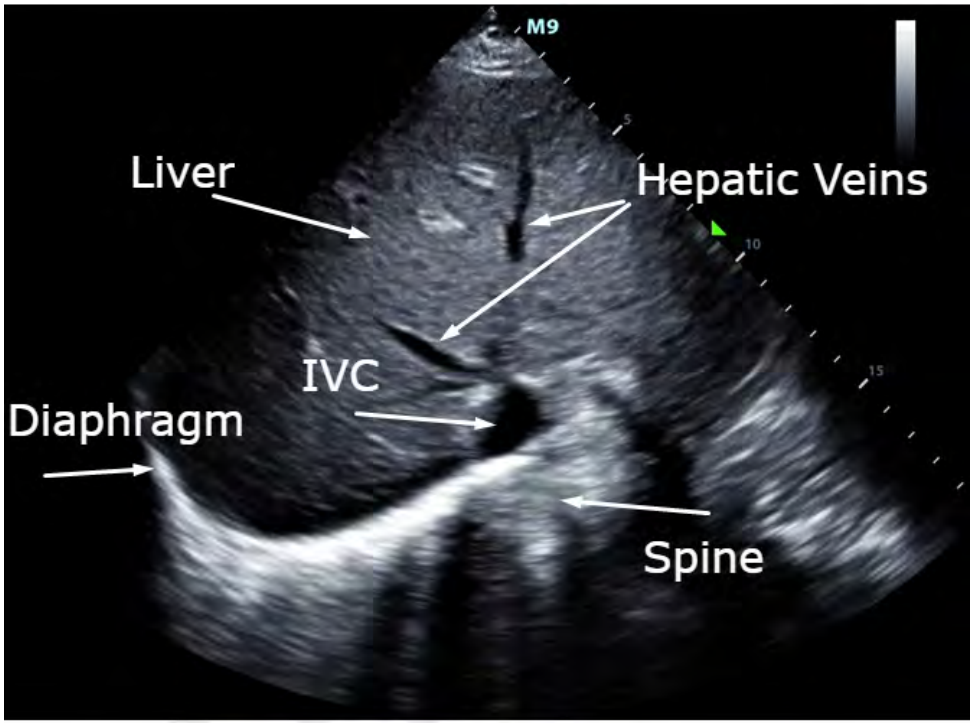

Figure 4: The IVC seen in short axis (transverse)
The liver is used as an acoustic window and is seen adjacent to the IVC. The hepatic veins are seen entering the IVC which is centrally located anterior to the spine.

4. From this view keep the IVC in the centre of the screen and slowly rotate the transducer clockwise until the marker is towards the patient's feet, or slightly further. The transducer should end up approximately between 5-7 o'clock (Figure 5).

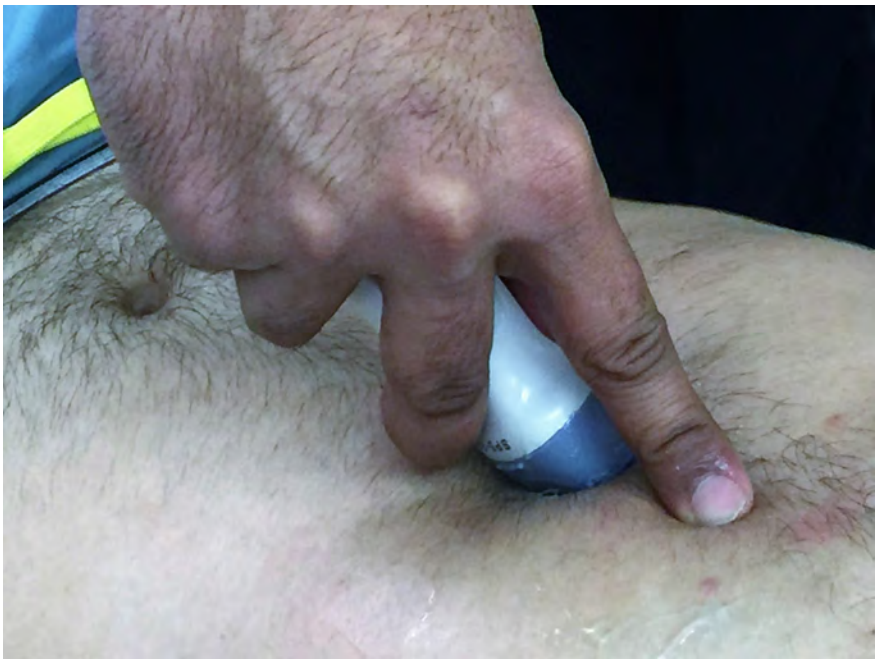

Figure 5: Transducer positioning for IVC in long axis
The position of the index finger remains directly on the xiphoid to assist keeping the IVC centred on the screen.

5. It is important to keep the transducer oriented in the long axis of the IVC. It can also be helpful to look closely at the IVCs walls in this view, if the walls are very echogenic/bright white throughout the respiratory cycle it is likely that the IVC is being well visualized in the long axis (Figure 6).

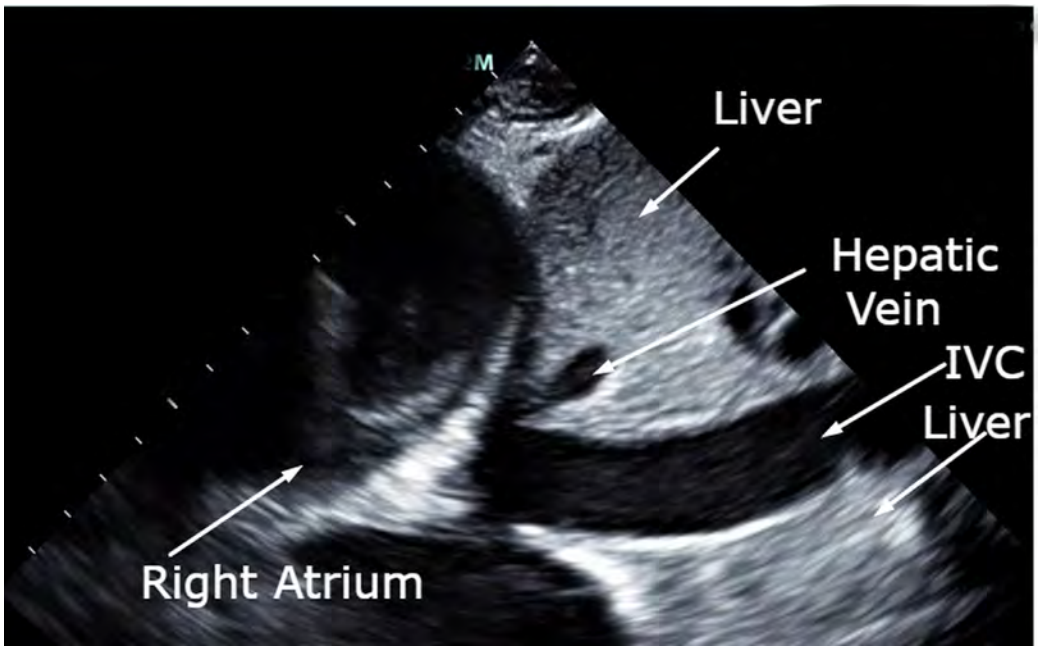

Figure 6: Good quality longitudinal view of the IVC
The right atrium can be seen on the left side of the screen the hepatic vein entering the IVC and the liver adjacent to the IVC.
The bright white echogenic walls of the IVC confirm the good view.

6. Fanning the transducer from left to right over the IVC can help ensure that one selects the best view of the IVC.
   - If bowel gas obscures the view, first try to shift the transducer position superiorly to be as close to the xiphoid as possible. If this doesn't work, move the transducer to the patient's right within the right xiphocostal angle.
   - Sometimes having the patient take a deep breath and hold it can make it easier to initially find the IVC by bringing the liver down in the field of view. One may also apply pressure to the transducer to move bowel gas out of the scan field.
   - A common pitfall among novices using the long axis method is to incorrectly identify the aorta as the IVC. Avoid this mistake by visualizing the hepatic vein entering the IVC.
7. With the transducer in this position monitor the patient during a few respiratory cycles.
8. Confirm the IVC is still well orientated in the long axis and save a clip or press the 'freeze' button to pause scanning and using the touch pad scroll through the last 30-60 seconds of scanning. Watch the IVC over multiple respiratory cycles.
9. Closely evaluate the portion of the IVC immediately distal to the hepatic vein for collapsibility during a respiratory cycle (Figure 7). Identify the maximum diameter and minimum diameter and use the equation below to calculate the collapsibility index.
   - For novices, it is recommended to use the callipers to measure the degree of collapsibility.
   - For more advanced users it is acceptable to 'eyeball' the degree of collapsibility.

$$\text{IVC collapsibility} = \frac{\text{Maximum IVC diameter} - \text{Minimum IVC diameter}}{\text{Maximum IVC diameter}}$$

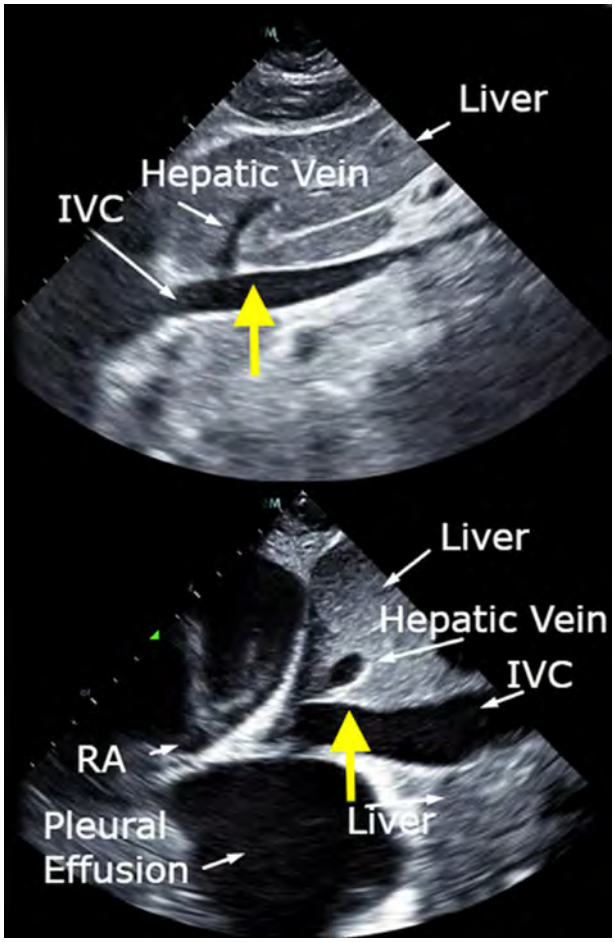

Figure 7: Two good quality images of the IVC in long axis in different patients
The anatomy can appear quite variable from patient to patient, but one can consistently use the liver, and the relationship of the hepatic vein and IVC to identify the proper vessel. The yellow arrow demonstrates where along the IVC the degree of collapsibility should be assessed.

Scanning notes for IVC volume status

– If the patient is severely dehydrated or in shock (e.g. sepsis, blood loss), the IVC may be difficult to visualize. The IVC may be extremely small or completely collapsed and difficult to view in the long axis.

– In the long axis it is important to be directly over the centre of the IVC (Figure 8) as mal-positioning (Figure 9) can lead to incorrect results.

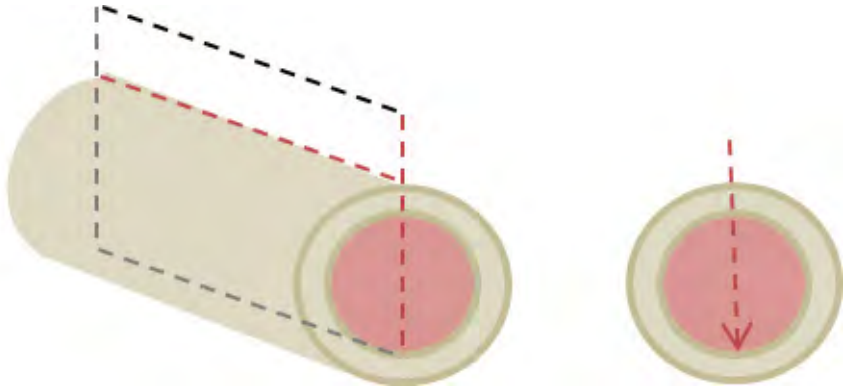

Figure 8: Proper scanning positioning over the centre of the IVC

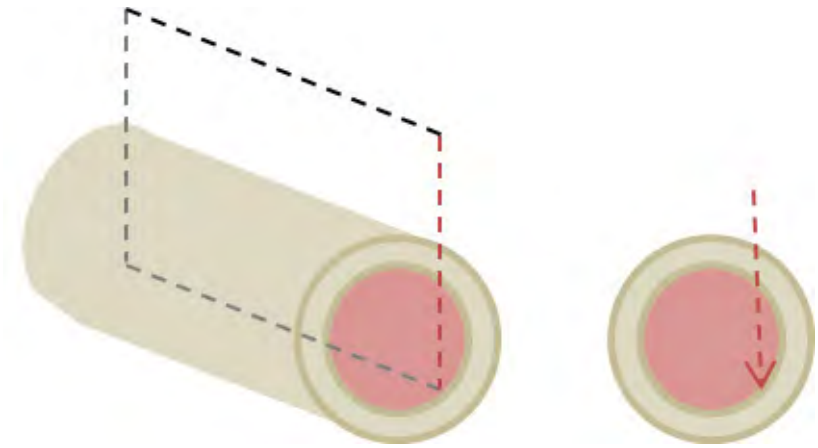

Figure 9: Mal-positioned scanning, not directly over the centre of the IVC

Always image over the centre of the vessel in long axis. If the image drifts to the left or right with respiration or transducer movement, it can give a false impression of IVC collapse.

– The best way to differentiate the IVC from the aorta is by directly tracking the hepatic vein into the IVC. Pulsatility and determining if the IVC enters the right atrium are not very reliable.

– IVC ultrasound should always be correlated clinically. It cannot tell you if fluids should be given. Rather it informs the clinician on whether or not the cardiac output will increase in response to fluid loading.

– Volume responsiveness with IVC ultrasound has not been validated in patients with right heart failure, cardiac tamponade or pulmonary embolism.

In ventilated patients the intrathoracic pressures are reversed, and the diameter of the IVC will increase in mechanical inspiration and decrease in mechanical expiration. See references for the most appropriate way to use the IVC in an intubated patient as it is outside the scope of this chapter.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

12.2 IVC collapsibility and fluid responsiveness

The degree of IVC collapsibility is the key determinant to identify patients that are likely fluid responsive:

– A patient with an IVC that collapses <15 % is unlikely to respond to fluids and additional volume should be limited under most circumstances (Figure 10).
– A patient with an IVC that collapses >40 % is likely to respond to fluids and can be administered if clinically appropriate (Figure 11).
– A patient with an IVC that collapses between 15-40 % represents a grey zone with higher uncertainty.

IVC Collapsibility	Fluid responsiveness
<15 %	Unlikely
15-40 %	Uncertain. Consider cardiac and lung ultrasound. Evaluate breathing pattern. Use alternatives for volume status (see below).
>40 %	Very likely

When the IVC collapsibility falls within the 'grey zone' (15-40 %) it is recommended to combine cardiac and lung ultrasound alongside IVC ultrasound to enhance its accuracy. Additional considerations should be entertained prior to determining fluid responsiveness:

– Evaluate the cardiac function and determine how well additional fluids may be tolerated. Dysfunctional hearts tend not to tolerate additional fluid loading.
– Evaluate the lungs for signs of pulmonary oedema. If present, additional fluids may exacerbate the pulmonary oedema and may not be well tolerated even in fluid responsive patients.
– Consider the breathing pattern of the patient. Dyspnoeic patients taking laboured breaths may be able to collapse their IVC even in a volume overloaded state. Patients with a grey zone IVC are less likely to be fluid responders in this circumstance.
– Consider the need for additional volume, risks/benefits of fluid loading, and other available tools to help determine fluid status.
– For example, one may want to be more cautious with fluids in a patient with severe cardiac dysfunction and diffuse B-lines on ultrasound, even if the IVC collapses >40%.

For more information, see Chapter 11 Cardiac and Chapter 23 Paediatric Lung.

Ultrasound findings and IVC collapsibility must always be correlated clinically.

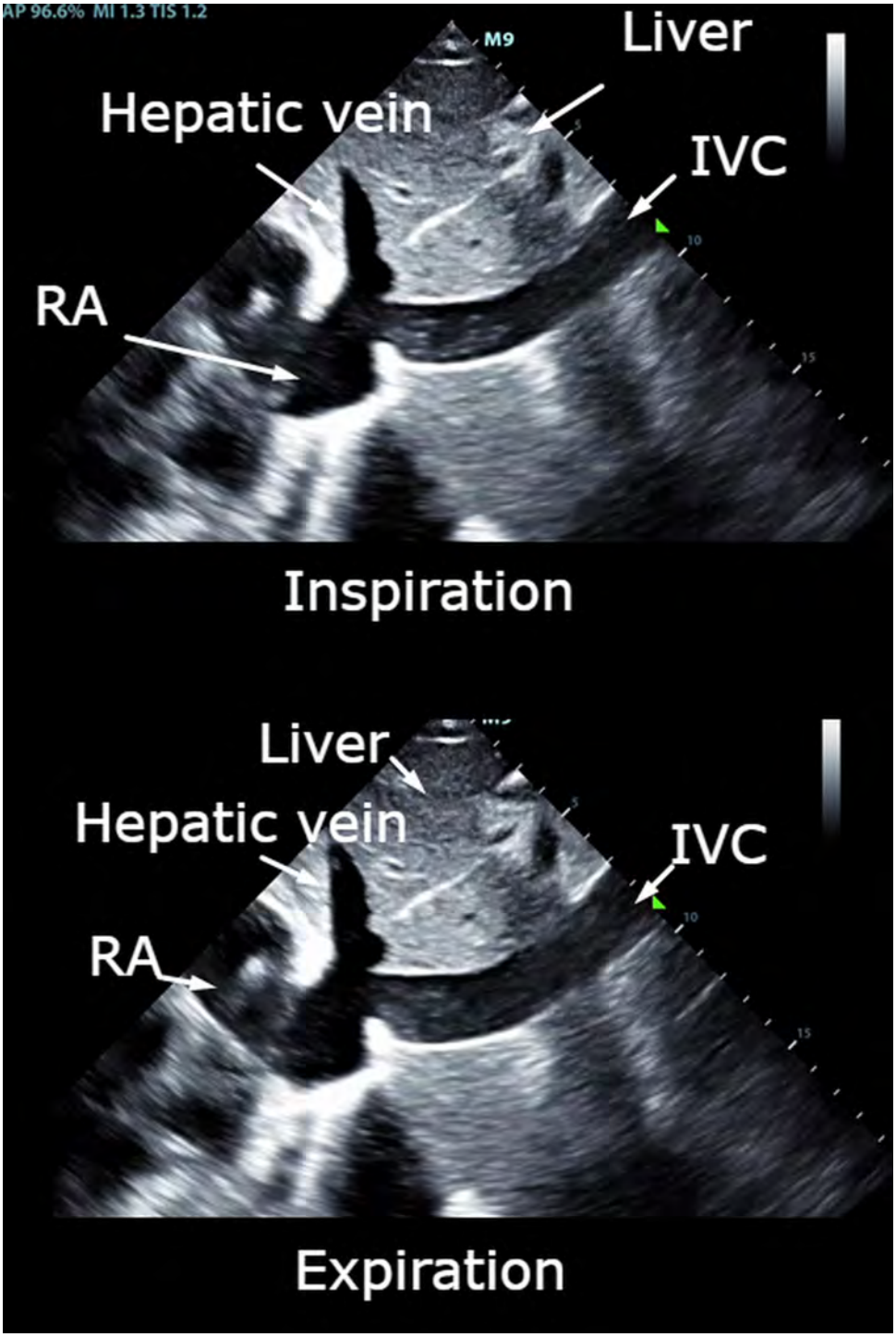

Figure 10: Good quality long axis IVC seen in inspiration and expiration
There is essentially no collapse seen (i.e. obviously less than 15 %),
this indicates the patient is not fluid responsive.

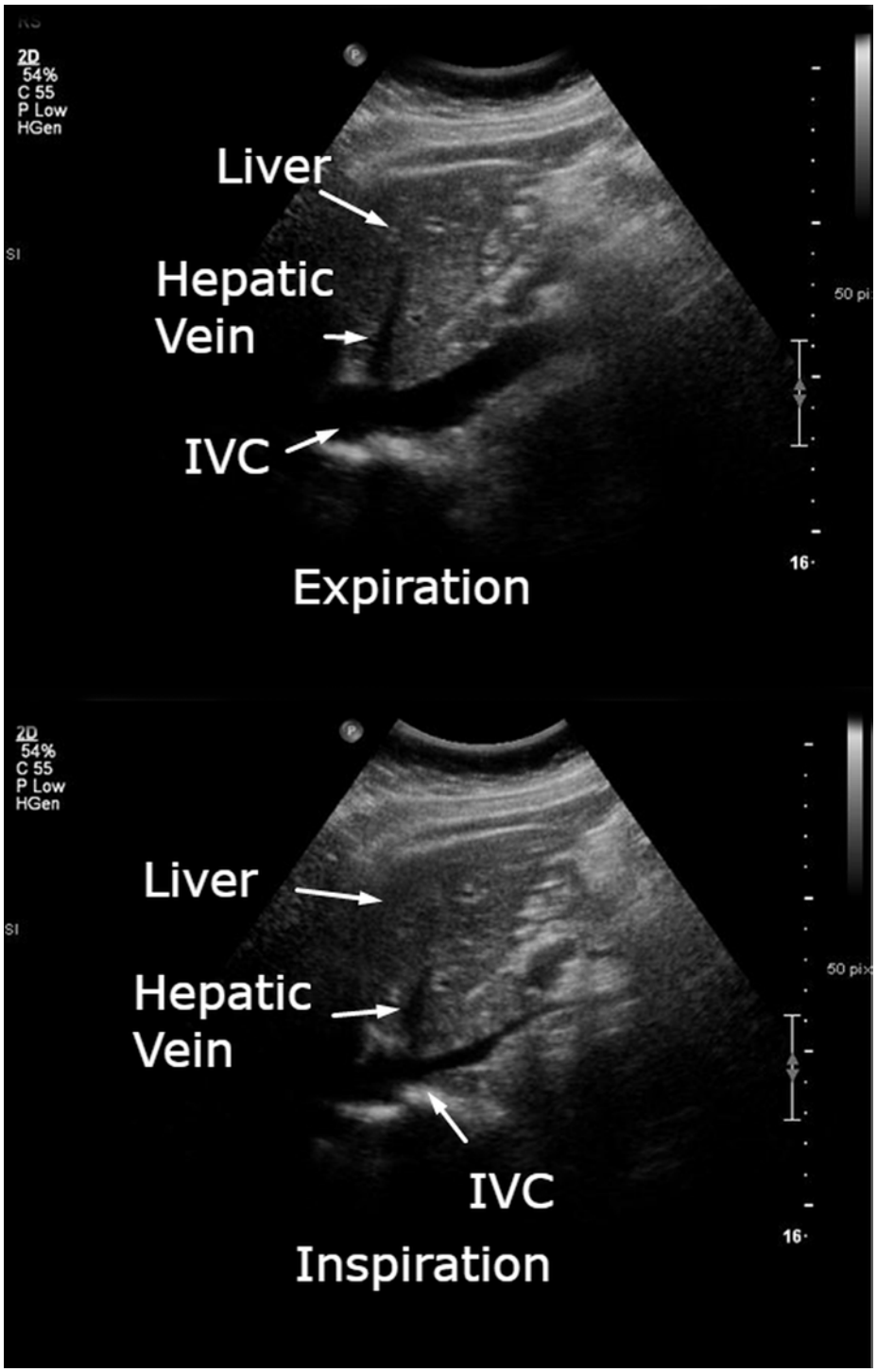

Figure 11: Good quality long axis IVC in expiration and inspiration This IVC has significant collapse (i.e. obviously greater than 40 %) and indicates the patient is very likely volume responsive.

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13. Abdominal aorta

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The abdominal aorta is the large artery that, as a continuation of the descending aorta, transports oxygenated blood from the heart to the abdominal cavity and lower body. An abdominal aortic aneurysm (AAA) is a dilation of the abdominal aorta which occurs as a result of weakening of the vessel wall and may lead to rupture of the aorta. The consequences of ruptured aorta without urgent access to appropriate medical care are often fatal.

In patients, especially those older than 50 years, presenting with abdominal, flank or back pain AAA should be considered as symptoms are often non-specific. Differentiating an aortic cause from a range of conditions such (e.g. renal stones) that may cause similar symptoms has direct impact on patient management. Specific risks for AAA include smoking, male gender, hypertension, and diabetes.

13.1 Scanning technique – abdominal aorta

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine.

Scanning steps and technique – abdominal aorta

1. The patient's position should be supine.
2. Start by positioning the transducer just below the bottom of the sternum, i.e. xiphoid process in the transverse position with the marker pointing to the patient's right.
3. Identify the aorta: The aorta is anterior to the spine on the left side. The aorta has a thicker, more echogenic, i.e. whiter, wall and is difficult to compress. The inferior vena cava (IVC) is anterior to the spine on the right side, parallels the aorta, has a thinner wall, and is easily compressible. While both vessels may show pulsation, the pulsation of the aorta is more prominent. Identification of the vessels may be confirmed by Doppler showing arterial signals in the aorta and venous signals in the IVC.
4. With the transducer still in the transverse position slide it slowly towards the patient's feet and evaluate the aorta until the bifurcation is reached at the level of the umbilicus. If bowel gas obscures the view, apply pressure to the transducer to move gas out of the scan field.

5. Turn the transducer into the longitudinal position with marker pointing towards the patient's head. Keep the aorta in the middle of the image and slowly slide the transducer towards the patient's head to the level of the xiphoid process while re-evaluating the aorta.
6. The diameter of the aorta is measured in a direct transverse image made perpendicular to the spine without angling toward the patient's head or feet. By convention the aortic diameter is measured by ultrasound from inner wall to inner wall in anterior-posterior dimension.

Scanning notes for the abdominal aorta

– Visualisation of the aorta in large patients can be difficult. Adjust gain and depth, and apply pressure to the transducer to improve visualization.

– Slight pressure is optimal for visualization of the aorta and other abdominal structures obscured by gas in the bowel. Warn the patient that you are about to apply pressure to the abdomen. Ask the patient to inform you immediately if the pressure is too uncomfortable. First apply the transducer gently to the abdomen. Then gradually increase pressure slowly downward until the gas is moved out of the way and the aorta is visualized. Sudden application of transducer pressure without warning the patient may be painful and will impair cooperation of the patient to the examination.

– A tortuous (i.e. curving) aorta may be difficult to trace and requires altering the angle of the transducer to ensure a true transverse image.

– In transverse view vertebral bodies, i.e. thick oval segment of vertebra, have been mistaken for an abdominal aortic aneurysm, especially if excessive transducer pressure has been applied and the aorta is compressed. Confirm proper visualization of the aorta with longitudinal views and Doppler to demonstrate blood flow.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

13.2 Normal aorta

The normal abdominal aorta tapers in diameter from the diaphragm until the bifurcation into the left and right iliac arteries. During this course, it gives rise to the celiac axis (CA) and superior mesenteric artery (SMA) left and right renal arteries. The normal lumen of the aorta is anechoic (black) with echogenic (white) walls and is located anterior to the spine, running parallel to the IVC which typically has thinner more compressible walls (Figures 1 and 2).

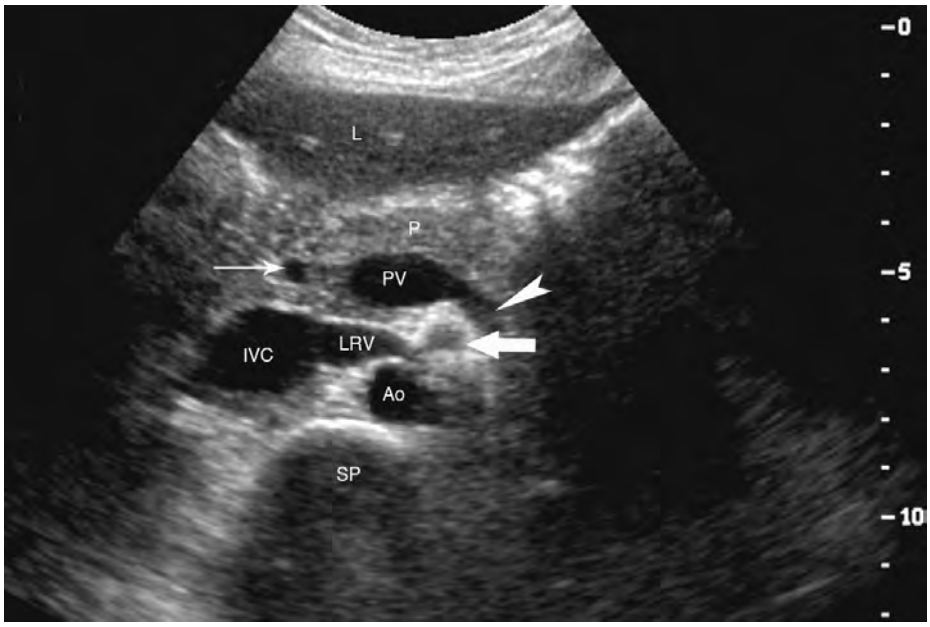

Figure 1: Normal Abdominal Aorta – Transverse View
Transverse ultrasound image obtained in the mid-epigatrium reveals the normal abdominal aorta (Ao) and normal surrounding structures. The inferior vena cava (IVC) receives the left renal vein (LRV) after it passes between the aorta and the superior mesenteric artery (fat arrow). The portal vein confluence (PV) is formed by the junction of the superior mesenteric vein coming from below and the splenic vein (arrowhead) coming from the left. The pancreas (P) is identified anterior to the portal and splenic veins. The gastroduodenal artery (skinny arrow) courses inferiorly through the head of the pancreas. The liver (L) provides a good sonographic window at this level. The echogenic outline of a vertebral body of the lumbar spine (SP) is seen posterior to the aorta and inferior vena cava. The bony structure of the vertebral body casts a dense acoustic shadow.

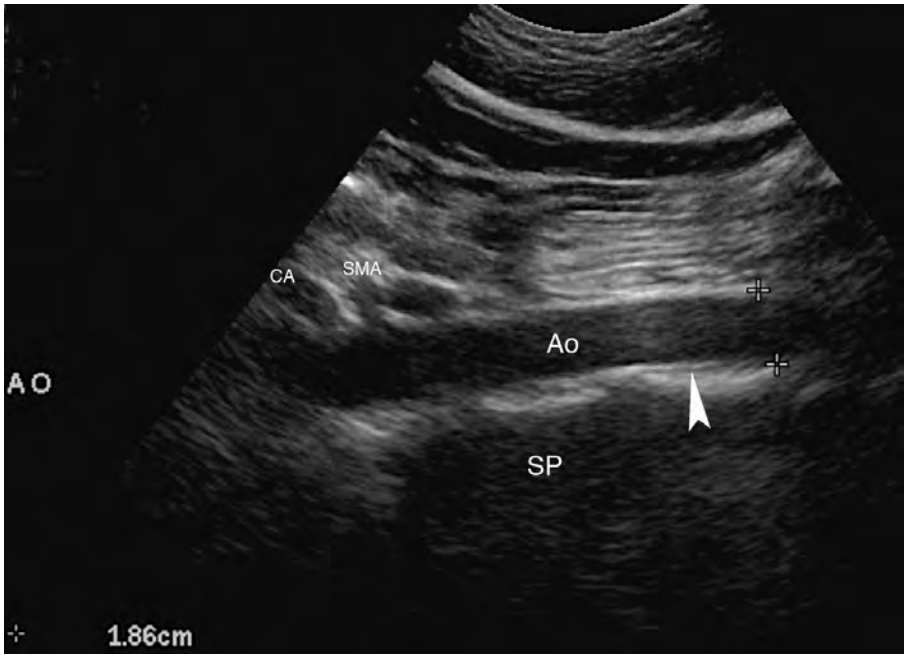

Figure 2: Normal abdominal aorta - Longitudinal view
Sagittal plane image shows the normal straight course and mild tapering of the abdominal aorta (Ao) as it coursing distally anteriorly to the spine (SP). The bony vertebrae cast dense acoustic shadows. In this patient the diameter of the distal abdominal aorta measures 1.86 cm (between cursors, +). The wall of the aorta (arrowhead) is of uniform thickness. The celiac axis (CA) and superior mesenteric artery (SMA) arise anteriorly off the aorta in the upper abdomen.

13.3 Abdominal aortic aneurysm

An abdominal aortic aneurysm (AAA) is a dilation of the abdominal aorta. This can be localized to a specific section of the aorta or in more severe cases extend along the length of the vessel. The dilation is associated with weakening of the wall of the vessel and an increased risk of rupture.

An abdominal aorta >3 cm, measured from the outer margins of each wall, in true transverse is considered an AAA. Risk of rupture increases with increasing diameter of the AAA. An AAA >5 cm diameter is associated with a high risk of rupture. At 7 cm diameter the risk of rupture within 5 years is 75 %.

As stated above, by convention the aortic diameter is measured with ultrasound from inner wall to inner wall in anterior-posterior dimension, rather than outer wall to outer wall (the way aneurysms are defined clinically). This is because of the difficulty in defining with ultrasound exactly where the outer margin of the aortic wall is; particularly the posterior wall is difficult to impossible to distinguish from the anterior margin of the spine.

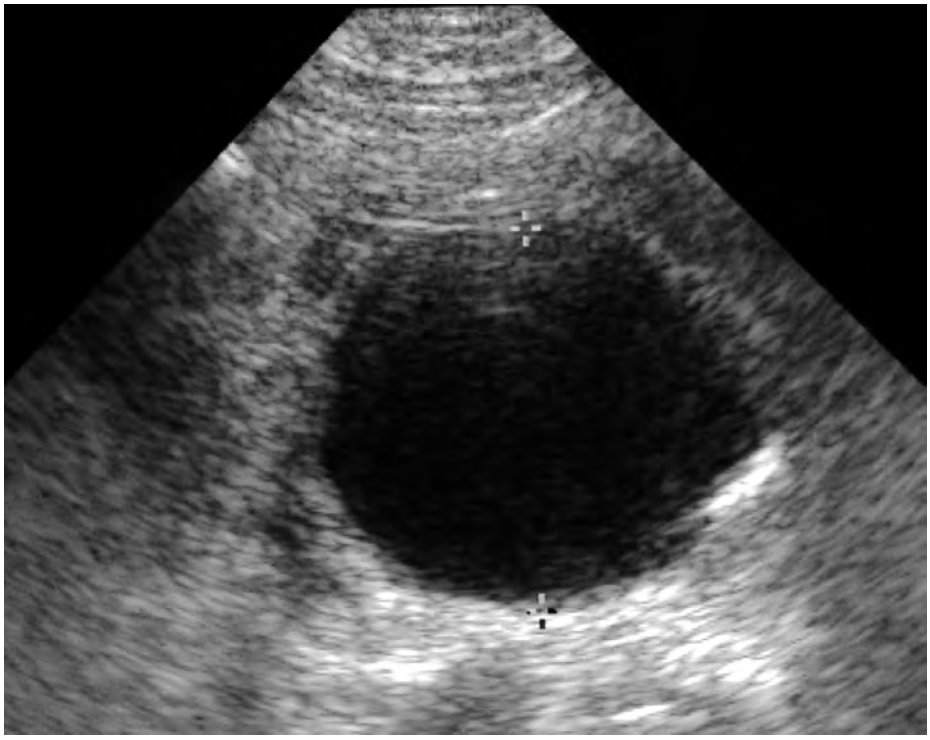

Figure 3: Abdominal aortic aneurysm (AAA)
Transverse image shows an abdominal aortic aneurysm measuring 5.3 cm (between callipers, +) in anterior-posterior diameter.

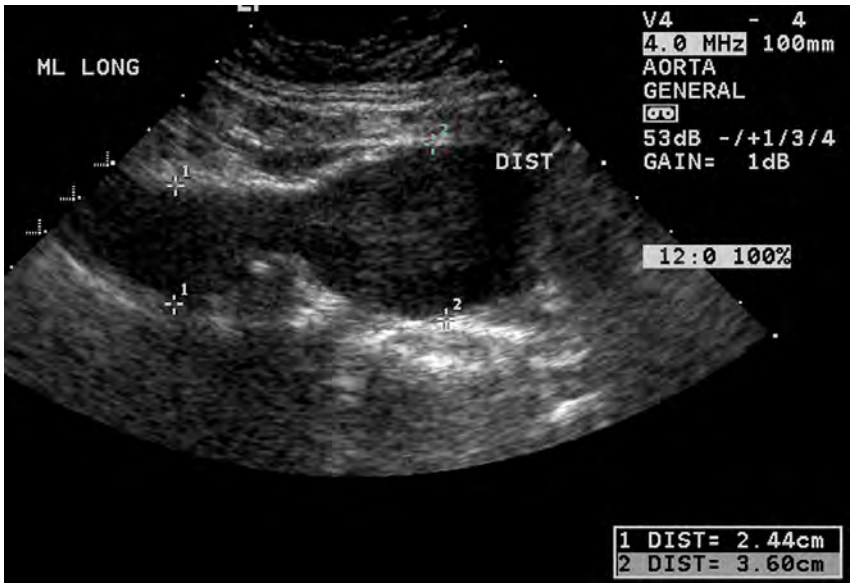

Figure 4: Aortic aneurysm
Longitudinal image of the aorta in a different patient shows a dumb-bell shape of the aorta with a small distal aneurysm measuring 3.6 cm (between callipers +2). The aorta is severely atherosclerotic measuring 2.4 cm in diameter superiorly; the patent lumen narrows to approximately 1 cm diameter due to calcified plaque, and then dilates forming the aneurysm.

Rupture or leakage of AAA

Rupture or leakage of an AAA is indicated by visualization of fluid or hematoma adjacent to the AAA (Figure 5). Colour Doppler ultrasound may show blood flow through the wall of the AAA into the adjacent hematoma. The hematoma may show variable echogenicity from nearly echolucent, i.e. dark, to brightly echogenic, i.e. medium white. Careful examination of the tissues surrounding the AAA is needed to make a correct diagnosis.

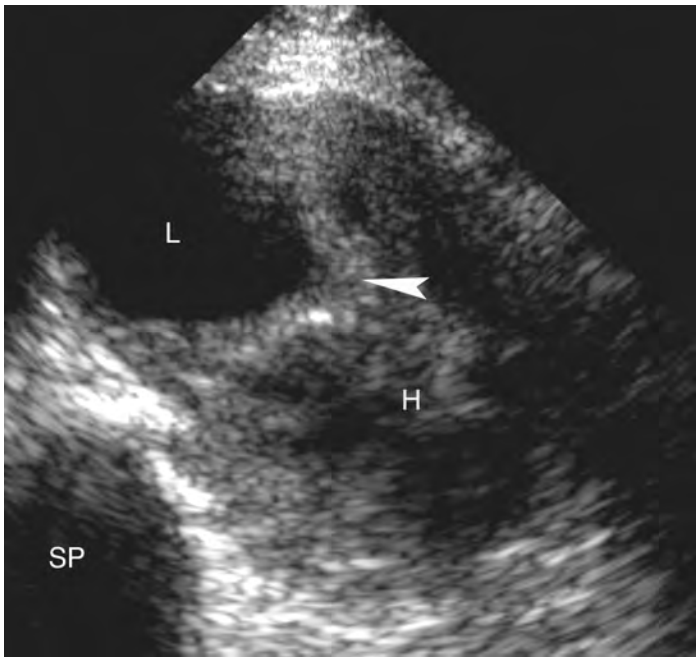

Figure 5: Rupture of abdominal aortic aneurysm
Transverse image of the aorta shows a large hematoma (H) extending from and partially surrounding the patent lumen (L) of the aortic aneurysm. The wall of the aneurysm (arrow) is irregular and disrupted at the site of the rupture. A vertebral body of the lumber spine (SP) is seen posteriorly casting a prominent acoustic shadow.

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Suggested Reading

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14. Upper abdominal scan

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Right upper quadrant (RUQ) pain, tenderness, jaundice, clinical hepatomegaly or splenomegaly are common indications for ultrasound of the upper abdomen. Sonography is particularly sensitive to biliary and gallbladder disease. Common causes of RUQ pain include gallstones, cholangitis, liver abscess, liver tumour, renal colic or pyelonephritis.

Left upper quadrant (LUQ) pain may be caused by splenic infarction (sickle cell crisis), splenic abscess, renal colic, pyelonephritis, pancreatitis, pancreatic tumours, inflammatory bowel disease, or peptic ulcer.

Upper abdominal pain may also be related to aortic, cardiac and pulmonary disease.

14.1 Scanning technique – upper abdomen

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Begin with the patient lying on their back, i.e. supine scanning just below the bottom of the ribs. Left lateral, left anterior oblique or right lateral or right oblique positions may be required.

If the scan is planned, have the patient fast for 4 hours prior in order to distend the gallbladder and to limit gas and food in the stomach.

Scanning steps and technique – right upper quadrant

1. Start in the right mid clavicle line under the ribs with the transducer in the transverse position with the marker pointing to the patient's right to identify the liver.
2. Then begin a 'sweep' of the liver, slowing moving the transducer and scanning in the transverse direction. Have the patient take a deep breath in and hold it while assessing the liver in this position.
3. Oblique the transducer towards the patients left and then right shoulder repeating the 'sweep' of the liver in both positions. This will expand the visualisation of the superior and posterior segments of the RUQ.
4. Repeat the assessment with the transducer in the longitudinal position, i.e. marker pointing towards the patients head, angled towards the head and move medially and laterally as required.

5. As an alternate view due to overlying bowel gas or difficult visualisation, position the patient on their left side or slightly oblique. Align the transducer between the ribs at different levels to ensure complete visualisation of the liver and gall bladder and use 'sweeps' through the region obscured by bowel gas in the supine position.

Scanning notes for the right upper abdominal scan

– Adjustment of depth and gain throughout the assessment is required to accurately evaluate both anterior and posterior hepatic areas.
– The liver provides a good acoustic window for assessment of the gallbladder which should be visualised in both transverse and longitudinal orientations from the neck to the fundus for a complete assessment.
– The gallbladder appears contracted in a non-fasted patient and may be more difficult to assess.
– The normal width of the common bile duct is 4-5 mm, dilation (> 6 mm) can indicate obstruction from a stone or mass, however this can be difficult to locate and accurately measure for non-experienced operators.
– Colour Doppler can be used to assess the hepatic arteries and veins for hypertension, portal or hepatic thrombosis and differentiate from the common bile duct (as clinically required) but is more difficult for non-experienced users.

Scanning steps and technique – left upper quadrant

1. Begin in the left posterior axillary line at the bottom of the ribs, with the transducer in the transverse position and 'sweep' to identify the spleen and left kidney. Adjust depth and gain as required.
2. Rotate the transducer and obtain views with the transducer in the longitudinal position.
3. If bowel gas obscures the view oblique the transducer and position between the lower ribs (approx. 9th-10th) to obtain an intercostal view. Repeat as required at different intercostal spaces.

Scanning notes for the left upper abdominal scan

– Demonstration of the stomach separate to the spleen is important to avoid misdiagnosis of a pathological spleen.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

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14.2 Liver

14.2.1 Normal liver

The normal liver is homogeneous in echogenicity equal to or slightly greater than the echogenicity of the kidney (Figure 1). The portal triads, consisting of portal veins, hepatic arteries, and bile ducts, appear as small echogenic foci in the periphery of the liver. Ligaments and fissures are usually fat-filled and are highly echogenic.

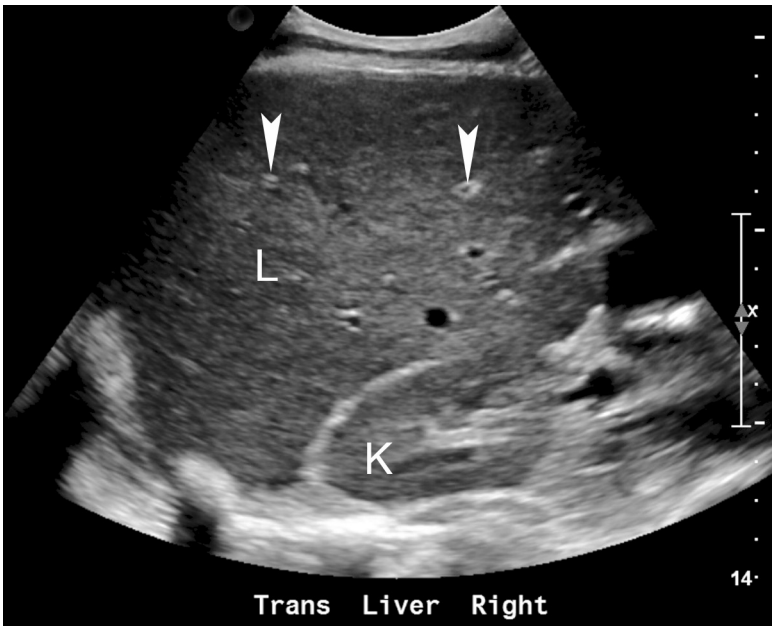

Figure 1: Normal liver
The normal liver parenchyma (L) is uniform
and is equal in echogenicity to the normal kidney parenchyma (K).
The portal triads appear as echogenic foci (arrowheads) in the periphery of the liver.

14.2.2 Liver abnormalities

Hepatitis

Acute hepatitis usually does not alter the appearance of the liver. Rarely, because of oedema, the liver parenchyma echogenicity is decreased resulting in increased prominence of the echogenic portal triads and hepatomegaly. Chronic hepatitis causes overall mildly increased echogenicity of the liver parenchyma.

Fatty liver

Infiltration of liver cells with fat is a common and non-specific reaction to liver cell injury from any cause. Common causes of fatty liver include malnutrition, alcohol abuse, diabetes mellitus, and obesity (Figure 2). Fatty infiltration dramatically increases the echogenicity of liver parenchyma such that the liver becomes much brighter than the kidney. Severe fatty infiltration limits the ability of ultrasound to penetrate through the liver. Fatty infiltration may be diffuse or involve only portions of the liver.

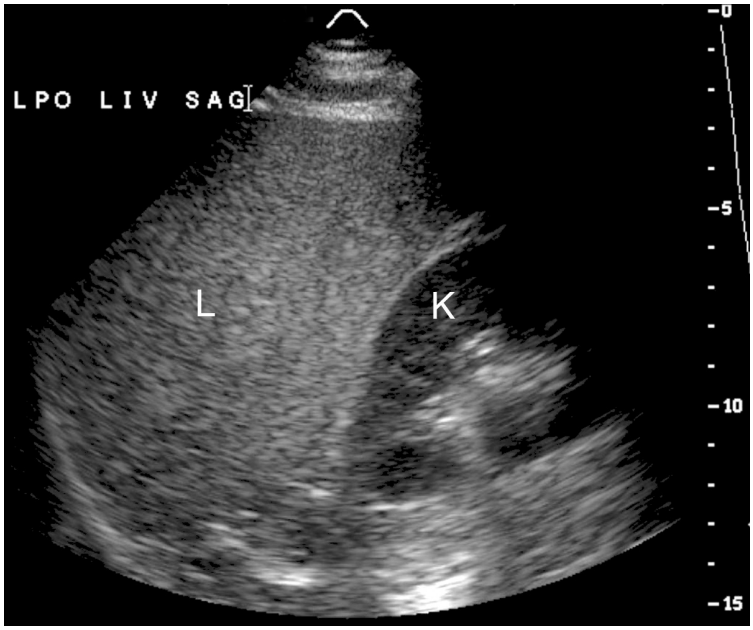

Figure 2: Diffuse fatty liver
In this malnourished patient the liver (L) is much more echogenic (brighter) than the kidney (K). This finding is indicative of injury to liver cells.

Cirrhosis and portal hypertension

Cirrhosis is the result of chronic progressive injury to liver cells. Parenchymal necrosis is followed by progressive fibrosis and nodular regeneration. This process distorts the parenchymal and vascular architecture of the liver resulting in reduced liver size and volume in later stages with jaundice and ascites. The liver will have a coarse echotexture, with mildly increased echogenicity, irregular nodular surface, iso- or hypo- echoic nodules (Figure 3). As portal hypertension develops the portal vein becomes dilated (>13 mm) with biphasic or reverse blood flow which can be assessed by a more experienced user with colour Doppler. Portal hypertension is most commonly caused by cirrhosis but can be caused by other conditions such as portal vein thrombosis, Budd-Chiari syndrome and right heart failure. Cirrhosis is caused most commonly by viral hepatitis type C and B, alcohol abuse, parasitic diseases, sclerosing cholangitis, metabolic diseases, and primary biliary cirrhosis.

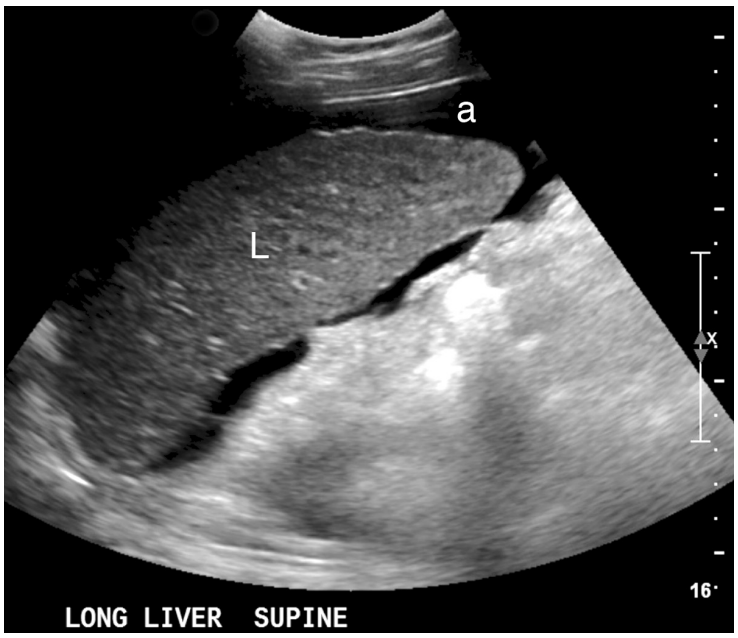

Figure 3: Liver cirrhosis
The liver (L) shows heterogeneous mildly increased echogenicity characteristic of cirrhosis. Ascites (a) outlines the nodular surface of the cirrhotic liver.

Benign liver cyst

Benign liver cysts are common, occurring in 2-5 % of the population. In most instances benign liver cysts are incidental findings of no clinical significance. Rarely may they develop internal haemorrhage or infection. Simple hepatic cysts are anechoic with sharply defined thin avascular walls (Figure 4). The contour of the cyst is often lobulated. Size ranges from 1-2 mm to huge. Accentuated through-transmission is commonly present with larger cysts. Thin internal septations may be present. Cysts are often multiple and may occur in clusters. Doppler ultrasound confirms the absence of blood flow in the cyst walls and septa.

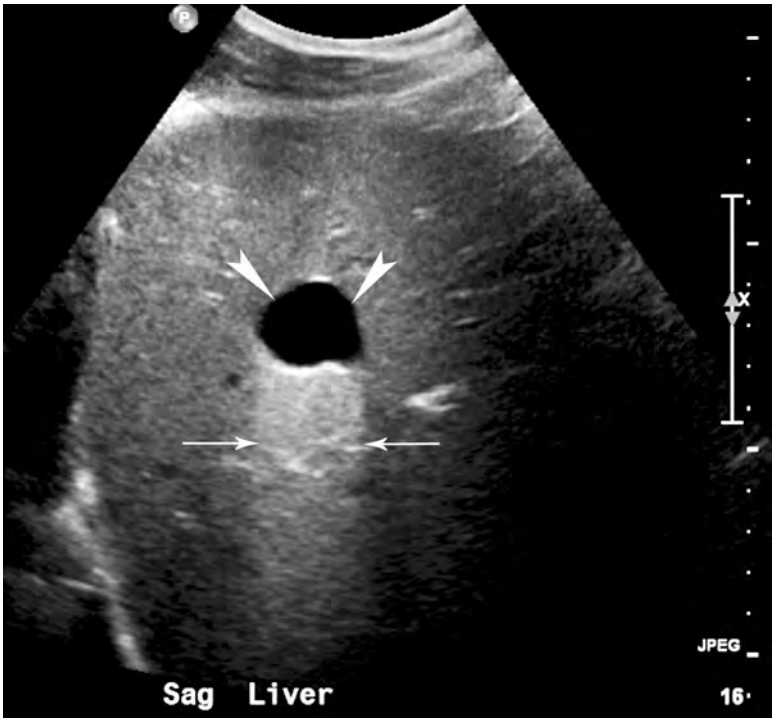

Figure 4: Benign liver cyst
Longitudinal image of the liver reveals a well-defined anechoic mass (arrowheads) with ultrasound characteristics of a benign liver cyst. The cyst is sharply defined and lobulated in contour. No internal echoes are present within the cyst. Accentuated through-transmission (arrows) is evidenced by bright echoes deep to the cyst.

Liver abscess

Liver abscesses occur as a result of:

- Amoebiasis,
- Hydatid disease,
- Pyogenic infection,
- Opportunistic infection in immunocompromised patients.

The ultrasound appearance of liver abscesses is variable. Most appear as an ill-defined hypoechoic mass of variable size with thick wall containing fluid appearing as echogenic particulate matter. Most have thick, poorly marginated walls, septations and multiple locules are common.

Amoebiasis

Infection with *Entamoeba histolyica* is one of the most common parasitic infections found worldwide especially prevalent in resource-constrained settings of low income countries with inadequate sanitation facilities. It is primarily an intestinal infection for which ultrasound has no diagnostic role. However, invasive extraintestinal disease is common, including liver abscess, pleuropulmonary, renal, peritoneal, cardiac, and cerebral disease and for some of extraintestinal

manifestations ultrasound is a useful diagnostic tool. Mortality rate from extraintestinal amoebiasis is reported as high as 7-14 %.

Liver abscess is the most frequent and important complication. Amoebic liver abscesses occur predominantly in the right lobe adjacent to the diaphragm (Figure 5). Intestinal amoebic trophozoites migrate through the portal vein to the liver and form colonies that coalesce, i.e. unite, to produce usually large abscesses. Smaller colonies may also be present forming micro-abscesses. The typical appearance is a relatively homogeneous unilocular mass abutting the diaphragm or surface of the liver. This appearance is in comparison to pyogenic abscess, which is usually multilocular, heterogeneous, and may contain gas bubbles (Figure 9). A common complication of liver abscess is rupture through the diaphragm infecting the pleural space (Figure 6), or rupture through the liver capsule infecting the peritoneal cavity or retroperitoneum.

Other ultrasound findings that may present include thickening of the wall of the biliary tract and gallbladder, findings of pancreatitis, pericarditis and cardiac tamponade. Also, an abscess in the retroperitoneal space involving the kidney may occur. Ultrasound is the imaging method of choice to detect the presence of amoebic abscess, rupture, spread of disease, and response to treatment.

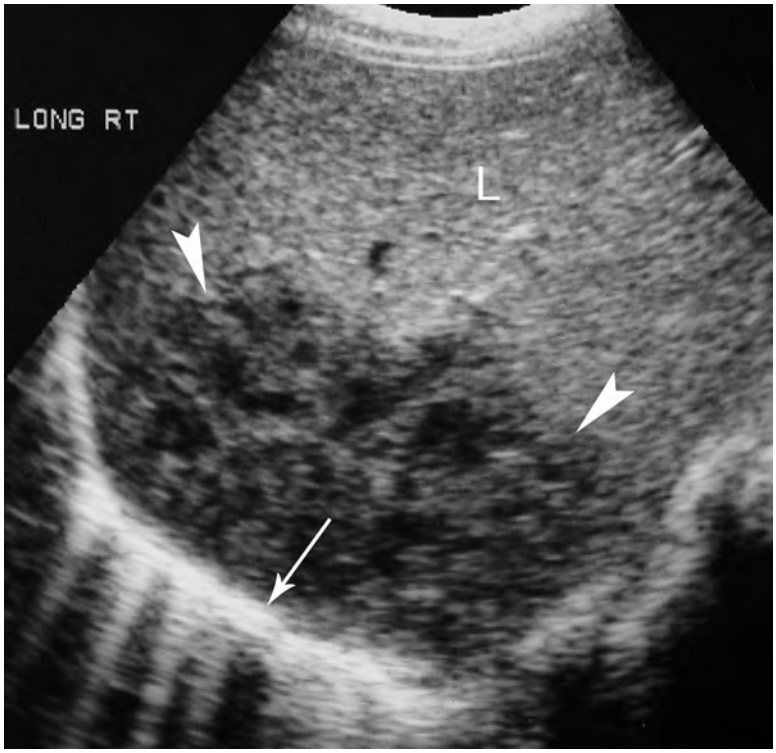

Figure 5: Amoebic liver absces
The abscess is represented as a large mass (between arrowheads)
in the posterior dome of the right lobe of the liver (L).
The mass presents a large surface to liver capsule abutting the diaphragm (arrow).
This is the most common location for amoebic abscess.

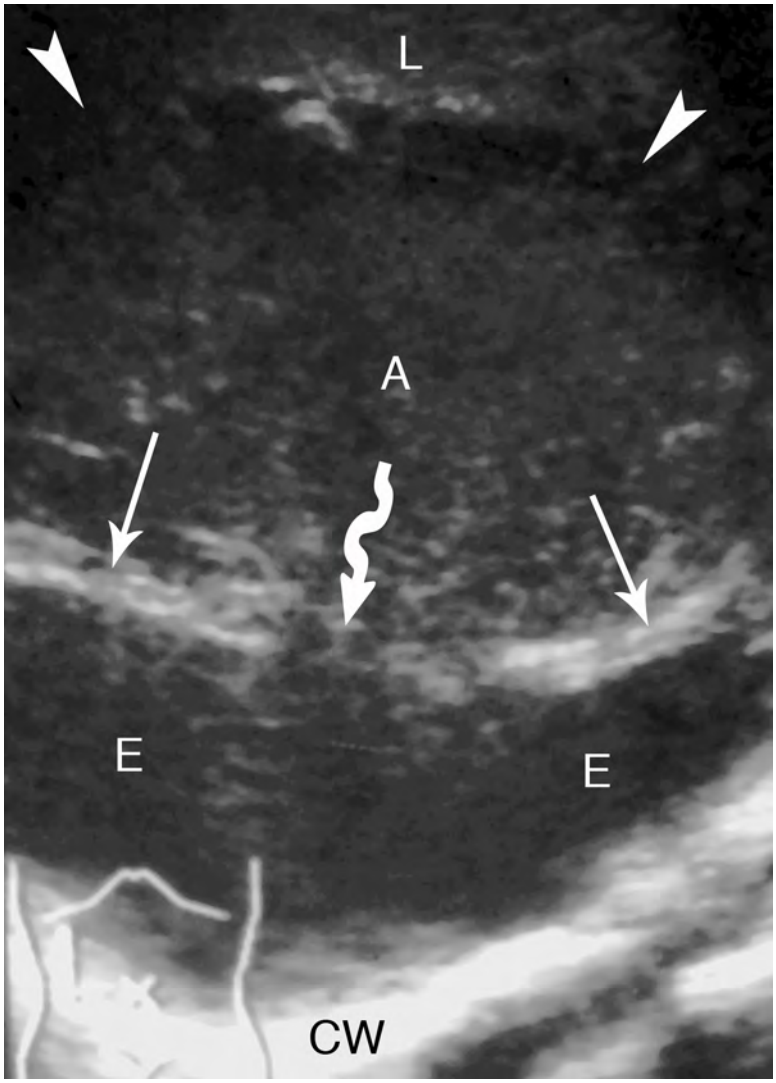

Figure 6: Rupture of hepatic amoebic abscess through the diaphragm
A large amebic abscess (between arrowheads) in the right lobe of the liver (L) has ruptured through the diaphragm into the pleural space causing an amebic empyema (E).
The diaphragm is seen as a thick bright line (straight arrows).
The defect in the thick bright line (curvy arrow) is the site of rupture.
The posterior chest wall (CW) is seen as a thicker bright interface.

Hydatic disease

Another common parasitic disease which can be demonstrated by abdominal ultrasound is hydatid disease caused by the tapeworm, *Echinococcus granulosa*. Hydatid cysts, are most common in the liver but may occur in any organ. Hydatid liver disease presents with low-grade fever and a tender liver. Definitive diagnosis is made by laboratory examinations after aspiration and drainage, which is efficiently guided by ultrasound.

The disease is endemic to grazing areas of the world particularly Africa, South America, Australia, New Zealand, the Middle East, and the Mediterranean region. Humans become infected by ingesting contaminated food or water containing the eggs of the tapeworm. Free embryos enter the portal circulation through the intestinal wall and become lodged in the liver parenchyma. Some embryos may enter the systemic circulation and become lodged in the lungs or other organs. The lodged embryos develop into cysts containing clear fluid. The cysts are commonly unilocular, but often contain daughter cysts (Figure 7). Commonly particulate matter made up of scolices, hooklets, and ruptured cyst debris known as ‘hydatid sand’ can be found in the cysts (Figure 8). The cyst wall is multi-layered appearing on ultrasound as a double echogenic line.

Daughter cysts are smaller anechoic cysts initially attached to the wall of the mother cyst. Over time they become detached and produce an undulating floating membrane and collapsed cyst mass. Hydatid sand appears as echogenic particulate matter that may layer within the anechoic cyst or fill the entire cyst. Chronic echinococcal cysts demonstrate calcification in the cyst wall or calcification of the entire cyst. Echinococcal cysts are by far most common in the liver, but may also be found in the spleen, lung, pleural space, mediastinum, pericardium and heart, gallbladder, mesentery, peritoneal cavity, kidney, brain, and bone. The radiologic appearance of echinococcal cyst is the same no matter its location.

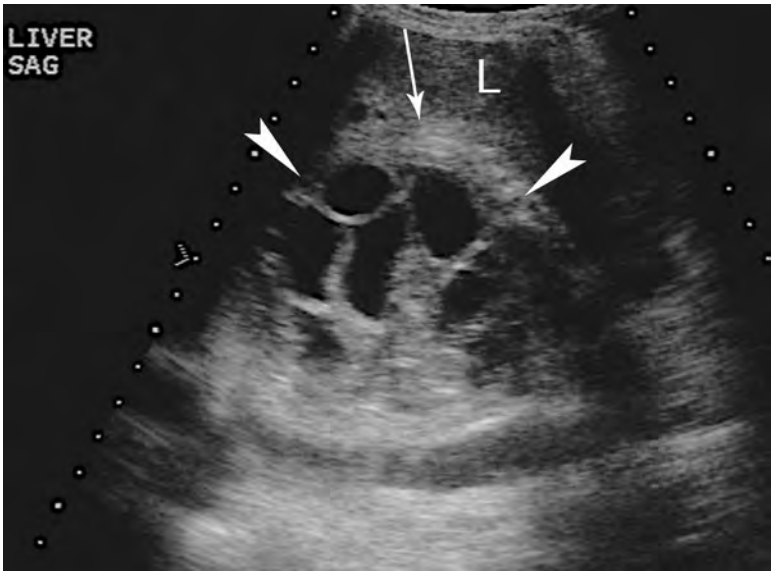

Figure 7: Hydatid liver cyst
Ultrasound image of the liver (L) reveals a multiloculated cyst (arrowheads) with a multi-layered thick wall (arrow).
The appearance is typical of a hydatid mother cyst containing multiple daughter cysts.

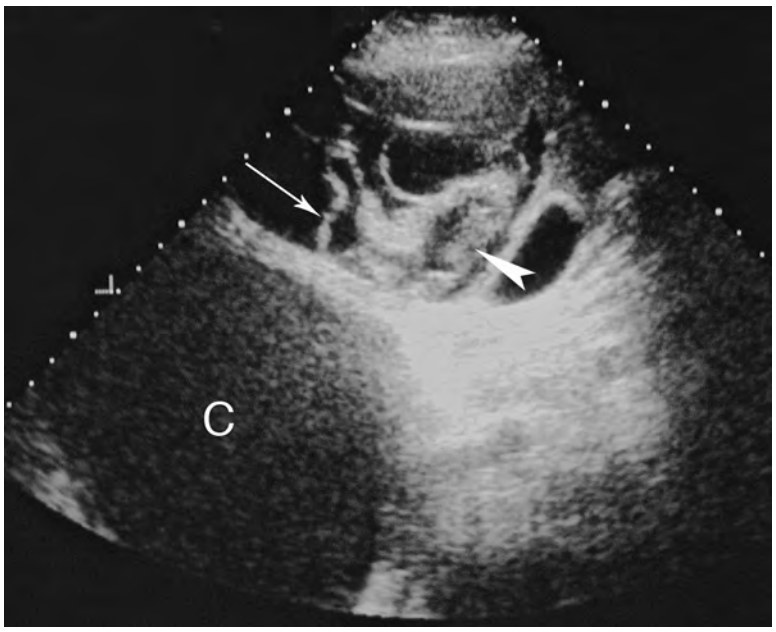

Figure 8: Hydatid cysts containing hydatic sand and floating membranes
Ultrasound of the liver in a different patient reveals two hydatid cysts.
The more proximal cyst contains daughter cysts that have detached from the wall of the mother cyst and are collapsed (arrowhead) in the bottom of the mother cyst.
A characteristic floating membrane (arrow) is also present. The larger more distal cyst (C) is filled with particulate echoes characteristic of hydatid sand.

Pyogenic abscesses

Pyogenic abscesses present with acute fever, pain, and jaundice. Additional symptoms include anorexia, vomiting, malaise, and weight loss. Laboratory investigations shows leukocytosis and elevated liver function tests. Pyogenic abscesses develop as a complication of biliary tract infection, trauma or sepsis. In some patients no precipitating cause is evident. Affected patients are more acutely ill than those with amoebic or hydatid liver abscesses. Ultrasound reveals a poorly defined hypoechoic mass with irregular, thick walls (Figure 9). The abscess contains thick, poorly mobile, particulate fluid that is hypoechoic compared to normal liver parenchyma. Fluid-fluid levels may be present and the abscess may contain gas. Internal septations and multiple locules are common. Pyogenic abscesses are often multiple and occur in clusters. Doppler ultrasound reveals absence of blood flow in the purulent fluid component and increased blood flow in the thick walls and septa. The diagnosis is confirmed and may be definitively treated by ultrasound-guided aspiration and drainage. Most pyogenic abscesses are polymicrobial with *Escherichia coli* and *Klebsiella pneumoniae* as the most common organisms. Blood cultures may be positive in some patients.

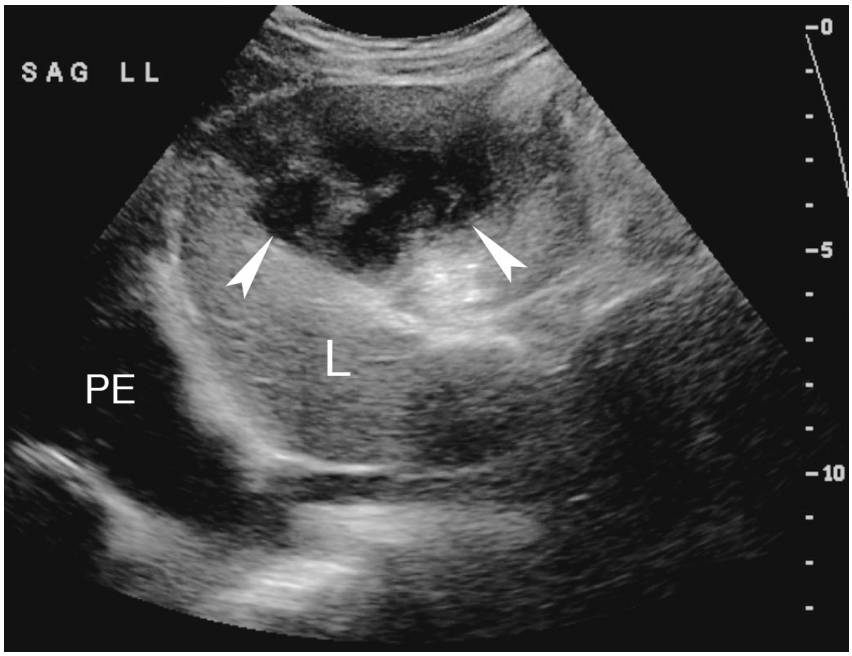

Figure 9: Liver abscess
Longitudinal ultrasound image through the liver (L) in an acutely ill febrile patient reveals a cystic mass (arrowheads) with irregular thick walls, thick septa, and containing fluid with echogenic particulate matter.
On ultrasound-guided aspiration this lesion proved to be a pyogenic abscess caused by *Escherichia coli*. An associated right pleural effusion (PE) is also present.

Opportunistic infections

Liver abscesses in immunocompromised patients are usually micro-abscesses and innumerable, small (<10 mm), cystic lesions (Figure 10) that often occur in the spleen as well as the liver. Causative organisms include fungi (e.g. Candida, Aspergillus, Cryptococcus, Histoplasma, Mucor), Pneumocystis, cytomegalovirus, tuberculosis and non-tuberculous mycobacterium. Characteristic of fungal micro-abscesses are target lesions with a central echogenic dot surrounded by a hypoechoic halo. Characteristic of Pneumocystis are innumerable tiny echogenic lesions seen diffusely throughout the liver and spleen. Micro-abscesses may calcify as they heal.

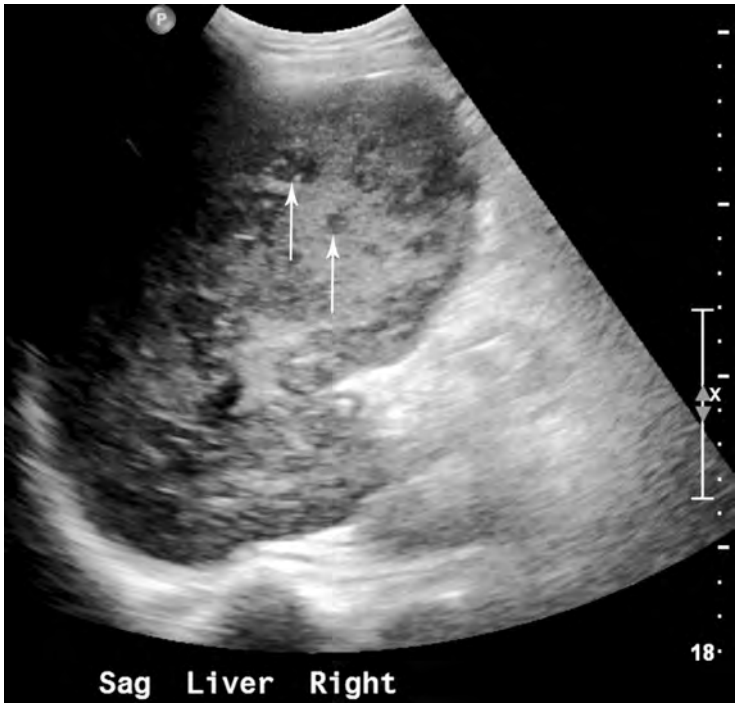

Figure 10: Liver micro-abscesse
Longitudinal ultrasound image through the liver in an HIV-positive patient reveals innumerable small hypoechoic lesions (arrows) highly indicative of micro-abscesses. Similar lesions were present in the spleen. Note the punctate echogenic foci in many of the lesions strongly suggestive of fungal infection. Candida was proven to be the causative organism.

Haemangioma

Haemangioma is the most common primary tumour of the liver, often found in asymptomatic patients. All are benign with no malignant potential. Haemangioma consist of blood-filled vascular channels lined by epithelium. The lesions are typically small, well defined, homogeneous, and hyperechoic in appearance (Figure 11). Larger lesions (>3 cm) may thrombose resulting in scarring and occasionally calcification. In 10 % of patients multiple haemangioma are present.

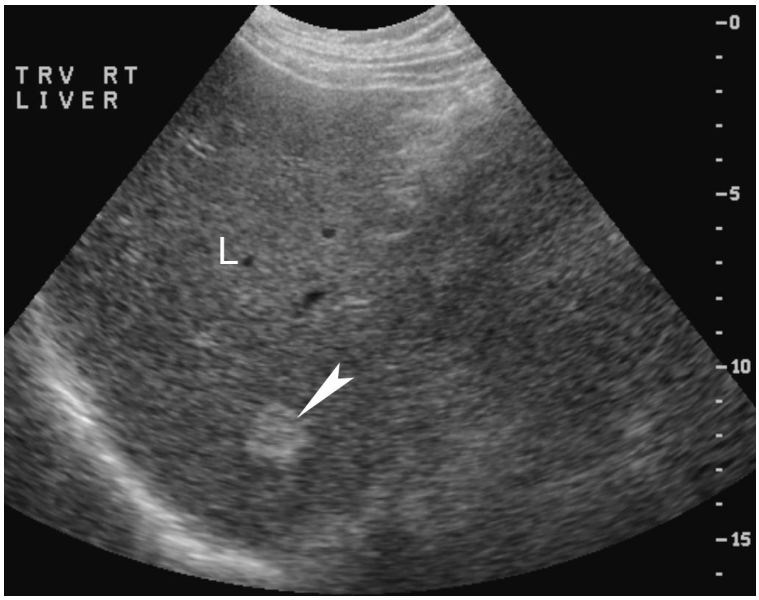

Figure 11: Liver haemangioma
Transverse ultrasound image of the liver shows a small well-defined, uniformly echogenic, mass (arrowhead) characteristic of a benign hepatic haemangioma.
As this is a benign lesion no further evaluation or follow up is required.

Hepatocellular carcinoma (HCC)

HCC is a common primary malignant tumour of the liver occurring nearly always in the presence of cirrhosis or chronic hepatitis B or C. Tumours appear as a solitary mass, a dominant lesion with satellite nodules, or as diffuse parenchymal infiltration. Small HCC's (<3 cm) are difficult to differentiate from the regenerative nodules of cirrhosis. Large tumours are more obvious (Figure 12). Commonly larger tumours have heterogeneous areas of necrosis and haemorrhage. Tumour invasion of the portal or hepatic veins is characteristic.

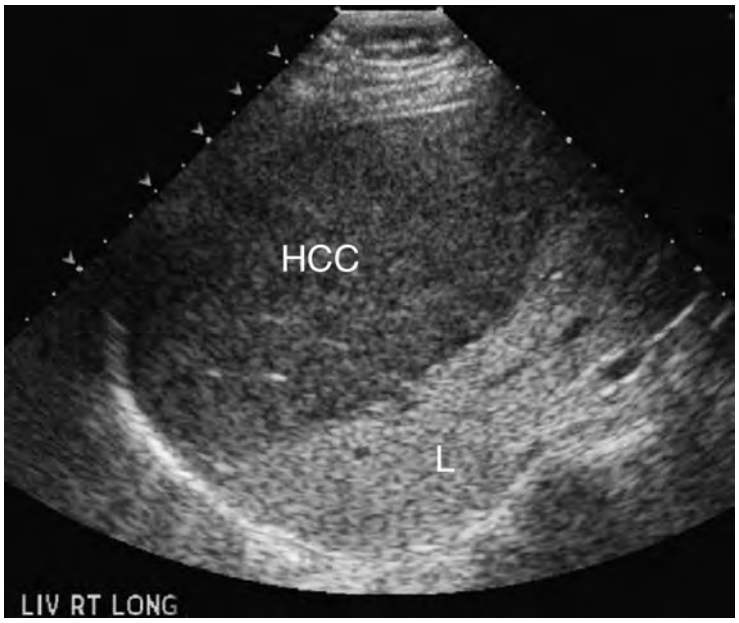

Figure 12: Hepatocellular carcinoma
Longitudinal image shows a large hepatocellular carcinoma (HCC) arising in a liver (L) affected by chronic hepatitis C.

Liver metastases

Metastases are the most common liver tumour. The liver is a common site of metastatic disease especially from cancers of the gastrointestinal tract, breast, pancreas, and lung. Metastasis may resemble any other lesion in the liver and must always be considered in the differential diagnosis. The presence of multiple lesions (Figure 13) should always suggest the possibility of metastatic disease, though solitary metastases also occur especially with colon carcinoma. A target or bull's eye appearance is most common. Lesions may be solid, cystic, calcified, and hyper- or hypoechoic.

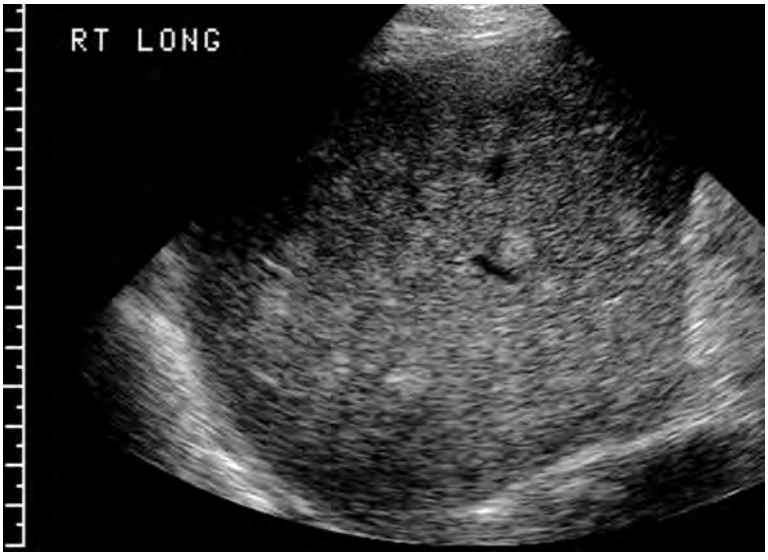

Figure 13: Liver metastases
Innumerable small hyperechoic nodules are distributed throughout the liver in this patient with metastatic colon carcinoma.

Schistosomiasis

Hepatic and colorectal schistosomiasis is caused by chronic infection by several species of *Schistosoma* parasitic flatworms, which occur in restricted geographic areas. *S. mansoni* is prevalent in sub-Saharan Africa, South America, the Middle East and the Caribbean. *S. japonicum* is endemic in China, the Phillipines, Indonesia and Thailand. *S. mekongi* is found in Cambodia and Laos. *S. intercalatum* is reported in Mali, Central African Republic, Chad, Congo, and Nigeria. Schistosomiasis of the urinary tract is caused by chronic infestation with *S. haematobium* and is reviewed in Chapter 15, Urinary tract.

Ultrasound demonstrates complications of chronic disease affecting primarily the liver and spleen. Hepatic fibrosis is most apparent in the periportal regions causing hyperechoic thickening of tissues surrounding the portal veins, termed periportal 'ruff' (Figure 14). Echogenic thickening of periportal tissues is considered significant at 3 mm and may exceed 7 mm. Smaller portal veins become thickened and straightened producing a 'pipe stem' pattern and 'starry sky' appearance of the liver (Figure 15). The liver surface becomes irregular as fibrosis progresses. Fibrosis of the portal vein results in portal hypertension manifest by dilatation of the portal veins (main portal vein diameter >13 mm in adults), splenomegaly, and development of porto-systemic collaterals especially in the perigastric, paraumbilical, and splenorenal regions. The portal vein may thrombose. Echogenic fibrosis may also develop around the gallbladder resulting in marked echogenic wall thickening. In distinction to cirrhosis normal liver architecture is preserved, liver function blood tests remain normal, regenerative nodules do not develop, and the hepatic veins are not affected remaining patent with normal pulsatility on Doppler ultrasound. In advanced cirrhosis the hepatic veins are narrowed and flow is monophasic on Doppler. In addition hepatic schistosomiasis is reversible with treatment, while cirrhosis is not. Findings of periportal fibrosis and portal hypertension commonly resolve within months or years following effective treatment. Co-infection with hepatitis B and C is common and results in rapid progression of liver disease, including development of classic cirrhosis. Schistosomiasis has been reported in 17 % of sub-Saharan human immunodeficiency virus (HIV) infected patients.

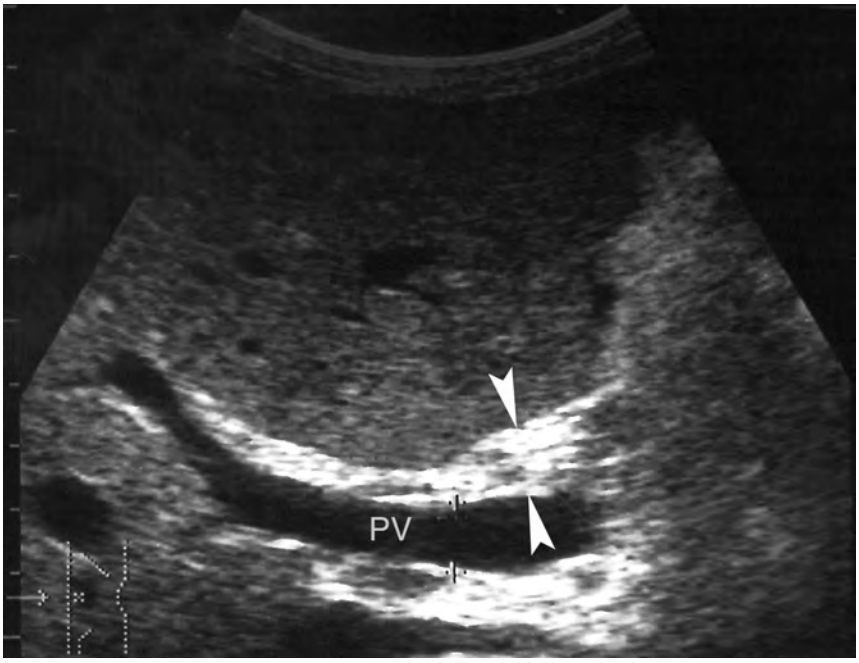

Figure 14: Periportal fibrosis due to hepatic schistosomiasis
Ultrasound image of the liver in a 12 year old boy shows marked echogenic thickening of the tissues surrounding the main portal vein, i.e. 'ruff' (PV).
The periportal fibrosis exceeds 11 mm in thickness (between arrowheads).
This finding is strongly associated with hepatic schistosomiasis.
The portal vein is measured at 10 mm (between cursors, +), which is considered dilated for a child of 12 years (normal diameter = 8 mm).
Portal vein diameter in children increases progressively with age.
A dilated portal vein is evidence of developing portal hypertension, an important complication of hepatic schistosomiasis.

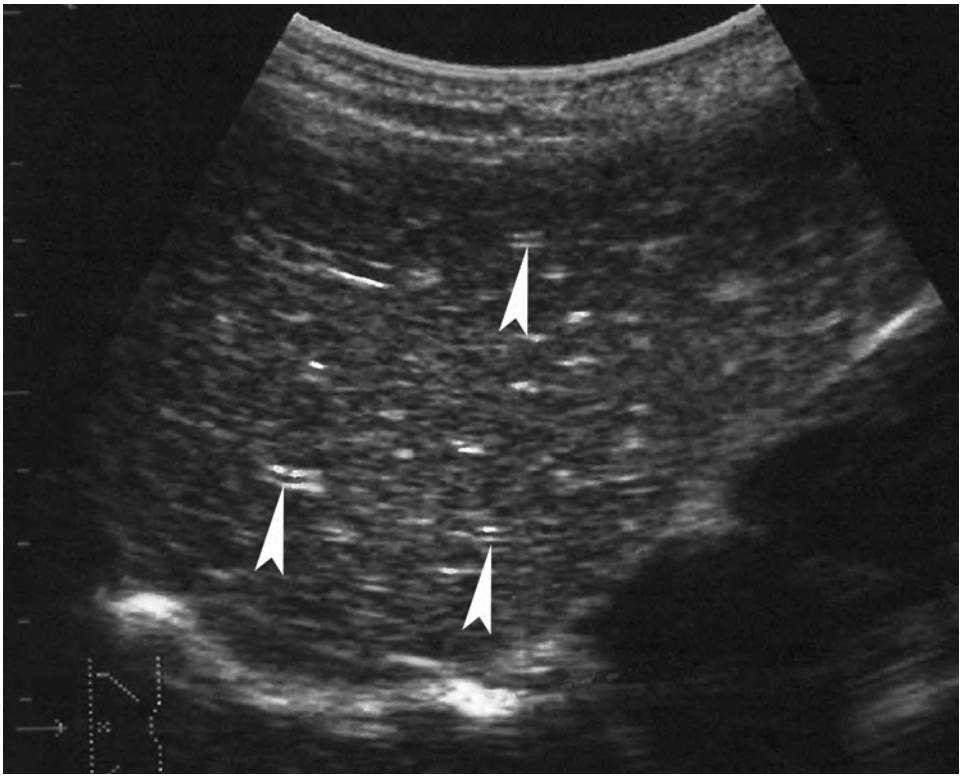

Figure 15: Periportal fibrosis of small portal veins due to hepatic schistosomiasis
Liver ultrasound in a 25 year old man reveals the 'starry sky' appearance of echogenic fibrosis (arrowheads) involving small portal veins within the liver parenchyma.
Fibrosis of the portal veins thickening the tissue surrounding the veins and causes the portal triads to appear highly echogenic on a background of normal liver parenchyma. Progressive fibrosis straightens the small portal veins causing a characteristic 'pipe-stem' appearance and eventually leads to portal hypertension.

14.3 Gallbladder

14.3.1 Normal gallbladder

The gallbladder appears as a pear-shaped fluid-filled sac usually positioned in a concave fossa on the inferior surface of the liver (Figure 16). With fasting the gallbladder distends with bile and is most easy to visualize. After eating the gallbladder is collapsed and may be difficult to recognize. The gallbladder may be elongated and folded back on itself.

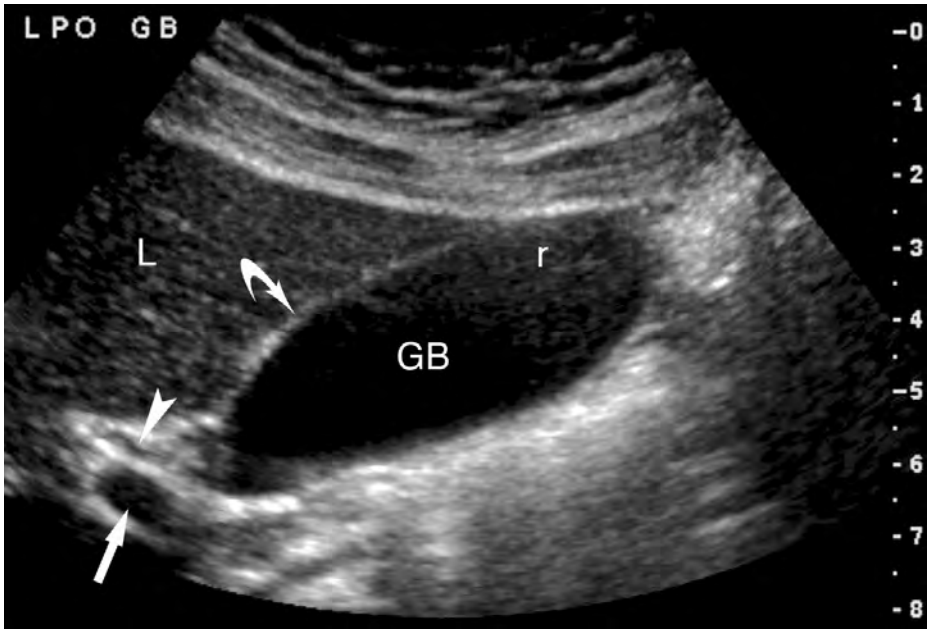

Figure 16: Normal gallbladder
The normal distended gallbladder (GB) appears as a fluid-filled sac on the inferior surface of the liver (L). Reverberations echoes (r) are a common artefact seen in the anterior aspect of the gallbladder and should not be misinterpreted as pathology.
The neck of the gallbladder extends toward portal vein (straight arrow) and common bile duct (arrowhead) in the porta hepatis. The wall of the gallbladder (curved arrow) appears as a uniformly thin echogenic line abutting the liver. This region should always be examined for wall thickening and oedema that would indicate gallbladder disease.

14.3.2 Gallbladder abnormalities

Cholelithiasis / gallstones

Gallstones appear within the lumen of the gallbladder as dense echogenic foci causing posterior shadowing (Figure 17). Gallstones typically move within the gallbladder as the patient's position is changed. Gallstones are variable in size and are commonly multiple.

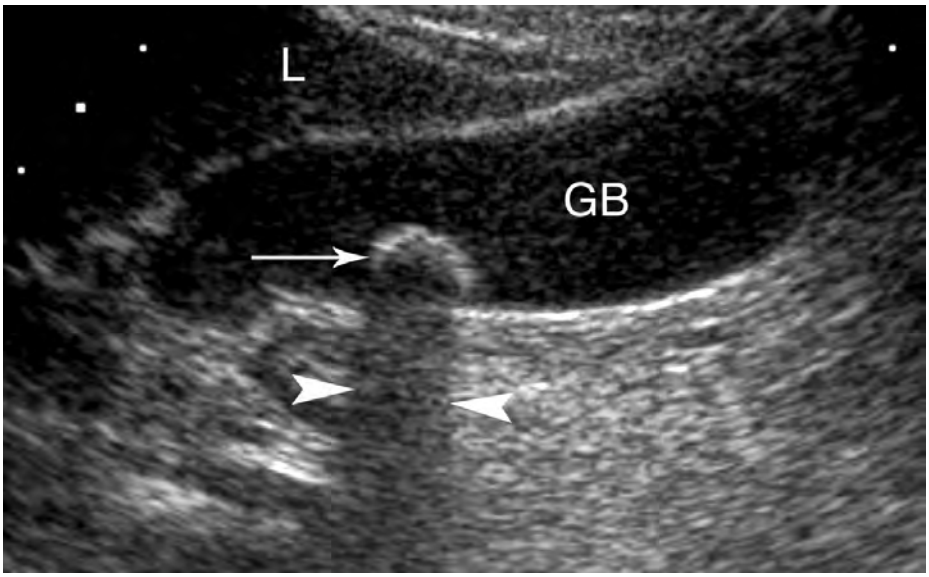

Figure 17: Gallstone in the gallbladder
Ultrasound image through the liver (L) in the long axis of the gallbladder (GB) reveals a gallstone in the gallbladder lumen. The gallstone (arrow) appears as an echogenic nodule that casts a prominent acoustic shadow (between solid arrowheads). The gallstone was observed to move within the gallbladder as the patient rolled into a different position.

Acute cholecystitis

Acute cholecystitis is most commonly caused by gallstones impacted in the neck of the gallbladder in 90-95 % of cases (Figure 18). In severely compromised adults it may occur without gallstones, i.e. acalculous cholecystitis (Figure 19). In children approximately half of all cases of acute cholecystitis are acalculous.

In acute cholecystitis the gallbladder wall is thickened (>3 mm) often with a layered appearance representing oedema in the wall. The gallbladder itself is often distended (>5 cm diameter). Echogenic particulate matter in the gallbladder lumen may be pus, blood, necrotic tissue or sludge, i.e. concentrated bile.

The sonographic Murphy's sign, when properly performed is highly specific for acute cholecystitis. Transducer pressure is gently applied to multiple areas on the abdomen. The sonographic Murphy's sign is positive when maximum tenderness is evident directly over the visualized gallbladder. The sonographic Murphy's sign is negative if no tenderness is present, if tenderness is diffuse, or if maximum tenderness is not clearly localized to the gallbladder.

Note: Gallbladder wall thickening can also be seen in other conditions such as: gallbladder carcinoma, renal failure, hepatitis, congestive right heart failure, cirrhosis and pancreatitis.

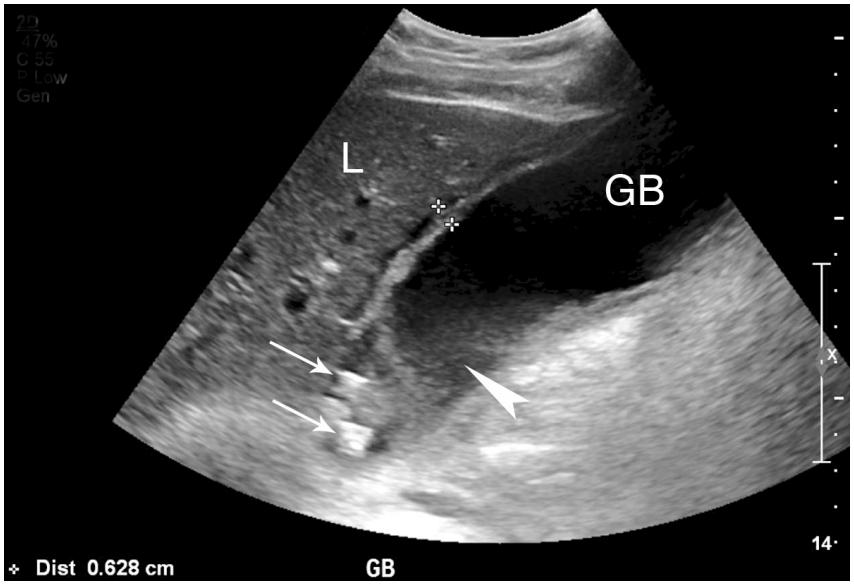

Figure 18: Acute cholecystitis
Using the liver (L) as a sonographic window the gallbladder (GB) is shown in its long axis.
Multiple gallstones (arrows) are impacted in the gallbladder neck.
These stones did not move with changes in the patient's position.
Echogenic debris (arrowhead) layers within the bile in the gallbladder lumen.
The gallbladder wall (cursors +) is thickened to 6 mm.
Acute cholecystitis was confirmed at surgery.

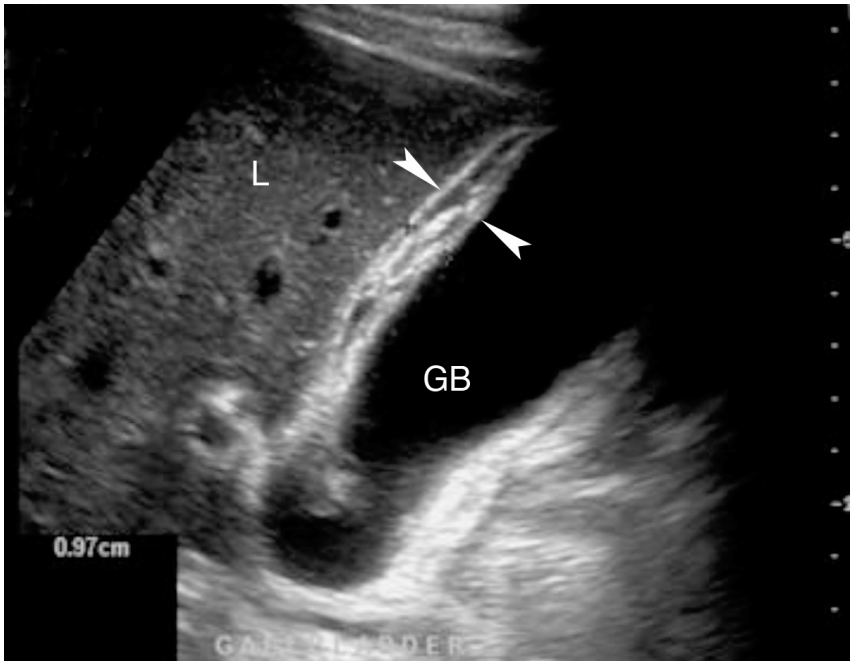

Figure 19: Acute acalculous cholecystitis
The gallbladder (GB), seen through the liver (L), is without detectable gallstones
and shows laminated wall thickening (between arrowheads) characteristic of oedema
and inflammation of the gallbladder wall. This acutely ill patient has acalcuous cholecystitis.

Dilated bile ducts

Normal bile ducts course through the portal triads in association with portal vein and hepatic artery branches. Normal intrahepatic bile ducts are not routinely visualized with ultrasound. However, when the biliary tract becomes obstructed due to an impacted gallstone, tumour or stricture, the bile ducts dilate creating a characteristic appearance sometimes said to look like the branches of a tree. The common bile duct is considered to be dilated when its internal diameter exceeds 6 mm (Figure 20). Patients with biliary obstruction are jaundiced.

Additionally, in the very elderly and in patients after cholecystectomy, the extrahepatic bile ducts may be somewhat more prominent in calibre in the absence of obstruction.

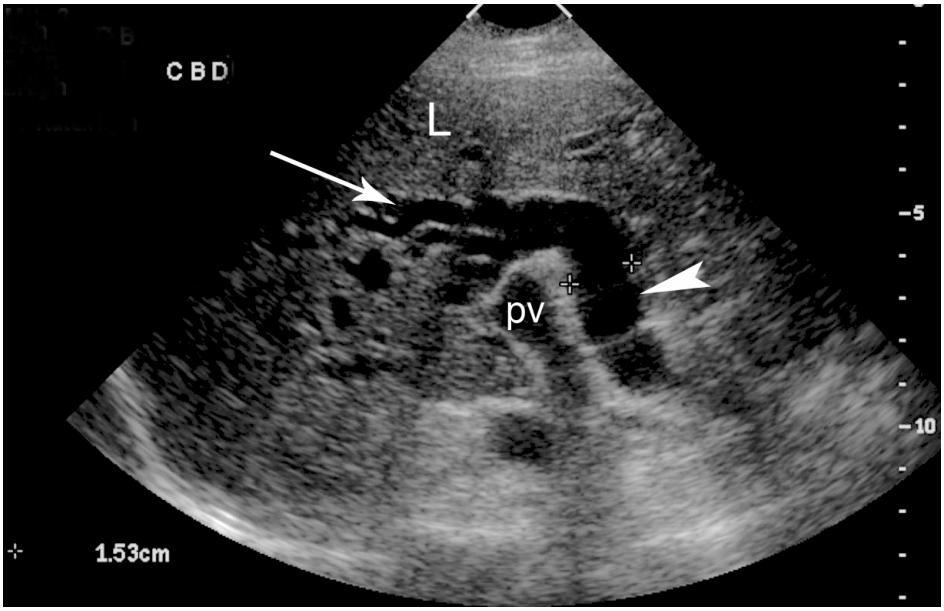

Figure 20: Dilated bile ducts
Oblique image of the liver (L) through the region of the porta hepatis shows the characteristic twisted appearance of dilated bile ducts (arrow). The common bile duct (arrowhead), seen anterior to the portal vein (pv), is measured at 1.5 cm (cursors, +) well above the upper limit of normal (6 mm). This patient had a malignant tumour in the head of the pancreas.

14.4 Pancreas

14.4.1 Normal pancreas

The pancreas is a small organ hidden in the epigastric region posterior to the stomach. Detailed examination by ultrasound requires a skilled examiner. The pancreas is most efficiently examined by scanning in a transverse plane in the midline epigastrium. The pancreas is identified by recognition of blood vessels within and around it. The tail, body, and neck of the pancreas course anterior to the splenic vein. The splenic vein courses from the spleen rightward to join the superior mesenteric vein (SMV), which courses from below, to form the portal vein just posterior to the neck of the pancreas (Figure 21). The pancreatic head wraps around the portal vein medial to the duodenum.

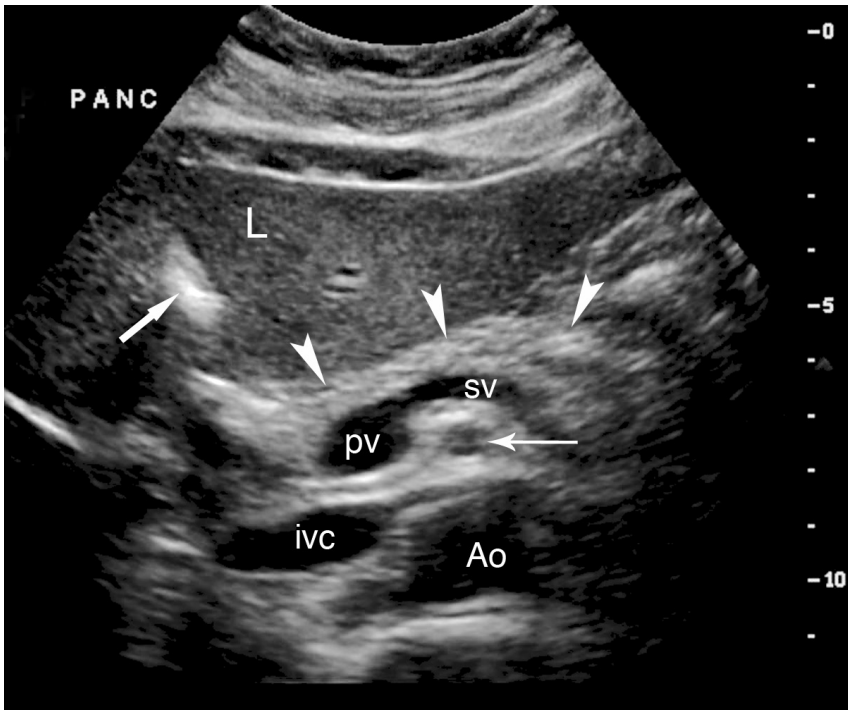

Figure 21: Normal pancreas
The normal pancreas is more echogenic than the liver, kidneys, or spleen. It is identified as the echogenic tissue (arrowheads) anterior to the splenic vein (sv) and portal vein (pv). A large left lobe of the liver (L) serves as a good acoustic window. The pancreas is commonly obscured on ultrasound by gas in the stomach or colon. Other anatomic landmarks to identify are the inferior vena cava (ivc), aorta (Ao), and superior mesenteric artery (thinner arrow). Fat (thicker arrow) in the fissure of the ligamentum teres in the liver is normal and should not be misidentified as a tumour.

14.4.2 Pancreas abnormalities

Pancreatic pseudocyst / peripancreatic fluid

The most common pancreatic pathology identified by ultrasound is fluid that accumulates anterior to the pancreas associated with acute pancreatitis (Figure 22). If the fluid collection is long-standing (>6 weeks) it is considered a pancreatic pseudocyst. While fluid collections associated with severe acute pancreatitis may be found anywhere in the abdomen the most common location is in the epigastric region. These fluid collections are usually sterile but commonly become infected resulting in increasing abdominal pain and sepsis. Infection is confirmed by guided fluid aspiration efficiently performed with ultrasound.

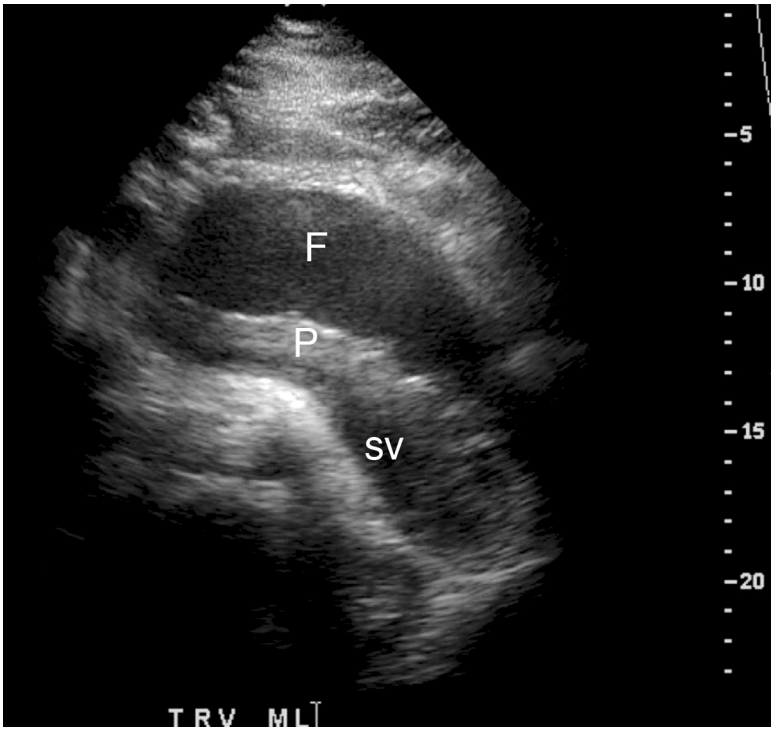

Figure 22: Peripancreatic fluid collection
Transverse image in the midline epigastrium shows a collection of fluid (F) containing echogenic particulate debris anterior to the pancreas (P). The pancreas is identified by its location anterior to the splenic vein (sv).

14.5 Spleen

14.5.1 Normal spleen

The spleen is identified in the left upper quadrant of the abdomen between the diaphragm and the fundus of the stomach. The contour of the spleen is smooth and conforms to the shape of structures around it. On ultrasound examination the spleen is homogeneous with echogenicity slightly greater than that of the liver (Figure 23). The diaphragmatic surface is convex conforming to the curve of the diaphragm (Figure 23). The medial surface is concave with a central hilum containing the splenic vein and the splenic artery. The normal spleen does not exceed 14 cm in any dimension.

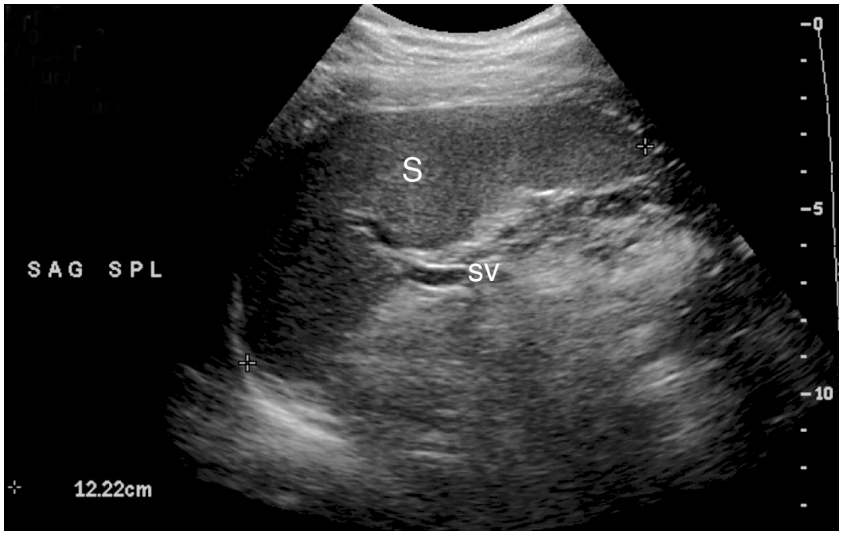

Figure 23: Normal spleen
Longitudinal image through the left upper quadrant of the abdomen demonstrates the normal appearance of the spleen (S). The convex outer surface of the spleen conforms to the shape of the diaphragm. The splenic vein (sv) is seen exiting from the splenic hilum.

14.5.2 Spleen abnormalities

Splenomegaly

Splenomegaly is non-specific and can be due to a broad range of infections, tropical diseases and neoplasms. Causes include portal hypertension, lymphoproliferative disorders such as lymphoma, malaria, infectious mononucleosis, AIDS, and splenic vein thrombosis. Splenomegaly is present if any dimension of the spleen exceeds 14 cm. To obtain the maximum dimension of the spleen lie the patient supine or in the right lateral decubitus position if needed. Scan through the spleen with whichever orientation of the transducer (i.e. transverse, longitudinal or oblique) creates an image that maximizes the long dimension of the spleen, and measure with the callipers.

Focal splenic lesions

Simple splenic cysts typically appear as solitary, round shapes with clear regular borders, uniformly anechoic, and with through transmission and posterior wall enhancement.

Pseudocysts are typically solitary with thick, sometimes calcified walls, and contain echogenic debris which can be caused by infection or haemorrhage.

Splenic abscesses are usually pyogenic caused by sepsis, penetrating trauma, or as a complication of splenic infarction. Patients usually present with pain, fever, and chills. Findings on ultrasound are variable including focal fluid collections containing particulate debris or gas with acoustic shadowing (Figure 24).

Splenic micro-abscesses occur in immune-compromised patients and appear as multiple small (<10 mm) echolucencies or echodensities, commonly in association with similar lesions in the liver.

Lymphoma in the spleen, most commonly manifested as splenomegaly, can sometimes mimic the appearance of micro abscesses, with numerous hypoechoic (though not anechoic) lesions of similar size located throughout the spleen, and often also in the liver.

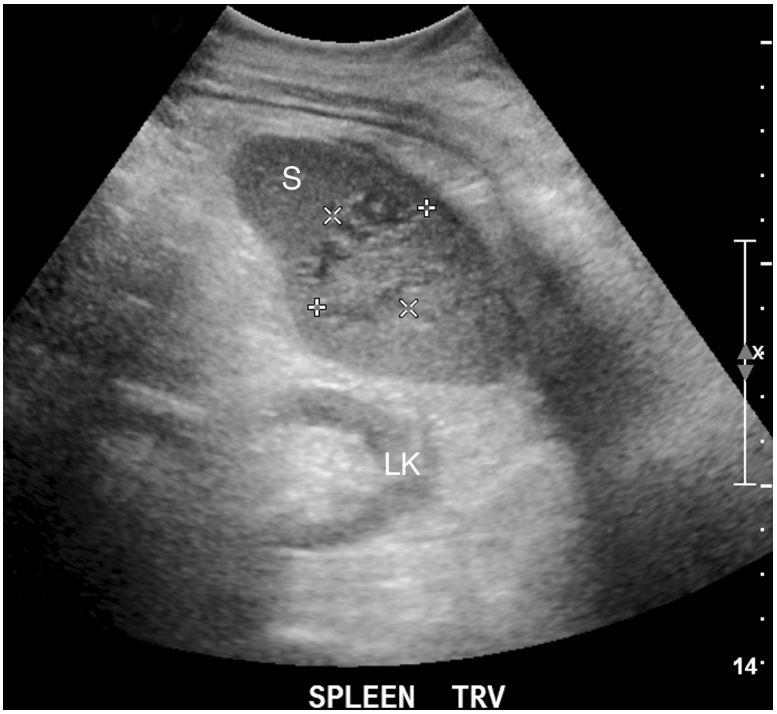

Figure 24: Splenic abscess
Transverse scan in the left upper quadrant in a patient with abdominal pain and sepsis shows a heterogeneous mass (marked by callipers: x, +) in the central portion of the spleen (S). This appearance is typical for splenic abscess.
The left kidney (LK) is evident.

14.6 Free fluid

Fluid in the peritoneal cavity

Fluid in the peritoneal cavity is an important sign of disease. Fluid may accumulate in the peritoneal cavity as a transudate, i.e. simple ascites, as a result of bleeding, i.e. haemoperitoneum, from an infection, or as a result of fluid leaking from abdominal organs, e.g. bile, urine, intestinal perforation.

Fluid fills and distends peritoneal recesses between organs. Bowel loops may float within the fluid. Simple fluid is completely anechoic, i.e. black without echoes, (Figure 25), or be composed of bile or urine.

Floating particulate matter, septations, and thickening of the peritoneal surfaces are signs of complex fluid, which may be blood, bowel contents, or represent infection (Figure 26).

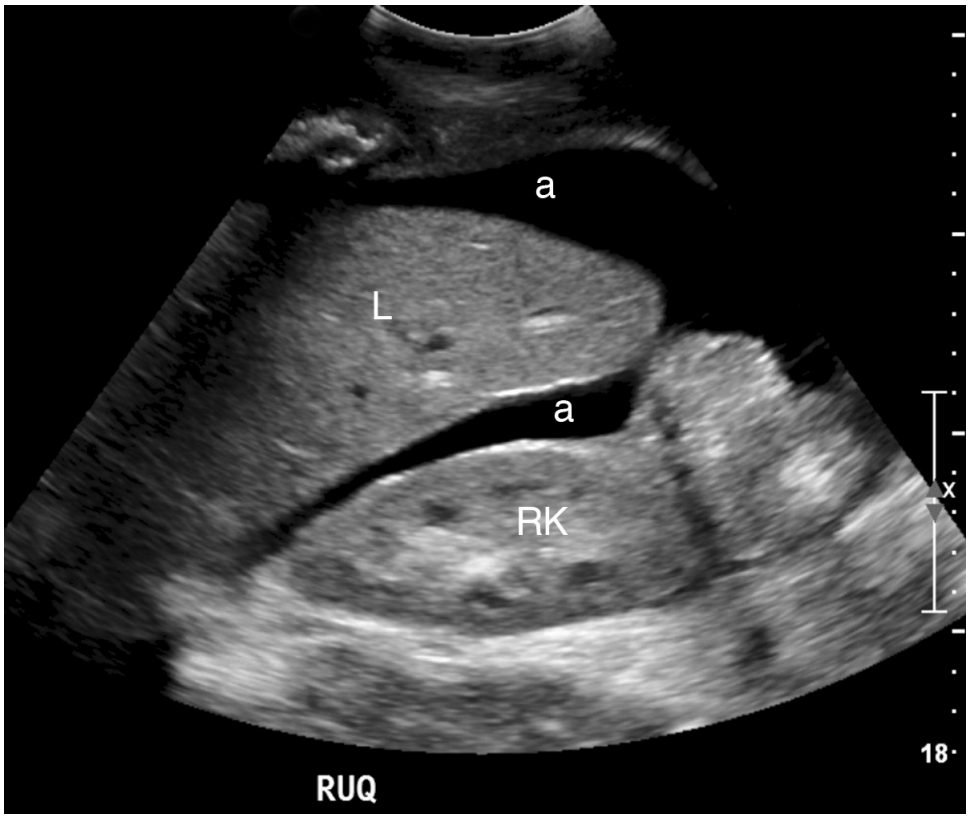

Figure 25: Free fluid
Longitudinal scan through the right upper quadrant reveals anechoic fluid (a) around the liver (L) and between the liver and spleen.
Clear fluid without echoes is likely a transudate most commonly associated with chronic liver disease, congestive heart failure or electrolyte imbalance.

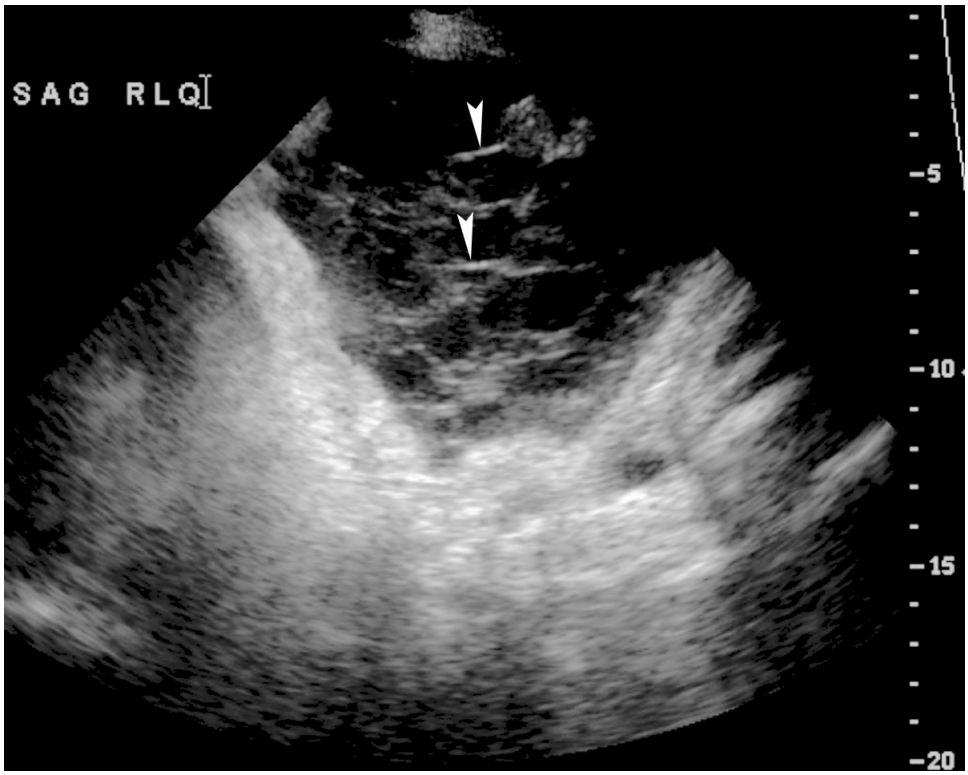

Figure 26: Tuberculous peritonitis
Longitudinal scan through the right lower quadrant reveals complex fluid with prominent septations (arrowheads) distending the peritoneal cavity. In this case the cause was tuberculous peritonitis. However, this appearance of complex ascites may be seen with trauma (e.g. blood or bowel contents), malignant disease (e.g. ovarian cancer), or other infections of the peritoneal cavity.

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15. Urinary tract

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The urinary system consists of the kidneys, ureters, bladder and urethra. The main roles of the renal system are filtration of blood to eliminate waste from the body in the form of urine, regulating electrolyte balance and controlling blood pressure. Pathology of the renal system may be congenital or acquired. Ultrasound is a valuable diagnostic tool for the evaluation of a range of conditions.

Renal and bladder ultrasound can be very useful in patients with common presentations such as abdominal or flank pain, fever, or blood in the urine, i.e. haematuria. It can assist in differentiating diseases of the renal system such as kidney stones, infection, renal masses and hydronephrosis from life threatening conditions such as abdominal aortic aneurysms. An evaluation of the aorta is recommended routinely with the above named presentations.

15.1 Scanning technique – urinary tract

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Begin with the patient lying on their back, i.e. supine. The kidneys are posterior structures so it may require the patient to roll onto their right or left side to obtain a good view. The bladder is best examined distended when full, ask the patient to avoid urination prior to ultrasound examination of the renal system. If the bladder is not full, it can be evaluated after waiting a period of time sufficient for physiologic filling of the bladder. This can be accelerated by asking the patient to drink several large glasses of water, if clinically feasible.

Scanning steps and technique

1. Start in the right mid-axillary line between the bottom of the ribs and the iliac crest. With the transducer in the longitudinal position, i.e. marker pointing to the patients head, sweep superior and / or inferior until the kidney is located. Angling the transducer slightly posteriorly may help. The right kidney is often best examined through the liver.
2. If shadow artefact from the ribs obscures the view alter the angle of the transducer and move it anteriorly or posteriorly into the intercostal space.
3. Bowel gas may obscure the inferior portion of the kidneys. Moving the transducer superiorly and increasing the angle towards the feet, or having the patient change respiration may help. Transducer compression may also displace bowel gas allowing full visualization of the kidney.

4. Scan superior to inferior beyond the margins of the kidney.
5. Turn the transducer 90 degrees anti-clockwise, i.e. marker to the patients' right, keeping the kidney in the middle of the screen and obtain images transverse to the long axis of the kidney.
6. Move to the left mid-axillary line in the same region and repeat for the left kidney. The left kidney is more difficult to examine because it is more likely to be obscured by bowel gas. If the spleen is large it may serve as a 'window' to the left kidney.
7. After scanning the kidneys, move to the suprapubic area and place the transducer just above the pubic bone in the longitudinal plane, i.e. marker pointing to the patients head. Angle the transducer laterally both ways to visualize the entire bladder.
8. Turn the transducer 90 degrees anti-clockwise, i.e. marker to the patients' right, to obtain a transverse view and compare findings from the longitudinal plane.
9. In patients with a full bladder assess the size, shape and any compression effect.

Scanning notes

– The kidneys normally lie on the psoas muscles resulting in the upper poles being more posterior than the lower poles. With the patient in a supine position longitudinal views of the kidneys are obtained in coronal plane with the lower part of the transducer angled a bit anteriorly. It is important to obtain full longitudinal views of the kidneys to accurately assess their size and to exclude significant lesions.

– The left kidney may be best visualized by asking the patient to turn left side up very slightly from the supine position. Reach around the left side of the patient and aim the transducer slightly anteriorly from the back of the patient. Turning the patient into a full right lateral decubitus position, i.e. right side down and left side up, will cause the left lung to hyper expand and will block visualization of the kidney.

– Use the spleen and liver as an acoustic window to improve visualisation of the left and right kidney respectively.

– Careful adjustment of the gain function is critical to accurately differentiating a cystic from a solid renal lesion. Too high a gain setting will make cysts appear as solid tissue. Too low a gain setting will make renal tumours appear as cysts. Gain should be adjusted so that normal renal tissue is mid-level grey in the image. Look carefully for accentuation through transmission, i.e. brighter echoes deep to the lesion, as an important sign of a fluid-containing lesion. Doppler may show blood flow within solid lesions but not within cysts.

– Ectopic kidneys are a normal variant. If either kidney cannot be identified in the expected location, search for an ectopic kidney, most commonly found in the pelvis.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

15.2 Kidneys

15.2.1 Normal kidneys

Normal kidneys in adults

The normal kidney in adults is bean-shaped with a smoothly convex, sometimes, lobulated outer border. The margins of the kidney are usually well-defined by echogenic perirenal fat. The echogenic fat continues into the renal sinus filling the middle of the kidney. The echogenicity of the renal cortex is approximately equal to the echogenicity of the liver parenchyma. The normal adult kidney is 9-13 cm in length (Figure 1 and Figure 2). The thickness of the renal cortex exceeds 1 cm. The renal collecting structures (calyces and pelvis) and proximal ureters are normally collapsed and not visualized.

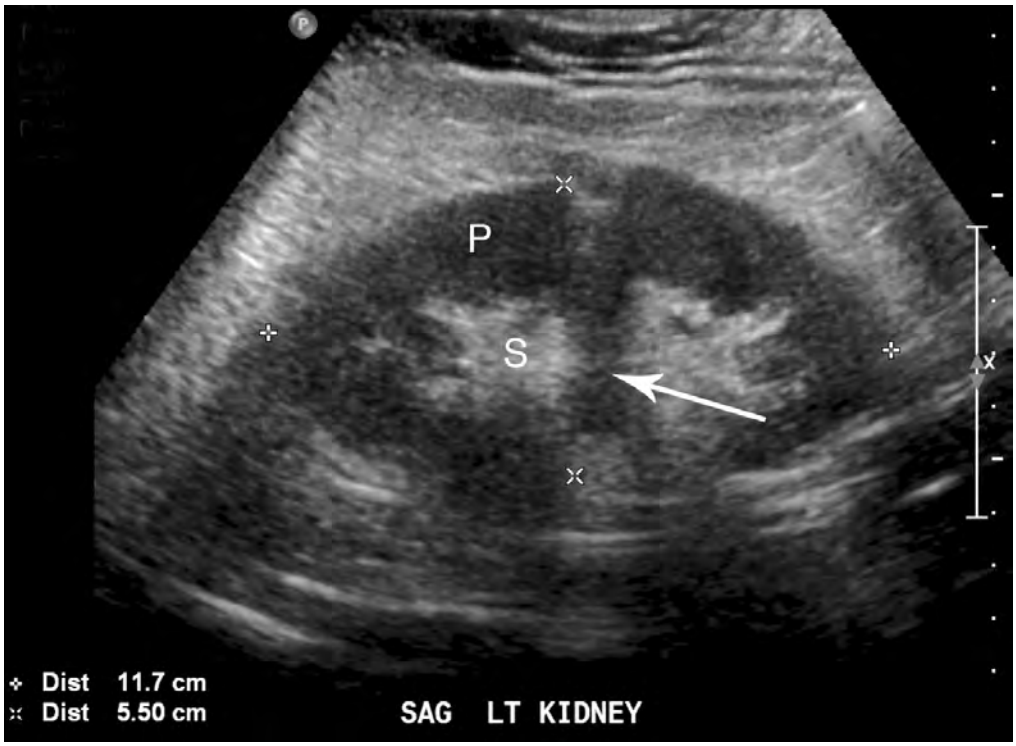


Figure 1: Normal adult kidney
A sagittal ultrasound image shows the normal appearance and size of the left kidney. The renal parenchyma (P) is of uniform mid-level echogenicity, while the central sinus (S) of the kidney is highly echogenic consisting mostly of fat. The kidney is smooth in contour. The thickness of the renal parenchyma is relatively uniform (approximately 1 cm) and is slightly thicker at the upper and lower poles of the kidney. A band of normal parenchyma (arrow) extends across the sinus of the kidney. This is a normal variant. Compare to the image of the normal right kidney. Renal dimensions are measured between the callipers (+, x). Normal renal length in adults is 9-13 cm.

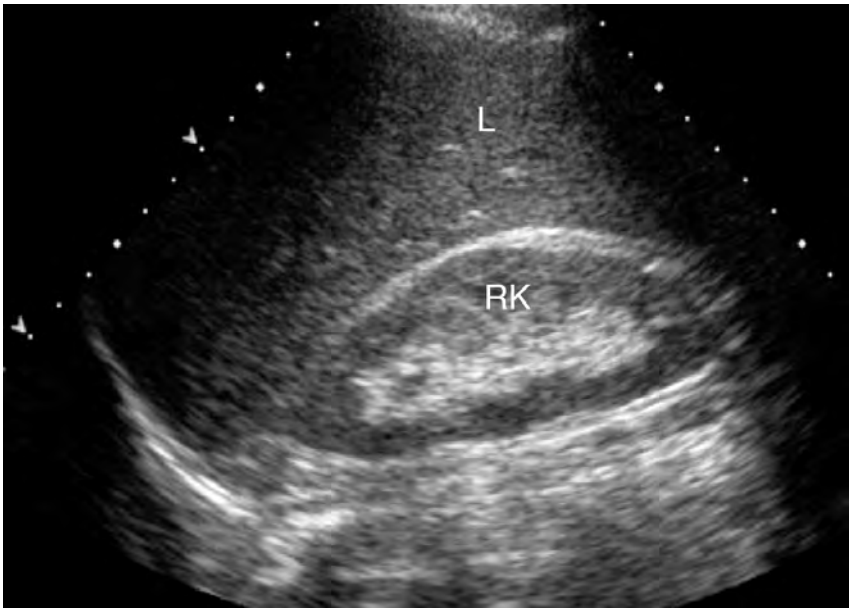


Figure 2: Normal adult kidney
Longitudinal ultrasound image through the liver (L) shows a normal right kidney (RK).
The renal parenchyma is approximately equal in echogenicity to the parenchyma of the liver.
The central sinus of the kidney is echogenic (white) because of the presence of fat investing the collecting system, arteries, veins, and lymphatics in the central portion of the kidney.

Normal kidneys in children

In new-born infants normal kidneys measure 4-6 cm in length. The cortex of the kidneys in new-borns is strikingly echogenic, much brighter than the liver parenchyma. This normal appearance of the kidneys of new-borns persists up to 24 months of age (Figure 3). As child age advances the kidneys continue to enlarge and reach adult appearance and dimensions by age 18. For more detailed scanning of children see 'Paediatric Urinary System' in Chapter 25.

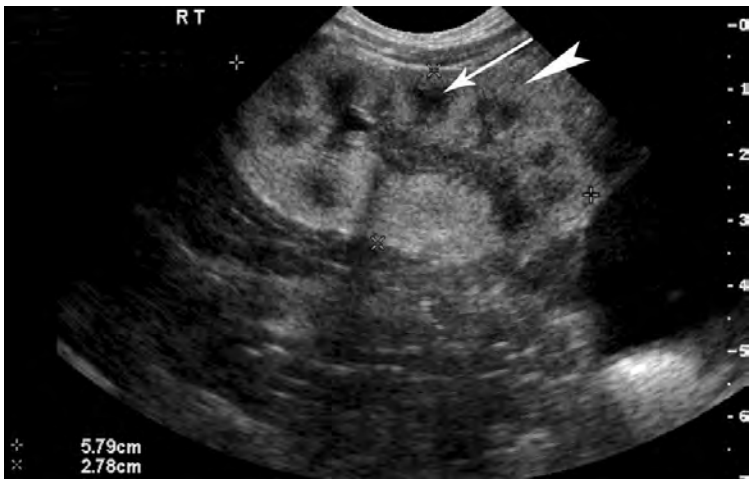


Figure 3: Normal kidney in a new-born
Compared to the normal kidney in adults the cortex (arrowhead) of the normal kidney in a young child (under 2 years of age) is highly echogenic.
The normal medullary pyramids (arrow) appear markedly hypoechoic compared to the cortex.
This normal appearance should not be mistaken for hydronephrosis.

15.2.2 Kidney abnormalities

Small kidneys

In adult's bilateral small kidneys, less than 9 cm in length, are associated with chronic kidney disease and impaired renal function. Renal failure is also associated with diffuse thinning of the renal parenchyma to less than 1 cm thickness. In end stage renal failure the kidneys are often diffusely increased in parenchymal echogenicity, being brighter than the liver parenchyma. Unilateral small kidneys may be congenital or reflect renal atrophy caused by prior infection, long-standing obstruction, or renal artery stenosis.

Large kidneys

Bilateral kidneys larger than 13 cm in adults are caused by diabetic nephropathy, human immunodeficiency virus (HIV) nephropathy, renal cystic disease, and leukaemia or lymphoma. Kidneys affected by HIV nephropathy usually have abnormally increased echogenicity. Unilateral large kidneys are caused by acute pyelonephritis, obstructive uropathy with hydronephrosis, or infiltrative tumours such as renal cell carcinoma, unilateral lymphoma or uroepithelial carcinoma.

Hydronephrosis

Hydronephrosis is the dilatation of the renal pelvis and calyces within the kidney due to an obstruction of urinary flow caused by renal stones or other obstructive pathologies such as tumour, scarring, stricture, or infection. Hydronephrosis is classified as mild, moderate or severe depending on the degree of dilation. Mild hydronephrosis may occur with over hydration and high urine production. Moderate to severe hydronephrosis occurs with obstruction to urine flow and with reflux of urine from the bladder into the ureter (Figure 4).

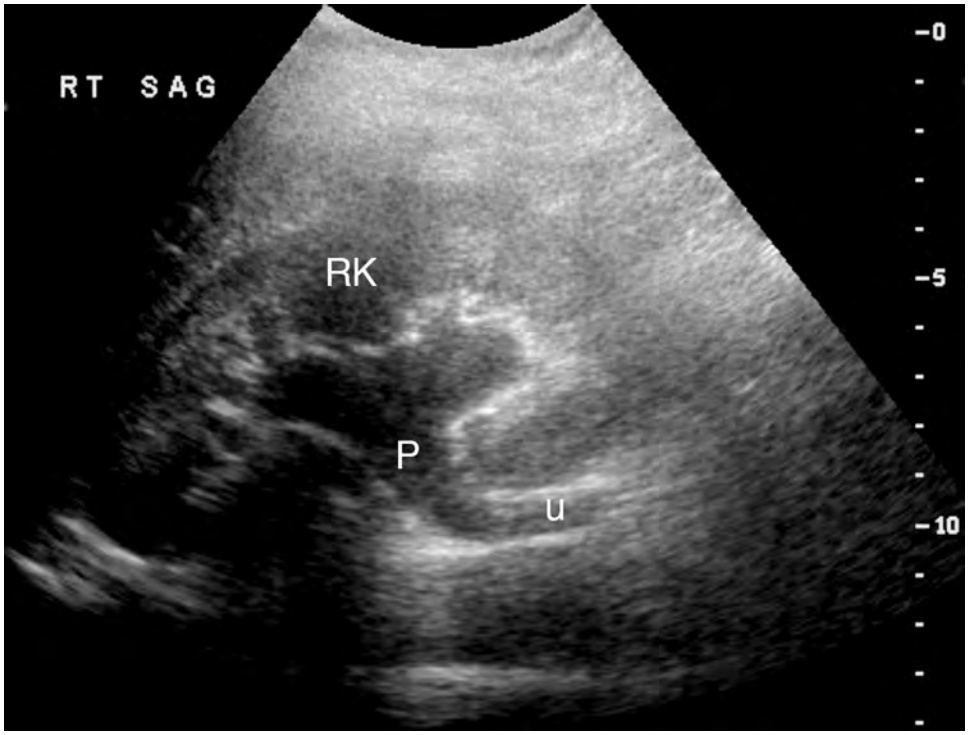


Figure 4: Moderate hydronephrosis
Longitudinal image of the right kidney (RK) demonstrates moderate hydronephrosis with dilatation of the renal collecting system, pelvis (P), and proximal ureter (u). The hydronephrosis was caused by an obstructing stone in the distal ureter.

Renal stones

Urinary tract calculi appear as hyperechoic, i.e. bright white, foci that produce a posterior acoustic shadow. Stones can occur in the kidney causing hydronephrosis (Figure 5) or without causing hydropnephrosis. Ultrasound can detect stones in the kidney >5 mm but often misses smaller stones. Typically stones in the ureter are difficult to identify unless they are very large as the mid to distal ureter is typically obscured by bowel gas.

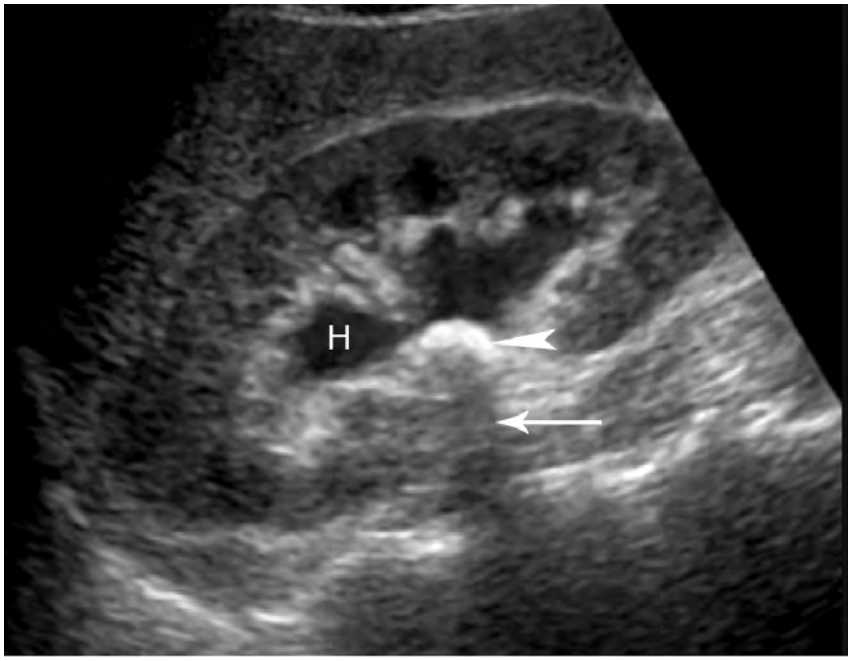


Figure 5: Stone causing hydronephrosis
Longitudinal image of the right kidney a renal stone (arrowhead) as a bright echogenic focus with a posterior acoustic shadow (arrow). The stone is obstructing the renal pelvis causing dilatation of the collecting system (H), hydronephrosis.

Renal cysts

Simple renal cysts are common findings especially in adults. Benign simple renal cysts are sharply defined, round or oval in shape, with thin walls and containing fluid without echoes, i.e. anechoic (Figure 6). Cysts meeting these criteria can be considered incidental findings without need for further evaluation.

Cysts that have uniformly thick walls, walls with thin calcifications, contain echogenic fluid, fluid with echogenic floating particulate matter, or have fluid-fluid levels, may be cysts that have been complicated by previous haemorrhage or infection, or may be acute renal abscesses in the appropriate clinical setting.

Cysts that have irregular thickened walls, thick septations or distinct solid components may be renal tumours and need further evaluation as potential malignancies.

Kidneys that contain a large number of cystic lesions may indicate congenital or acquired renal cystic disease.

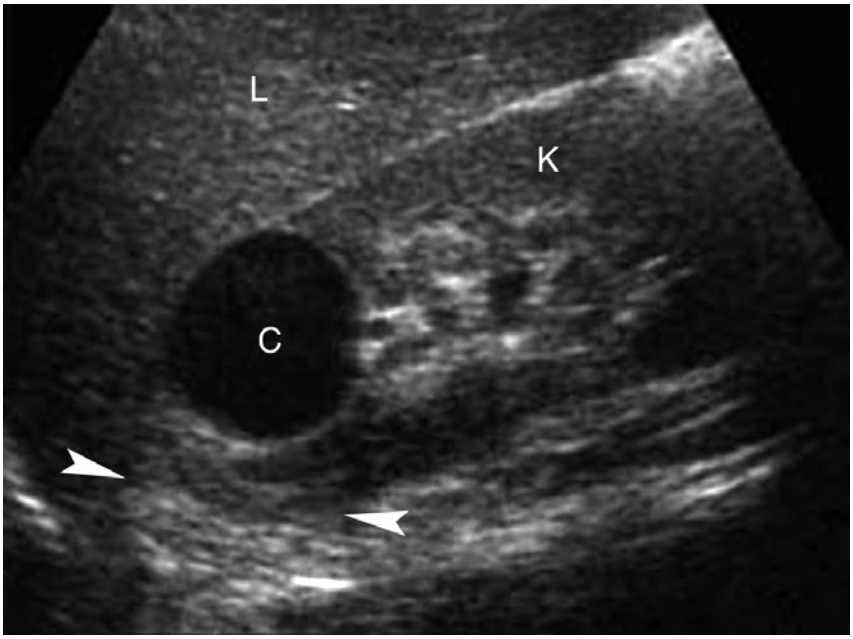


Figure 6: Benign renal cyst
Image of the right kidney (K) using the liver (L) as an acoustic window shows the characteristic appearance of a benign renal cyst (C). The cyst is spherical with sharply defined margins and non-discernible thin walls. Its fluid content is anechoic. Deep to the cyst are brighter echoes (between arrowheads) indicating accentuation through transmission of sound.

Renal cell carcinoma

Solid tumours of the kidney are likely to be renal cell carcinoma (Figure 7). All solid tumours discovered during ultrasound examination require further evaluation to determine if they are renal cancers. Ultrasound is very likely to miss small solid renal tumours because they are often of the same echogenicity as renal parenchyma. While CT detects nearly 100 % of tumours of 15-20 mm in size, ultrasound detects only about 58 % of tumours this size. Only solid tumours larger than 2 cm are reliably detected by ultrasound.

Notes on renal cell carcinoma:

- Renal tumours are detected because they cause a focal bulge to normal smooth contour of the kidney or because they have an echogenicity different from that of the renal parenchyma.
- Renal tumours may be hyperechoic, isoechoic, or hypoechoic compare to renal parenchyma.
- Necrosis, haemorrhage, or cystic degeneration may cause cystic spaces within a renal tumour.
- Cystic forms of renal carcinoma have irregular thick walls and commonly contain echogenic internal debris.
- Colour Doppler will frequently demonstrate the tumour to contain more blood vessels than the adjacent renal parenchyma.

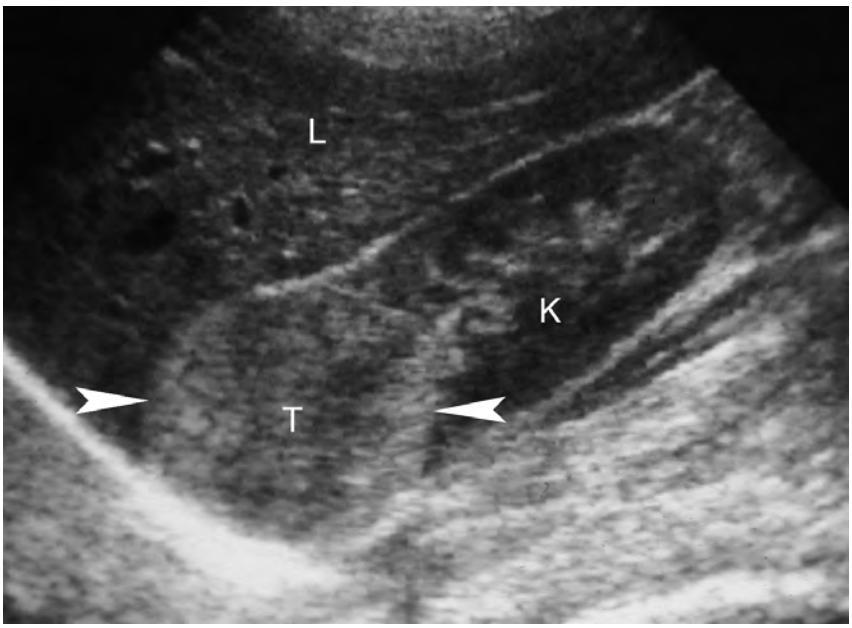
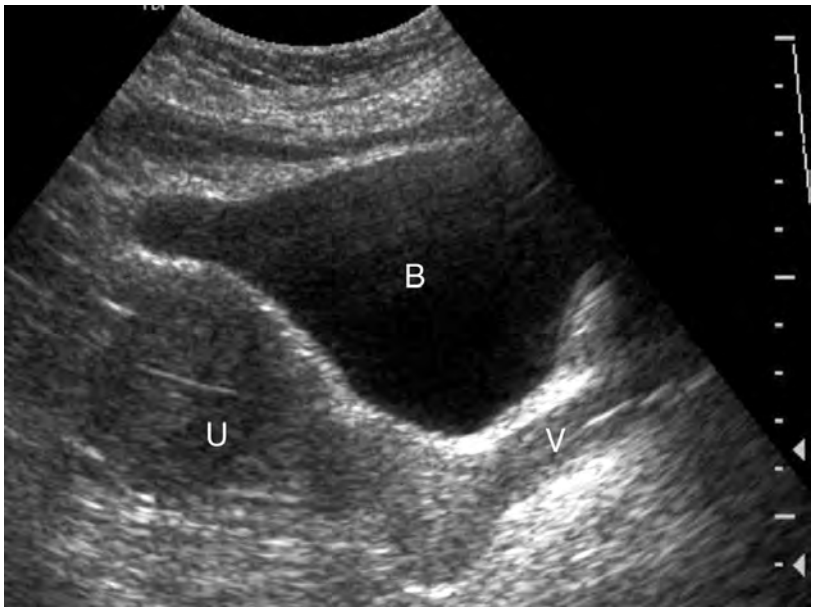


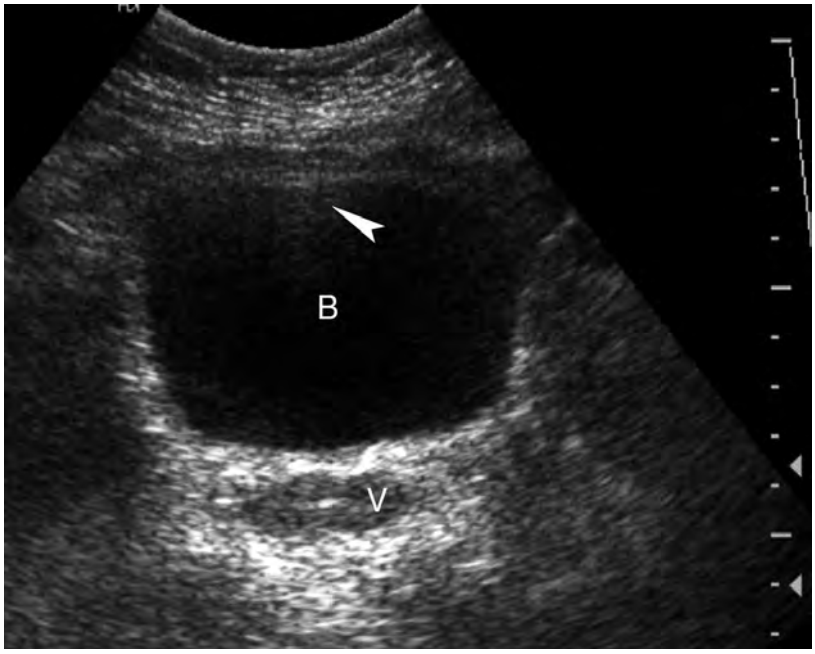
Figure 7: Renal Cell Carcinoma
A heterogeneous rounded solid mass (T, between arrowhead) arising from the upper pole of the right kidney (K) has a typical appearance of a renal cell carcinoma. The tumour is more echogenic (brighter) than the renal parenchyma and distorts the contour of the kidney. The image is obtained through the liver (L).

15.3 Bladder

15.3.1 Normal appearance of the bladder

The shape and appearance of the bladder varies with the degree of filling. When empty the bladder appears thick-walled and irregular due to contraction of the muscular bladder wall. With filling, the wall thins and the mucosa flattens to a smooth well-defined surface. When well-distended the normal bladder wall is 4 mm or less in thickness (Figure 8).

A 



B

Figure 8: Normal bladder
Longitudinal, A, and transverse, B, images demonstrate the normal appearance of the urine-filled bladder. Urine is anechoic (completely without echoes). The wall of the distended bladder is smooth and conforms to the space available to it in the pelvis. The longitudinal image in this female patient shows the normal appearance and location of the uterus (U) and vagina (V). The transverse image through the lower portion of the bladder shows the vagina (V) posteriorly. Note the presence of artefactual reverberation echoes (arrowhead) displayed within the anterior aspect of the bladder. This common artefact should not be mistaken for pathology.

15.3.2 Bladder abnormalities

Schistosomiasis

Schistosoma haematobium is the blood fluke that primarily targets the urinary tract. *S. haematobium* is endemic in Africa and the Middle East. After the larvae penetrate the skin, migrate through the blood stream to the liver, and mature in the liver vasculature, male and female parasites of the *S. haematobium* species pass upstream preferentially in the veins draining the distal ureters and bladder. Parasite eggs, released by the hundreds every day, elicit intense inflammation resulting in granuloma formation in the walls of the ureters and bladder. The granulomas induce fibrosis which stricture the ureters, stiffens the wall of the bladder, and causes irregularities and nodules in the bladder wall. Additional granulomas caused by *S. haematobium* may be seen in the ovaries, cervix, endometrium, female genitalia, and testes.

Ultrasound findings include hydronephrosis and hydroureter caused by ureteral strictures, which are most prominent distally but which can affect most of the ureter. Renal function is impaired by ureteral obstruction. The bladder wall thickens and its mucosal surface becomes nodular and irregular. The trigone area of the bladder is prominently affected producing a prominent bulge and causing in some patients bladder outlet obstruction resulting in urinary stasis and bladder enlargement.

Chronic *S. haematobium* infection is strongly associated with the development of squamous cell carcinoma of the bladder (Figure 9). Large or enlarging bladder masses are suspicious for malignancy. Chronic infection commonly results in calcification of the wall of the ureters and bladder. Conventional radiographs may be helpful in demonstrating the characteristic fine linear

calcifications of the distal ureters and bladder wall. Imaging findings overlap those of genitourinary tuberculosis. Tuberculosis primarily affects the kidneys, secondarily affecting the ureters and bladder. Schistosomiasis primarily affects the bladder and distal ureters, secondarily affecting the kidneys.

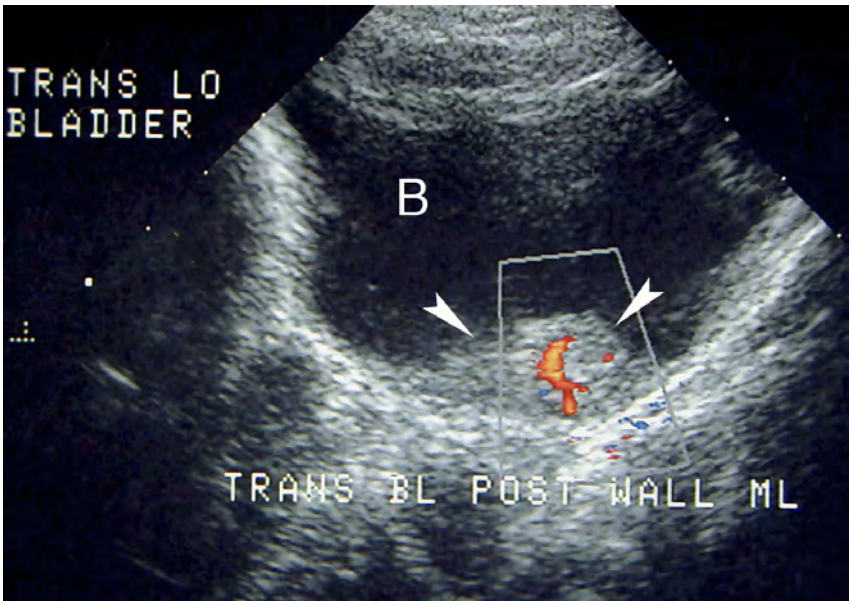


Figure 9: Bladder mass caused by schistosomiasis
Transverse ultrasound image of the bladder (B) reveals a large mass (arrowheads) in the posterior bladder wall near the midline.
Colour Doppler ultrasound reveals prominent blood flow.
A mass this large in a patient with schistomiasis is suspicious for squamous cell carcinoma.

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16. Ultrasound of the right iliac fossa and lower abdomen

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Right iliac fossa and lower abdominal pain is a common indication for an ultrasound examination. The key differential diagnoses to consider are acute appendicitis, bowel pathology which may include colitis, ileocecal tuberculosis and inflammatory bowel disease, and urological disorders. Acute appendicitis is the most common cause of an acute abdomen, defined as sudden, severe abdominal pain less than 24 hours in duration.

In female patients, additional considerations and gynaecological evaluation are required. Clinical review and ultrasound evaluation for ectopic pregnancy, tubovarian abscess and pelvic inflammatory disease, endometriosis, ovarian torsion and tumours should be considered.

16.1 Scanning technique - right iliac fossa

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Ideally the patient should have a full bladder to better visualize the pelvic organs as the air-containing bowel is pushed out of the way and the urine filled bladder provides a sonic window to look deep into the pelvis.

For right iliac fossa imaging of the bowel gentle but continuous compression moves the gas out of the bowel, clearing the view.

The patient should be positioned lying on their back, i.e. supine.

Scanning steps and technique – right iliac fossa

1. Have the patient identify the area of abdominal pain and the point of maximal tenderness.
2. Start at the right iliac bone with the transducer in the longitudinal position with the marker pointing toward the patient's head.
3. Scan slowly moving the transducer towards the midline of the patient whilst maintaining gentle pressure. The patient may experience mild discomfort which is made worse by removing the transducer, i.e. rebound tenderness.
4. Scan over the point of maximal tenderness to demonstrate an inflamed appendix or other cause of pain.

5. The position of the appendix is variable with an inflamed organ lying high behind the caecum or deep in the pelvis and occasionally also reaching across the midline. Adjusting depth and gain controls may improve visualization depending on the position of the structure.
6. Once the appendix has been located, rotate the transducer 90 degrees anti- clockwise so the marker is pointing to the patient's right. This will allow demonstration of the appendix's blind ending tubular form.
7. Any bowel inflammation will be seen as bowel wall thickening. The key in identifying appendicitis is demonstrating the blind end of the appendix. More advanced users can use colour Doppler to identify an increased signal in the inflamed bowel wall.
8. Tumours will be seen as a solid mass extending outside the bowel wall or inside the bowel compressing the lumen. Colour Doppler may confirm blood flow within the solid tissue to aid in the differentiation of tumour from faecal material.
9. The contents of the bowel should be examined to look for tubular structures suggesting intestinal parasites.
10. Scan in the transverse position from the right iliac bone down towards the groin to look for any free fluid within the pelvis which may indicate bowel perforation, bowel contents, ascites or blood.
11. The scan should involve an assessment of the para-aortic region for lymphadenopathy as lymphomas with large nodes may present with non-specific lower abdominal pain.

Scanning notes for the right iliac fossa

– Other causes of right iliac fossa pain may be inflammatory bowel disease which can give symptoms that are difficult to distinguish from appendicitis. In young adults the most common cause is Crohn's disease.
– In areas with endemic tuberculosis terminal ileitis may be caused by abdominoperitoneal tuberculosis. Intestinal parasites may also cause similar symptoms.

Additional considerations for female patients

In women right iliac fossa pain may be caused by a number of gynaecological disorders. For these patients a full clinical and sonographic gynaecological assessment should also be performed. Ectopic pregnancy is a consideration in every woman of child-bearing age as rupture can cause life-threatening bleeding. For scanning guides please see Chapter 7, Gynaecology.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

16.2 Appendix

The normal appendix is difficult to visualize on ultrasound. The normal appendix is a blind-ending tube approximately 6-8 cm in length and 4-5 mm in diameter. The appendix arises from the caecum always on the same side as the ileocecal valve, which is identified at the junction of the terminal ileum with the caecum. Posterior position of the ileocecal valve indicates a posterior position of the appendix. To identify the normal appendix first scan longitudinally in the right flank to identify the cecum by its larger size (>1 cm diameter) and target appearance typical of intestinal tract (Figure 1 and Figure 2). Follow the caecum to its blunt end and identify the smaller appendix arising nearby just inferior to ileocecal junction.

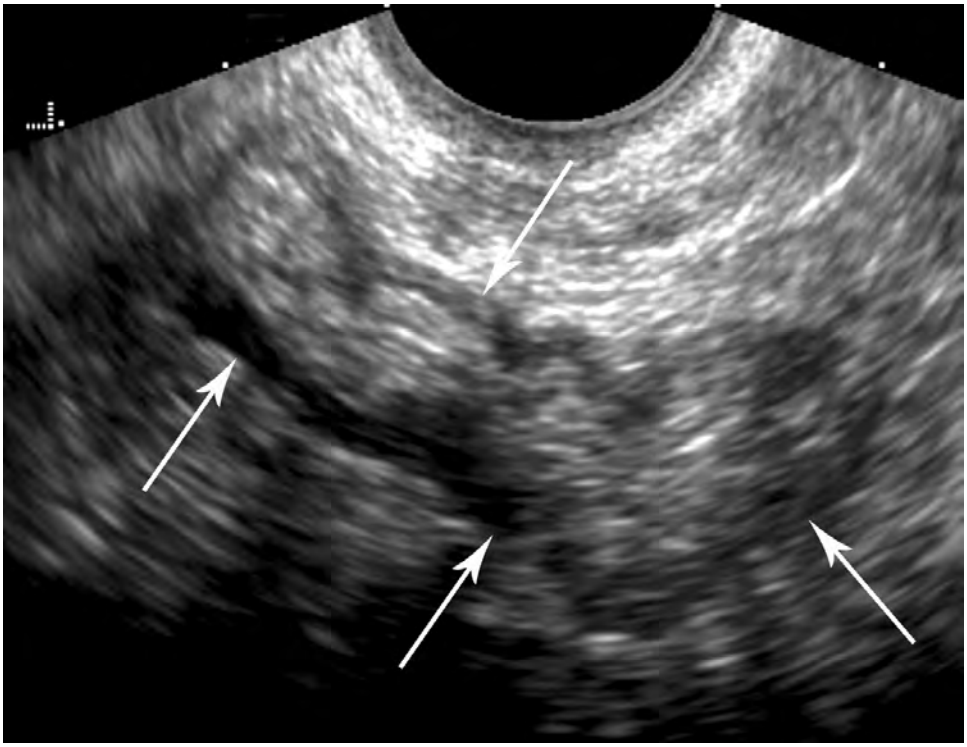

Figure 1: Normal caecum
A longitudinal view of the normal cecum (arrows) is obtained
by scanning in a longitudinal plane in the right flank.
The muscular wall of the caecum is seen as a linear hypoechoic structure.
The content of the caecal lumen is variable and may appear solid, liquid,
or gaseous producing an acoustic shadow.
Scanning with graded compression of the transducer on the patient's abdomen will help
to displace gas and improve visualization of the intestinal tract.

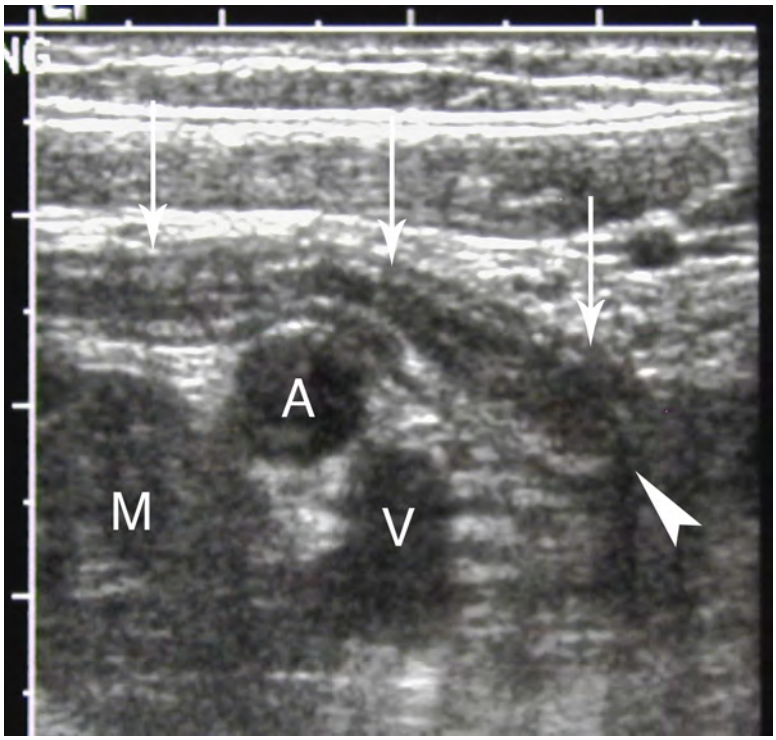

Figure 2: Normal appendix
The normal appendix (arrows) is identified by its normal gut signature bounded by the thin uniform hypoechoic muscular wall and internal hyperechoic submucosa and mucosa. The normal appendix is less than 6 mm in diameter and is easily compressible with transducer pressure. Identity of the appendix is confirmed by identifying its blunt tip (arrowhead). In this image the appendix overlies the right external iliac artery (A) and vein (V) as well as the iliopsoas muscle (M).

Appendicitis

Air in the bowel causes an acoustic shadow preventing visualisation of abdominal structures. An inflamed appendix will be seen as a solid tubular structure surrounded by brighter white intraabdominal fat. An acutely inflamed appendix is non-compressible and >6 mm in diameter (Figure 3 and Figure 4). Inflamed fat surrounding the inflamed appendix becomes more echogenic than normal fat and is fixed moving with the inflamed appendix.

Colour Doppler shows increased vascularity in the wall of the inflamed appendix. A shadowing appendicolith may be evident obstructing the appendix. An appendicolith is a calcified deposit within the appendix highly associated with acute appendicitis, especially in children. As the typical multi-layered appearance of bowel is preserved, care must be taken to ensure the visualised appendix arising from the caecum is blind ending.

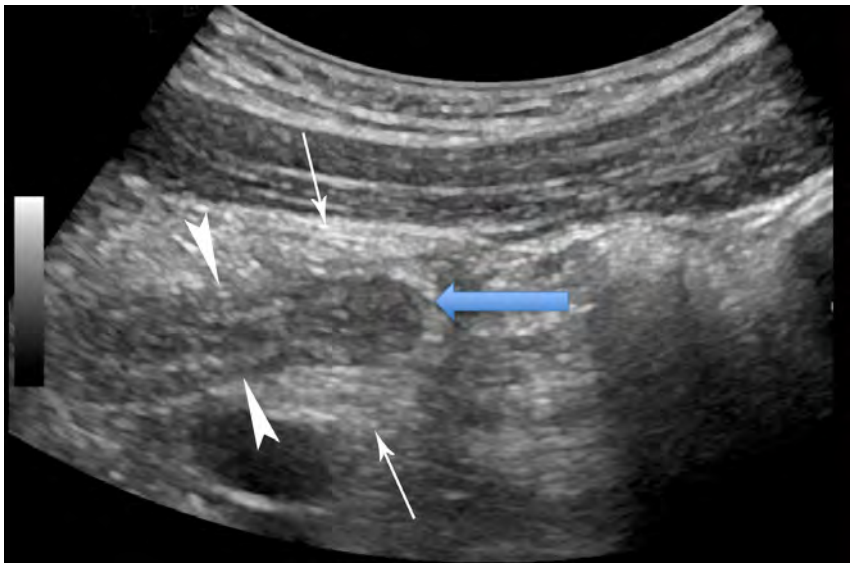

Figure 3: Acute appendicitis
Longitudinal view of the appendix in a patient with acute appendicitis.
The appendix (thick blue arrow) is surrounded by bright reflective fat.
The appendix is seen as a blind ending tubular structure with a thickened wall.
The wall of the appendix is thickened and the diameter of the appendix exceeds 6 mm with transducer compression applied. The location of the appendix corresponds to the area of the patient's maximal tenderness.

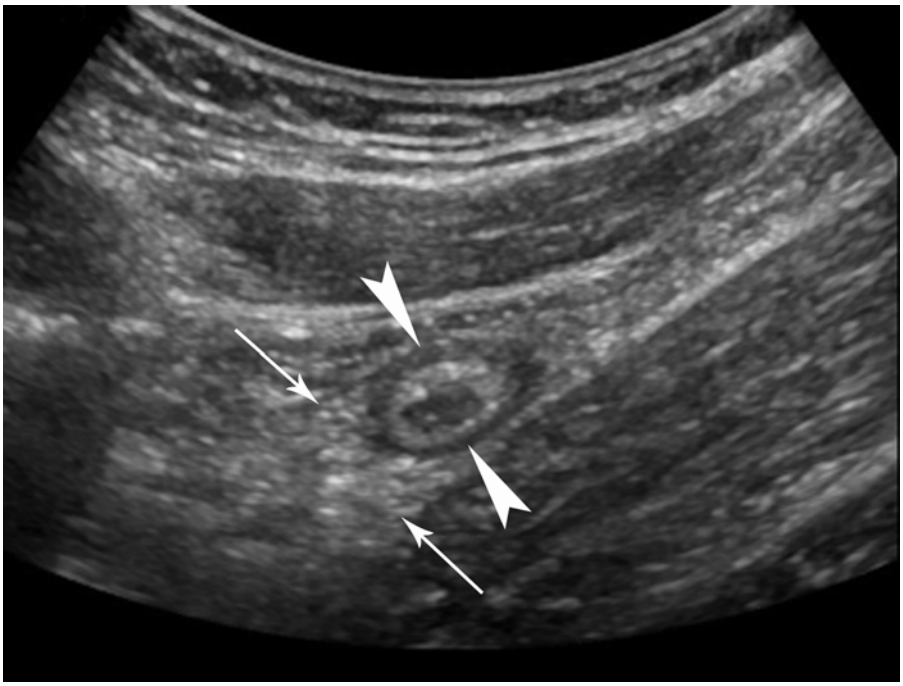

Figure 4: Acute appendicitis
Transverse view of an inflamed appendix (between arrowheads) shows a target appearance typical of the intestinal tract. This multi-layered round appearance is caused by increased fluid in the muscle layers of the appendix. The diameter of the appendix, measured by convention from outer wall to outer wall (between arrowheads) exceeds 6 mm with transducer compression applied. The periappendiceal fat (arrows) is stiff and is increased in echogenicity.

16.3 Inflammatory bowel disease

Inflammatory bowel disease, such as caused by Crohn's disease, tuberculous enteritis, amoebiasis, or Yersinia enteritis, produces circumferential thickening of the bowel wall, impaired peristalsis, and frequent involvement of the mesentery with inflammation. Wall thickening and inflammation produces rigid narrowing of the bowel lumen often resulting in bowel obstruction. Fluid collections, inflammatory masses, and fistulas may occur outside the bowel lumen adjacent to the inflamed bowel. The larger diameter of the involved bowel and the absence of a blind-ending blunt tip differentiate inflammatory bowel disease from acute appendicitis (Figure 5).

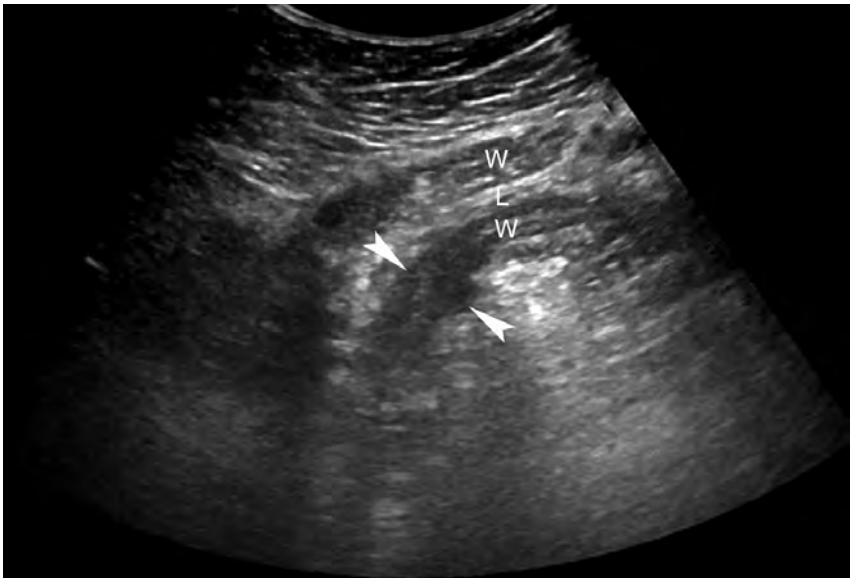

Figure 5: Terminal ileitis
A long-axis view of the terminal ileum shows marked circumferential thickening of the bowel wall (W) measuring 7 mm in thickness (between arrowheads). The lumen (L) of the bowel is narrowed. Real time imaging reveals a lack of bowel peristalsis. The mesenteric fat adjacent to the inflamed bowel is rigid and increased in echogenicity. The bowel demonstrates similar features to the inflamed appendix but without the blind end. The diameter of the inflamed bowel (measured outer wall to outer wall) exceeds 15 mm, much greater than the diameter of an inflamed appendix.

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17. Bones

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Ultrasound can be used to triage patients for bone fractures, with reasonable accuracy, in settings where an X-ray unit is not available.

In patients with bone infection, i.e. osteomyelitis, ultrasound can at times demonstrate fluid collections adjacent to the bone, e.g. subperiosteal abscess.

In patients with bone tumours, ultrasound can at times demonstrate lesional spread, e.g. bone cortex irregularity, periosteal reaction and occasional associated soft-tissue spread.

A bone fracture should be considered in a patient of any age who presents with a focal area of pain, swelling, deformity and tenderness to palpation. In most cases a history of trauma will also exist.

Bone infection should be considered in a patient with fever and focal area of pain, swelling, and tenderness to palpation.

A tumour should be considered in a patient with a focal area of swelling secondary to a firm mass that is usually painless.

17.1 Scanning technique - bones

Transducer

A 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Fractures are often very painful when the injured area is moved, so it is important to keep the patient in a comfortable position, and to avoid moving the injured area. Placing the affected limb underwater, i.e. waterbath, or scanning through a water filled glove if standoff pads are not available may be considered to avoid placing direct pressure on the injured site. Position the contralateral area in a similar alignment, to allow for comparison scanning.

Scanning steps and technique – bones for fracture

1. Start by positioning the transducer on a plane parallel to the long axis of the bone to be scanned (Figure 1). When scanning a limb, this will mean placing the transducer on a sagittal or coronal plane with the marker pointing to the patient's head.

2. Identify the cortical interface of the bone as a very echogenic (bright) unbroken line.
3. Move the transducer longitudinally along the bone, inspecting the cortex for the following signs of fractures: irregularities, bends, breaks and at times fluid accumulation.
4. If there is suspicion for bone infection, i.e. osteomyelitis, look for fluid accumulations adjacent to the bone. If there is suspicion for a tumour, look for cortical irregularities and occasional soft-tissue masses.
5. Scan the contralateral side for comparison.

Scanning notes for bones

– Be aware that children and adolescents will often have short gap-areas where the echogenic (bright) cortical line will be interrupted near the end of a long bone. These are the growth plates, normal structures that should be symmetric on both the affected and non-affected sides.
– Be aware that fractures can occur through the growth plates, manifested by an offset or an asymmetric gap when compared to the contralateral unaffected bone.
– Children will often have fractures that are incomplete, of which the most common is a 'buckle fracture', with a focal ridge arising from the echogenic (bright) cortical interface.

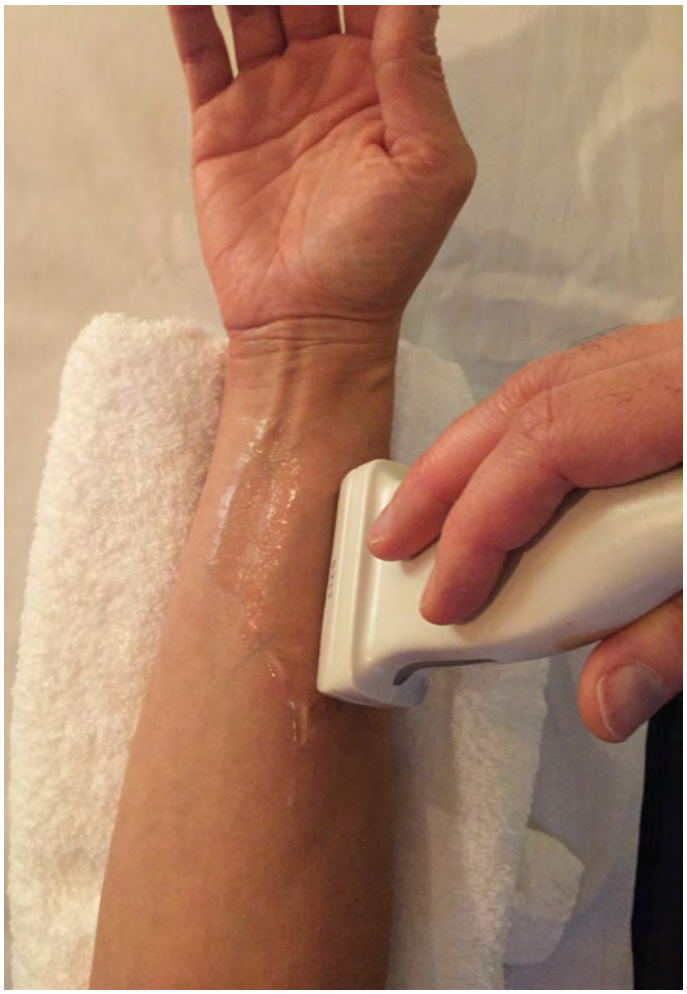

Figure 1: Positioning for scanning of the right radius
The transducer is placed along the long axis of the bone, marker pointing to the patient's head.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

17.2 Normal bone appearances

The cortical interface of the bone is identified as a very echogenic, i.e. bright, unbroken line, deep to the subcutaneous tissues (Figure 2). This line should be continuous, except in children. Children and adolescents will often have short gap-areas where the echogenic, i.e. bright, cortical line will be interrupted near the end of a long bone. These are the growth plates, normal structures that should be symmetric on both the affected and non-affected sides (Figure 3).

Note: Fractures can occur through the growth plates, manifested by an offset or an asymmetric gap when compared to the contralateral unaffected bone.

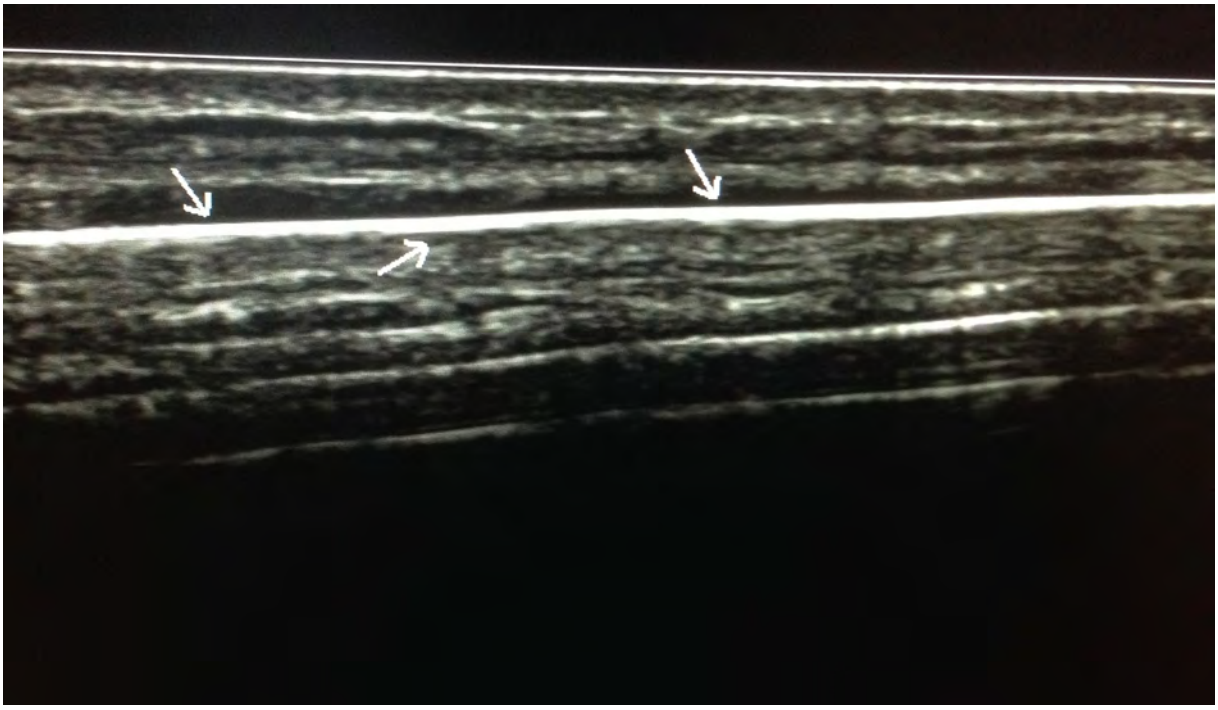

Figure 2: Normal bone appearance
Longitudinal view of the right ulna. The cortical interface of the bone is identified as a very echogenic (bright) unbroken line (arrows).
This line should be continuous, except in children where it can be interrupted near the end of the bone by the normal growth plate (as in Figure 3).

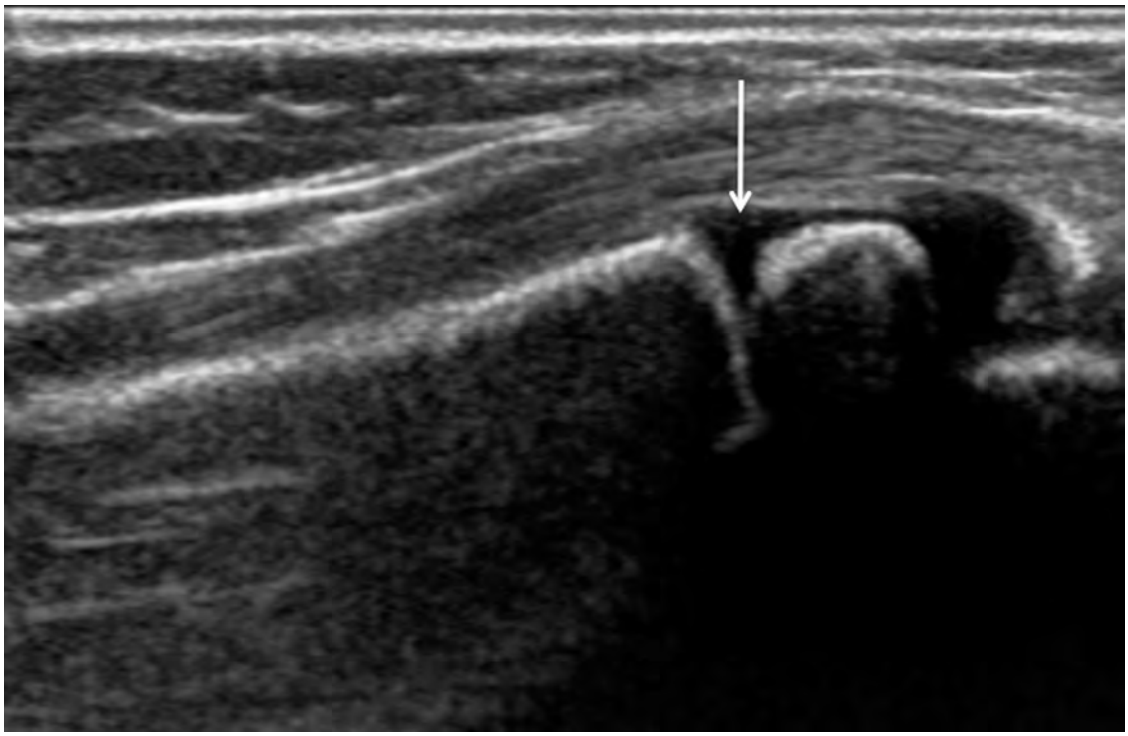

Figure 3: Normal appearing growth plate
Right radius of a six-year-old girl. A short gap-area (arrow) is seen near the distal end of the bone, where the echogenic (bright) cortical line is interrupted. The cortical lines are reasonably aligned at both ends of the gap, with no offset. An equivalent, symmetric gap was present in the contralateral (distal left) radius.

17.3 Fractures

Fractures of the bones usually occur in the context of trauma, either blunt or penetrating. 'Pathological' fractures can occur with even minor trauma in bones that are affected by pre-existing diseases such as infection or tumour. Paediatric patients have distinct fracture patterns. Their bones are especially vulnerable in regions of decreased mineral density, such as over growth plates and metaphysis. It's important, therefore, to be familiar with fracture patterns, depending on the mechanism and the force involved in the injury, as well as the age of the patient.

Fractures are grouped into two major categories:
– Simple / closed fractures – there is no communication between the outside environment and the fracture;
– Compound / open fractures – there is communication between the outside environment and the fracture.

Making this distinction clinically is quite important as open fractures have a higher risk of infection. Within these categories, there are many specific types of fractures including:
– Transverse, oblique, or spiral; depending on the angle of the fracture
– Comminuted; the bone breaks into multiple smaller pieces
– Avulsion; a small piece of bone breaks off.

In addition to the fracture patterns described above, children also may have fractures that are incomplete, as paediatric bones are 'softer', often bending with a force that would cause a complete fracture in an adult. The most common type of these is a 'buckle fracture', depicted on ultrasound as a focal ridge arising from the echogenic, i.e. bright, cortical interface (Figure 4).

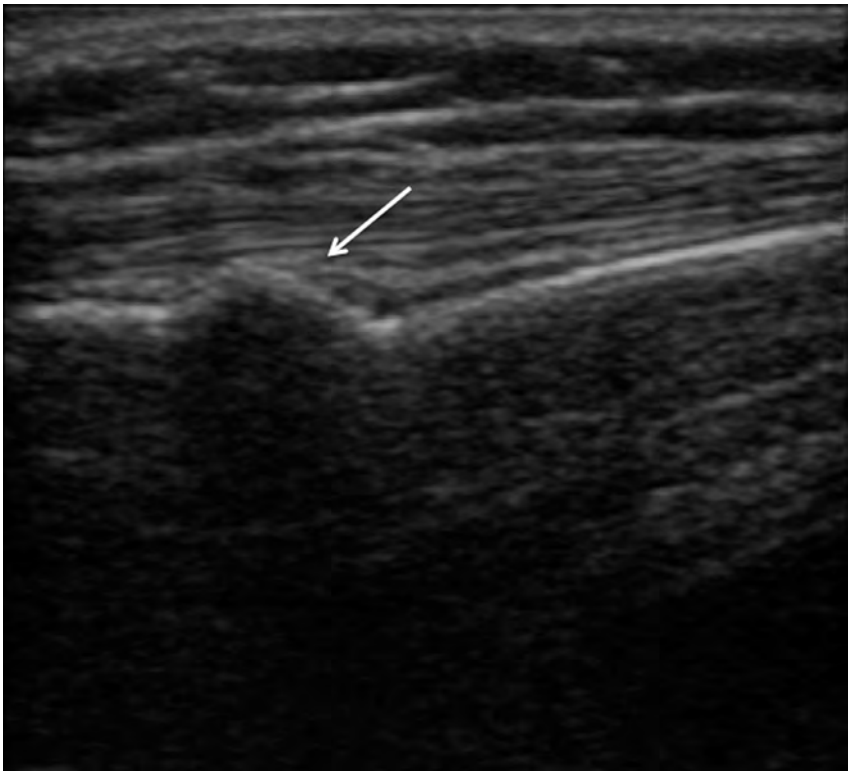

Figure 4: Incomplete 'buckle' fracture
Incomplete 'buckle' fracture of right radius in a child.
The fracture (arrow) is visualized as a ridge that arises from the cortical interface.

A complete fracture will be depicted on ultrasound by interruption and possibly misalignment of the cortical interface (Figure 5).

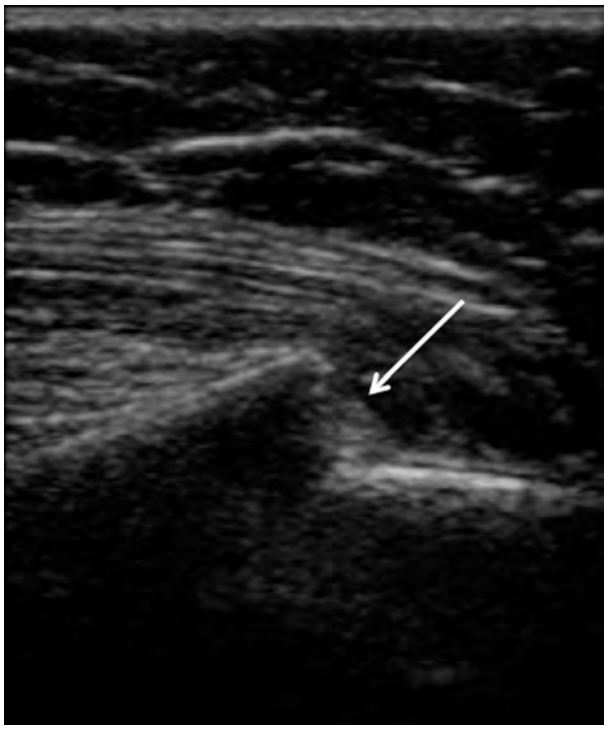

Figure 5: Fracture of a long bone
The echogenic (bright) cortex is interrupted and misaligned (arrow) at the mid-shaft.

A hematoma may accumulate adjacent to the site of fracture, seen on ultrasound as an oblong area that causes mass-effect and displace the adjacent soft-tissues (Figure 6).

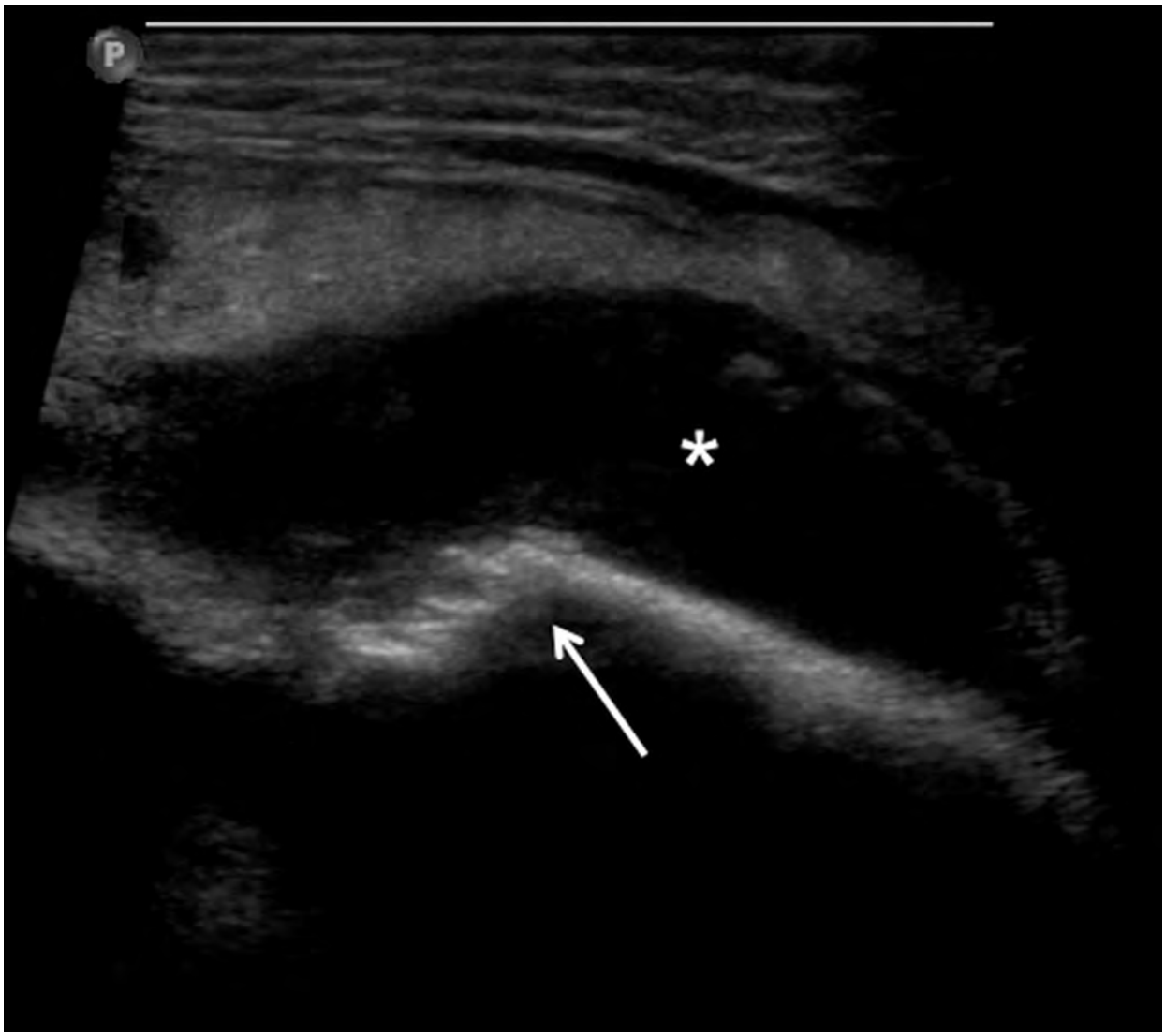

Figure 6: Fracture of a long bone
The echogenic (bright) cortex is interrupted and misaligned (arrow) at the mid-shaft on.
Fluid (hematoma) accumulates in the adjacent superficial planes (*).

17.4 Infection of the bone (osteomyelitis)

Osteomyelitis is infection of the bone and is most frequently caused by bacteria, although other pathogens such fungi and mycobacteria may also be involved. It may spread through the blood stream from distant sites, or nearby tissue as a complication of injury or surgery.

Osteomyelitis may present with no bone abnormality seen on ultrasound. However, at times a subperiosteal abscess may be present, depicted by ultrasound as fluid collection immediate superficial to the echogenic cortical outline (Figure 7). Cortical erosions may also be seen, as irregularities in the echogenic cortical interface. When cortical erosions are present, it may be difficult to differentiate osteomyelitis from a malignant bone tumour (see below on 17.5).

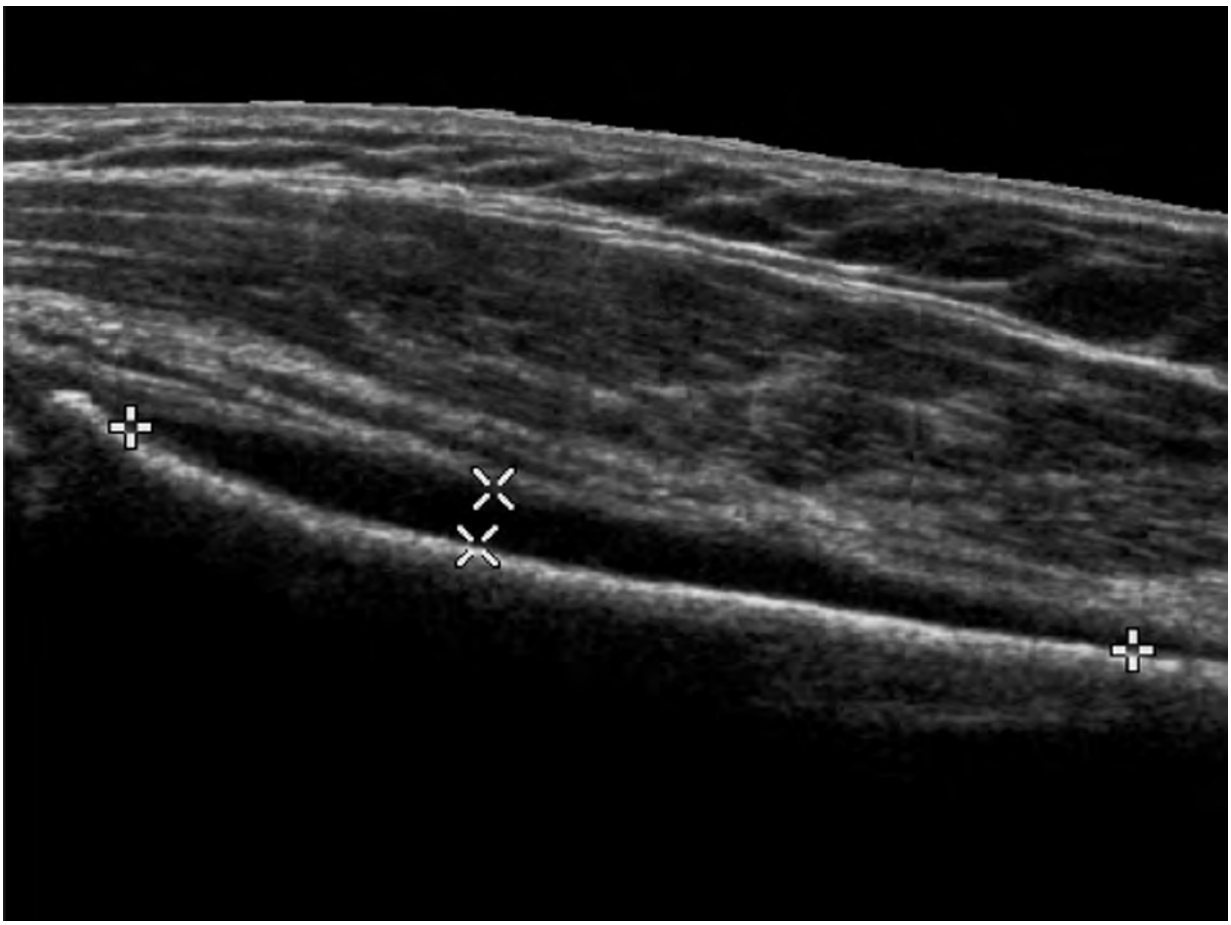

Figure 7: Fluid collection
Fluid collection (subperiosteal abscess), between the callipers superficial to the cortex of the left humerus in a patient with bone infection (osteomyelitis).

17.5 Tumours of the bone

Most primary tumours of the bone are benign. Primary malignant tumours of bone and metastatic lesions to the bone are less common. It may be difficult or impossible to differentiate a benign from a malignant tumour on ultrasound.

In resource-constrained settings, radiographs are the method of choice for such differentiation. However, one should suspect malignancy on ultrasound if there is erosion of the cortex, causing irregularities in the echogenic cortical interface (Figure 8), and / or if an associated soft-tissue mass is present, exerting extrinsic compression upon the adjacent muscle plane. Of note, infection of bone (osteomyelitis) is very common in low / middle income countries and can sometimes mimic a bone tumour in clinical presentation (with pain, swelling, and weight loss) on ultrasound.

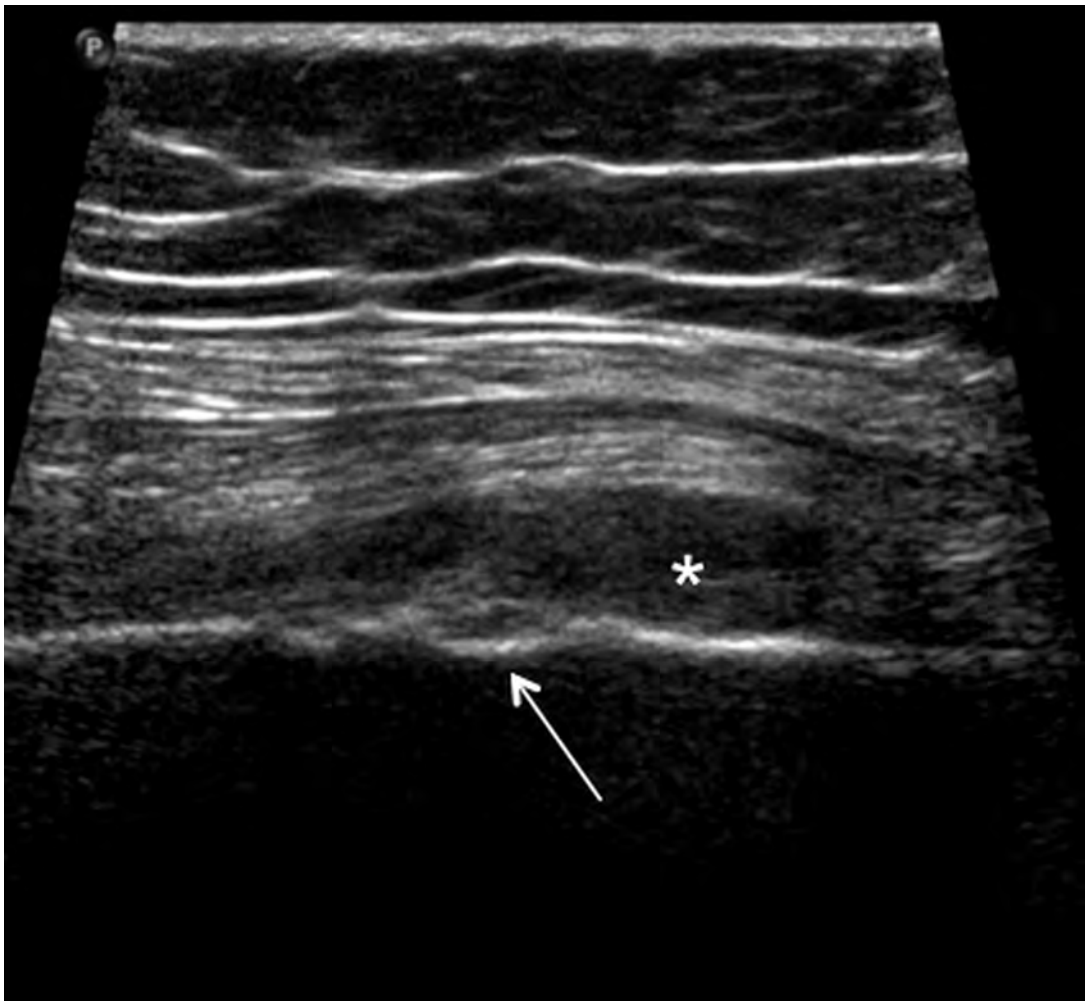

Figure 8: Primary bone tumour (osteosarcoma on histology)
A longitudinal view through the right distal thigh of a teenager demonstrates irregularities along the cortex of the left femur (arrow), as well as tumour extending into the adjacent soft-tissues (asterisk).
Cortical irregularity and soft-tissue extension should raise suspicion for either a malignant tumour or osteomyelitis.

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18. Ultrasound in HIV / TB (FASH)

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Focused assessment with Sonography for HIV / TB (FASH) is a technique to assist in the diagnosis of extrapulmonary tuberculosis (EPTB) and disseminated forms of tuberculosis (TB) frequently seen in patients with HIV. It was developed for resource-constrained settings in which access to alternate imaging modalities such as CT and MRI are limited. FASH is intended as an extension of the clinical consultation to quickly assess patients at the 'point of care' to assist patient's management.

Patients infected with HIV are at high risk of TB and also of EPTB. Common manifestations of EPTB include pericardial effusion, pleural effusion, and abdominal TB. Diagnosis of EPTB is hampered by vague clinical signs, the difficulty to obtain samples and the limited availability of culture and / or molecular diagnostic techniques. Consequently, the diagnosis is usually based on clinical case definitions.

Many of the common pathological findings of EPTB can be visualized by ultrasound. The FASH ultrasound (similar to FAST) is meant to identify pathological effusions in the body cavities which are suggestive of EPTB in the appropriate clinical setting.

Additionally, the FASH ultrasound looks for other findings like enlarged lymph nodes and (micro-) abscesses in the spleen or liver, which are frequently seen in HIV-infected patients and point towards HIV / TB co-infection. These are more difficult to recognize.

The following is intended as a short overview only. A more complete explanation and guidance can be found in the suggested readings section at the end of this chapter.

18.1 Scanning Technique - FASH

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient should be positioned lying on their back, i.e. supine.

The left and right lung bases can be reassessed if required with the patient in a sitting up i.e. an erect position.

Scanning steps and technique – FASH

Position the patient supine on the examination table or bedside. Six standard positions are used during the FASH scan (Figure 1).

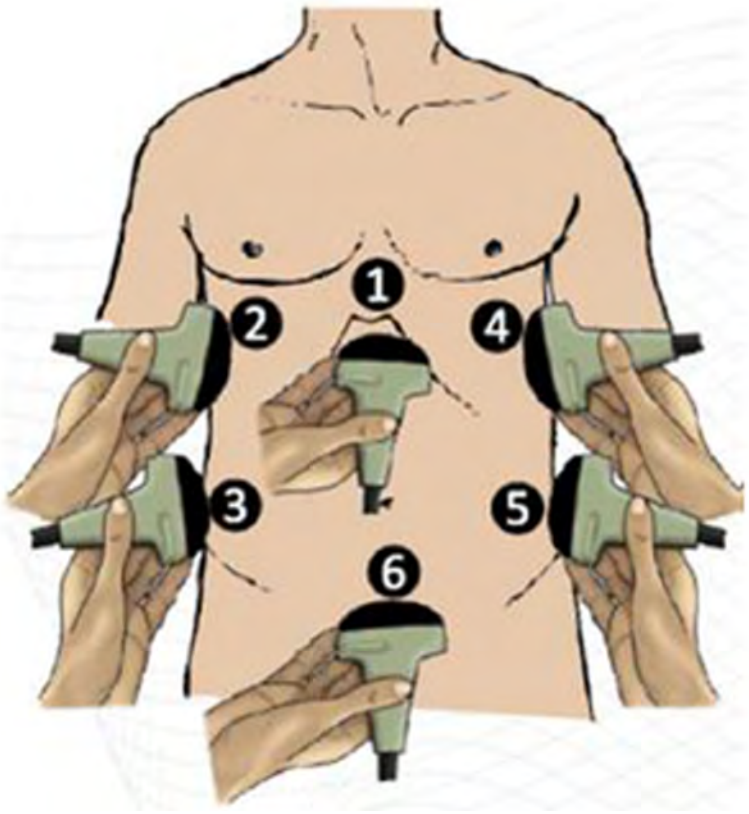

Figure 1: Ultrasound transducer positions in a FASH examination

1. Cardiac (subxiphoid or parasternal long-axis), aortic and upper abdominal view to assess for pericardial effusion and abdominal lymph nodes in the upper abdominal peri-aortic region.
2. Right lung base to assess for pleural effusion.
3. Right upper quadrant (RUQ) view to assess the liver, right kidney and the space between 'Morrison's pouch' for free fluid.
4. Left lung base to assess for pleural effusion.
5. Left upper quadrant (LUQ) view to assess the left kidney, spleen, subphrenic and splenorenal space.
6. Pelvic view to assess the suprapubic region, urinary bladder and rectouterine / retrovesical pouch.

18.2 Cardiac, aortic and upper abdominal view

Scanning technique – subxiphoid cardiac view

1. The transducer is placed in the midline of the patients' body (or just to the right) in the subxiphoid area slightly angled toward the patient's left shoulder with the transducer angled toward the heart.
2. Pressure on the transducer is required. Ensure it is almost parallel to the skin of the torso. If the patient can bend the knees this can help relax the abdominal wall muscles. If the patient is able to cooperate, ask her / him to take a breath in and hold it.
3. Slide the transducer superiorly until the moving heart is evaluated.

4. Use the liver as an 'acoustic window' allowing for direct penetration of the beam to the heart while avoiding the lungs and ribs. Solid organs can be used as 'acoustic windows' allowing the ultrasound beam to penetrate without interference from lung or bowel gas.
5. The transducer can then be tilted cranially to get a view of the intrathoracic organs and the heart.
6. Change the depth of the image, if needed, to include the pericardium and chambers of the heart.
7. An alternate method useful in obese patients is to use a left longitudinal parasternal approach scanning the heart between the ribs.

Normal and abnormal findings - cardiac view

– In a normal subxyphoid cardiac view, the pericardium is seen as a hyperechoic, i.e. white, line surrounding the heart. The interface between the right ventricle and the liver is assessed to identify pericardial fluid, which is absent in Figure 2a.
– In an abnormal view, a hypoechoic, i.e. black band between the rim of the liver and the heart wall represents fluid in the pericardial sac (i.e. pericardial effusion) (Figure 2b). The hypoechoic stripe of a pericardial effusion usually wraps around the apex of the heart.
– In high TB prevalence settings such as areas of sub Saharan Africa pericardial effusion due to TB is common. Other differential diagnoses to consider and correlate clinically include; infectious pericarditis, congestive heart failure, malignancy (e.g. lymphoma, Kaposi's sarcoma), and trauma.
– See the Extended FAST (Chapter 10) and cardiac (Chapter 11) chapter for additional examples of pericardial effusion (but in a different context).

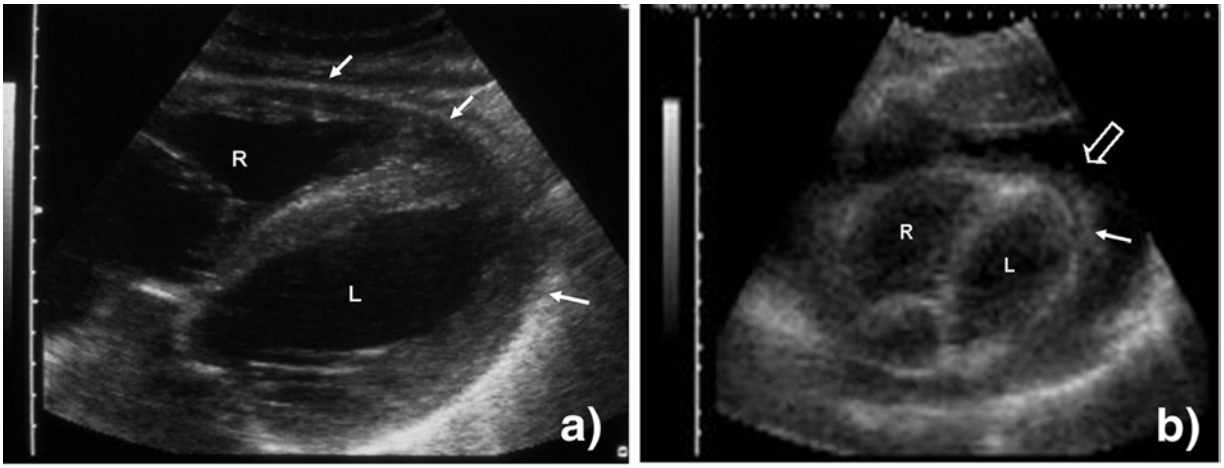

Figure 2: Subxiphoid cardiac view
a) A normal cardiac view. The pericardium surrounds the heart as an echogenic rim (filled arrows). The right (R) and left (L) ventricles of the heart are visible.
b) Pericardial effusion. Right (R) and left (L) ventricle of the heart are again visible. The heart is surrounded by a large hypoechoic band (open arrow), of a pericardial effusion. On the visceral side, echogenic fibrinous material (filled arrow) is visible inside the effusion.

Scanning technique – aortic and upper abdominal view

1. The transducer is tilted back perpendicular to the patient's skin from the last position in the cardiac view. In this position, the upper abdominal / periportal area can be visualized.

2. The transducer is then slowly moved towards the patient's feet to identify the aorta and inferior vena cava (IVC) are identified as round or oval shaped structures that run parallel. The aorta has a thicker, more echogenic i.e. whiter wall.
3. Slight pressure on the transducer may improve visualisation, especially if the abdominal structures are obscured by gas in the bowel.
4. The transducer is slowly moved along the course of the aorta towards the feet, assessing the periaortic area for lymph nodes to the bifurcation of the aorta.
5. Assessment of any suspected mass as a lymph node should be from the centre of the structure for accurate measurements.

Normal and abnormal findings – aortic and upper abdominal view

– Normal periaortic lymph nodes are round or oval shaped hypoechoic masses up to 1.5-2 cm in size that are located in the retroperitoneum close to the major vessels (Figure 3a) and are difficult to visualise by ultrasound.
– Lymph nodes larger than 2 cm may be pathological and are common in patients infected with HIV. Nodes may appear singular or in grouped together (Figure 3b). Typically these nodes are echogenic, but may also appear hyperechoic.
– In high TB prevalence settings, this is suggestive of TB. Other differential diagnosis to consider and correlate clinically include: non-tuberculous mycobacterial (NTM) disease, lymphoma, Kaposi's sarcoma and metastasis.
Note: metastatic lymph nodes are typically more echogenic, and malignant lymphoma tends to have rounder nodes larger in size.

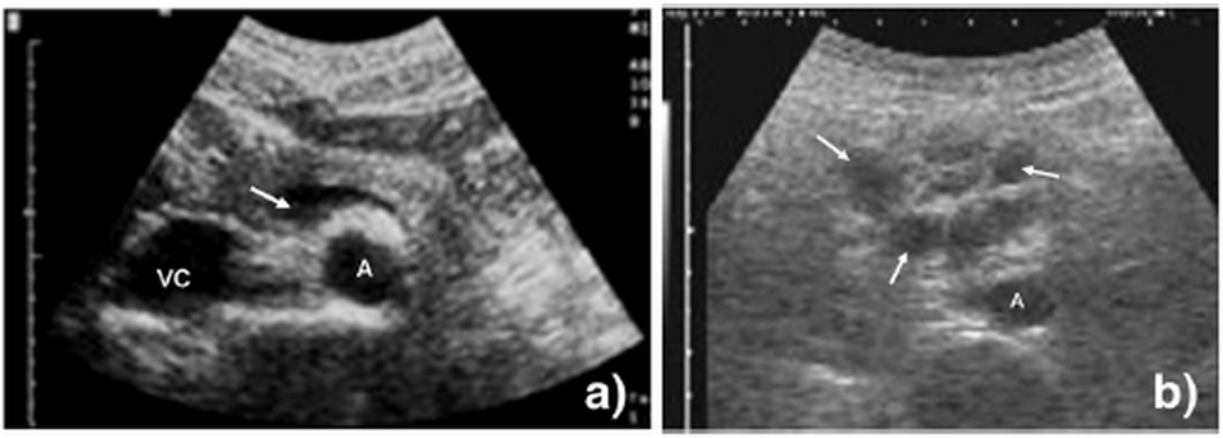

Figure 3: Lymph nodes and vascular structures
a) Vascular structures abdominal aorta (A), inferior vena cava (VC).
The portal confluence / splenic vein (arrow) of the upper abdomen are visible.
b) Multiple round hypoechoic structures are visible (arrow). These represent pathologically enlarged lymph nodes close to the aorta (A).

18.3 Right lung base

Scanning technique - right lung base

1. If possible have the patient put their arms behind their head to allow easier access to the side of the body.

2. Place the transducer with the marker pointing towards the patients head in the right mid-axillary line, at approximately the 8th to 11th intercostal space. It may need to be adjusted up, i.e. toward the head, or down, i.e. towards the feet depending on the patient.
3. Rib shadows can be minimised by rotating the transducer very slightly counter clockwise, so the marker is pointed toward the posterior axilla.
4. As an alternative, the transducer can be adjusted so that the long axis is parallel to the ribs, allowing a transcostal view.

Normal and abnormal findings – right lung base

- The diaphragm and normal pleural space produce a curving echogenic line and mirror artefact that is evidence of normal air filled lung, without a pleural effusion (Figure 4a).
- Pleural fluid will appear as an anechoic, i.e. black, triangle just superior to the diaphragm (Figure 4b). Rib shadows can be used to confirm a pleural effusion.
- Pleural effusions in a HIV-positive patient, especially unilaterally is suggestive of TB. Other differential diagnoses to consider and correlate clinically include: generalized Kaposi's sarcoma, other malignancies, bacterial infection and congestive heart failure.
- See images in Extended FAST chapter for additional similar examples.

18.4 Right upper quadrant (RUQ) and liver

Scanning technique – RUQ and liver

1. The transducer is moved a few centimetres towards the feet from transducer position 2.
2. Identify and asses the space between the liver and right kidney (Morrison's pouch).
3. It is then important to visualise the inferior pole of the kidney as a small volume of peritoneal fluid may first collect there. Slide the transducer inferiorly along axillary line to locate the inferior pole.
4. Move or angle the transducer slightly towards the head, reposition the liver centrally and angle the transducer to assess for focal liver lesions.

Normal and abnormal findings – RUQ and liver scan

– Morrison's pouch is the space between the Glisson's capsule of the liver and Gerota's fascia of the right kidney. Normally the kidney and liver are nearly (juxtaposed) next to one another. Retroperitoneal fat appears as a bright hyperechoic (white) line separating the two organs (Figure 4a).
– Abdominal free fluid presents a hypoechoic, i.e. a dark, stripe seen between the liver and the kidney (Figure 4c) or surrounding the tip of the liver.
– Abdominal free fluid such as ascites may be due to a number of possible reasons such as liver cirrhosis; however abdominal TB particularly in a HIV positive patient is possible and must be correlated with other clinical and laboratory findings.
– The normal liver is homogeneous in echogenicity equal to or slightly greater than the echogenicity of the kidney.
– Large liver lesions are typically relatively easy to identify (Figure 4d), however characterisation is more difficult. Abnormal findings may be due to TB, such as hepatic granulomatous TB disease, or tuberculomta, but there is a broad range of differential diagnoses. In tropical settings, in patients with HIV amoebic and bacterial abscesses are also common causes of liver lesions.

– The aim of the FASH assessment of the liver is limited to identify large lesions. More detailed assessment of the liver is beyond the scope of the FASH scan.
  • For a more detailed scanning instructions of the liver and lesion characterisation, see Chapter 14, Upper abdominal scan.

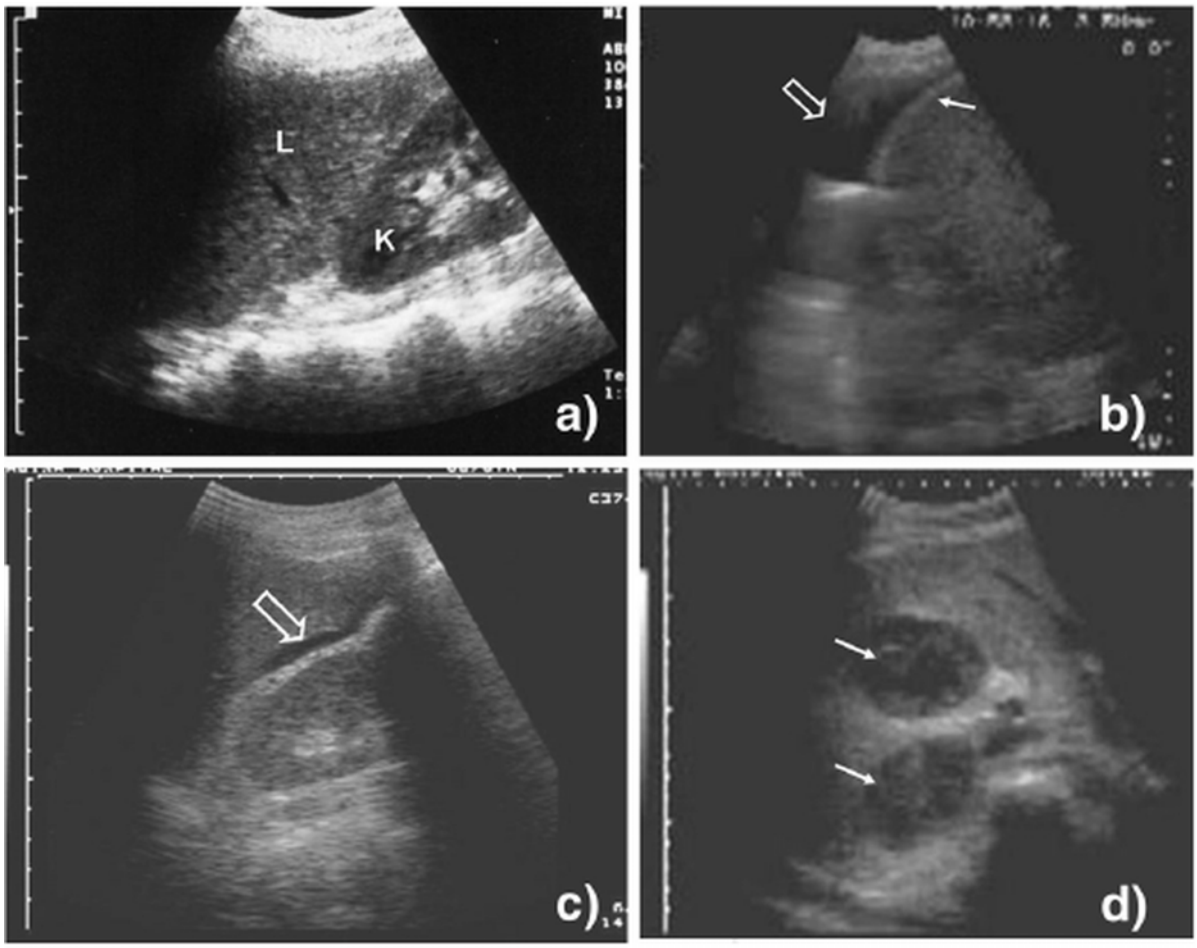

Figure 4: RUQ and right lung base
a) Liver (L) and right kidney (K) are visible; there is no echo-free fluid above or below the liver.
b) An anechoic fluid collection is visible above the liver and the echogenic diaphragm (filled arrow) representing pleural effusion (open arrow) on the right side.
c) A small anechoic (black) fluid collection is visible between the liver and the right kidney (open arrow) (Morrison's pouch) indicating free abdominal fluid.
d) Visualised in the parenchyma of the liver are two hypoechoic large lesions (filled arrows).

18.5 Left lung base

Scanning technique – left lung base

1. Mirroring the transducer position 2 from the right lung base, the transducer is placed on the left side of the thorax to assess for left sided pleural effusions.
2. Adjust the transducer and rotate it very slightly clockwise in order to remove rib shadows and obtain a suitable view of the spleen and diaphragm.

3. At the completion of the FASH exam the left and right lung bases can be reassessed if required with the patient in an erect position (i.e. sitting up).

Normal and abnormal findings – left lung base

– The diaphragm and normal pleural space produce an echogenic line. The perisplenic spaces are echogenic, without a pleural effusion (Figure 5a).
– Pleural effusion appears as an anechoic, i.e. black, stripe or triangle superior to the diaphragm (Figure 5b).
– See scanning notes on the right lung base view for comments on pleural effusions.

18.6 Left upper quadrant (LUQ) view

Scanning technique – LUQ

1. Mirroring the transducer position 3, the transducer is placed on the left flank to examine for free abdominal fluid in the dependent parts of the left abdominal cavity, i.e. between the spleen and kidney, and around the kidney.
2. Adjust posteriorly and superiorly in order to get the best image as the left kidney is more posterior and superior than the right kidney
3. Slide the transducer cephalad and rotate it very slightly clockwise in order to remove rib shadows and obtain a suitable view of the spleen and diaphragm.
4. Inspiration may not be helpful as pulmonary air obscures the spleen.

Normal and abnormal findings - LUQ

– The normal spleen has homogenous parenchyma with a smoothly rounded sharply defined capsule, and is located next to the left kidney separated by an echogenic thin space (Figure 5a).
– The spleen is smooth and homogeneous with an echogenicity slightly greater than that of the liver.
– Free fluid accumulates superiorly between the spleen and the diaphragm; and posteriorly around the inferior tip of the spleen (Figure 5c). Less frequently, only when there is a lot of fluid, will fluid accumulate between the kidney and the spleen.
– Miliary TB often involves the spleen and is more common in immunocompromised patients. Multiple hypoechoic lesions may represent abscesses secondary to disseminated TB (Figure 5d). Other differential diagnoses to consider and correlate clinically include; infection and disseminated malignancy.
– The aim of the FASH assessment of the spleen is limited. A more detailed assessment of the spleen is beyond the scope of the FASH scan. For a more detailed scanning instructions of the spleen and pathology, see Chapter 14, Upper abdominal scan

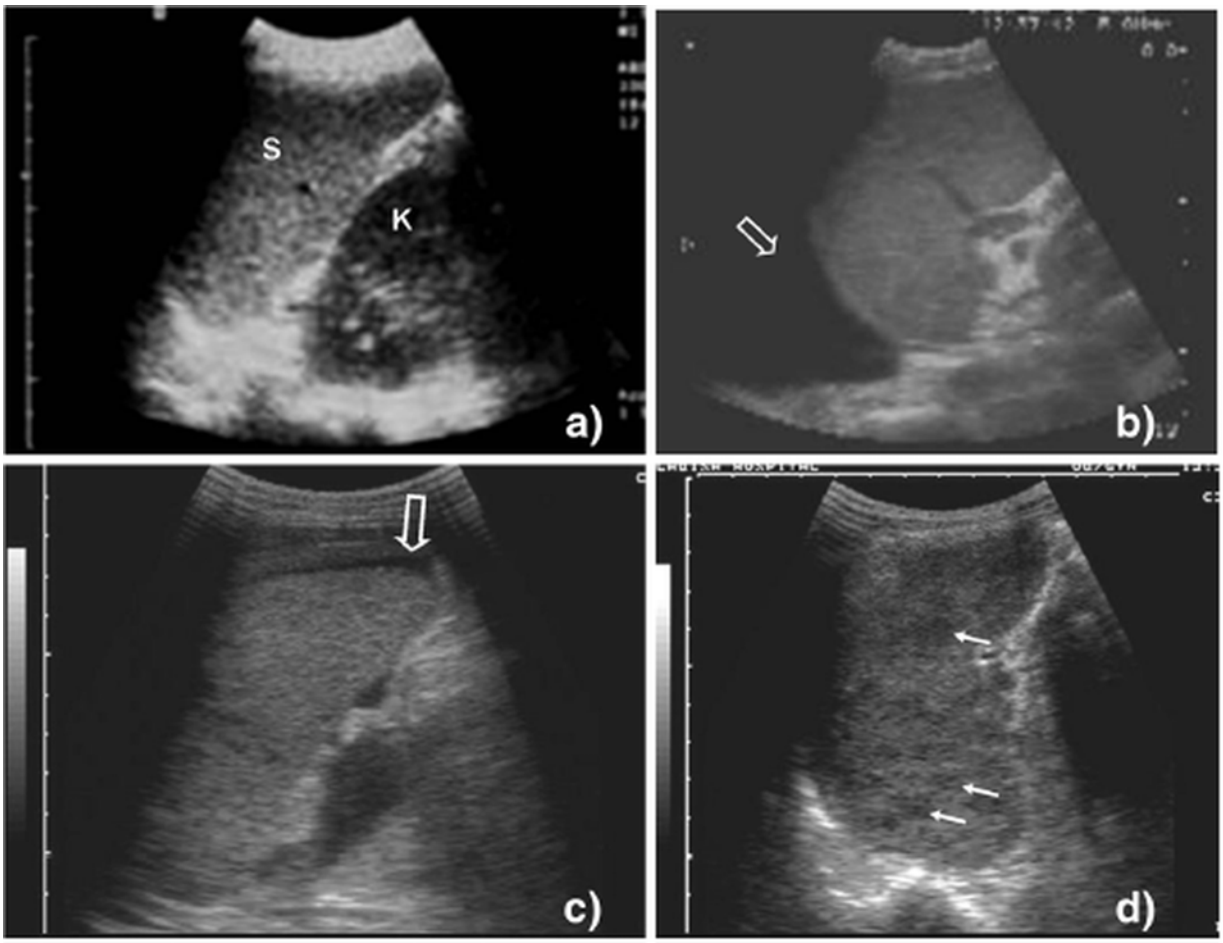

Figure 5: LUQ and left lung base

a) Spleen (S) and left kidney (K) are visible; there is no echo-free fluid above or below the spleen.
b) An anechoic fluid collection is visible above the spleen representing pleural effusion (open arrow) on the left side.
c) An anechoic fluid collection is visible around the lower pole of the spleen (open arrow) indicating free abdominal fluid.
d) Hypoechoic lesions can be seen inside the spleen (filled arrow). Micro-abscesses due to disseminated TB are a probable explanation.

18.7 Pelvic view

Scanning technique – pelvic view

1. This scan should be performed on a patient with a full bladder if possible.
2. Place the transducer just superior to the symphysis pubis in the midline of the abdomen. Ensure the marker points toward the patient's right side.
3. Angle the transducer inferiorly (toward the patient's feet) to visualize the urine-filled bladder
4. Scan side to side to identify pockets of free fluid between bowel loops.
5. Fluid collections may be seen lateral or posterior to the bladder or uterus.
6. Sliding the transducer right and left on the symphysis pubis provides full evaluation of the pelvis.
7. For an alternate longitudinal view, rotate the transducer 90 degrees with the marker at the patients head.

Normal and abnormal findings – pelvic view

– The normal pelvic view demonstrates an absence of free intraperitoneal fluid in the pelvis (Figure 6a).

– Free fluid is anechoic, i.e. dark, and found in the rectovesicular pouch in men and rectouterine pouch, i.e. pouch of Douglas, in women. This view requires that the bladder be moderately full to allow detection of small fluid collections (Figure 6b). Failure to adequately fill the bladder may result in false negative or indeterminate results.

– 30-40 % of women of reproductive age have fluid collections of up to 50 mL in the pouch of Douglas. These are considered physiologic when related to recent ovulation.

– Free fluid in the abdomen or pelvic region can represent ascites which may be due to TB, or other causes (as previously mentioned).

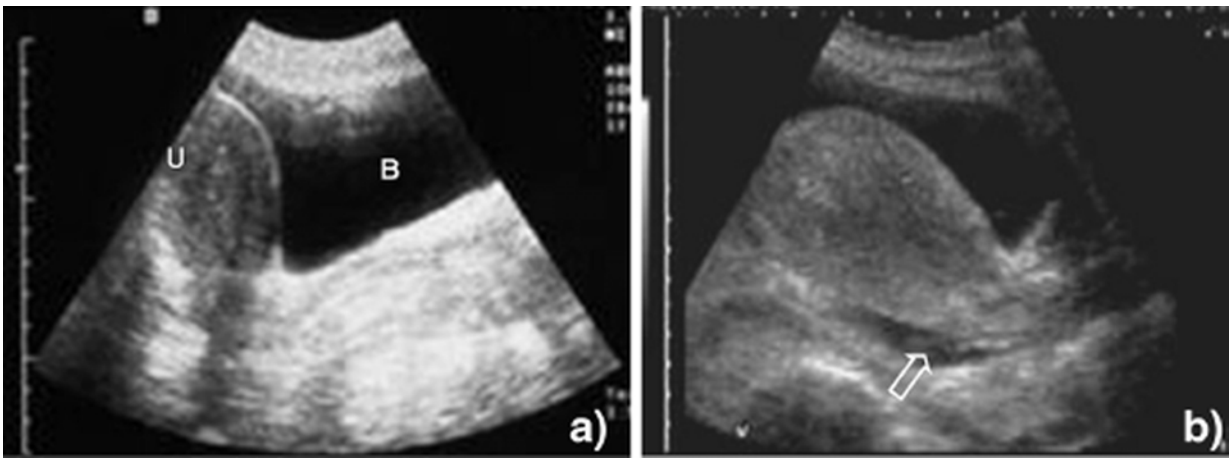

Figure 6: Pelvic view

a) The pear-shaped uterus (U) is visible behind the fluid-filled bladder (B). There are no extravesical fluid collections, especially no collections in the Douglas' pouch behind the uterus.

b) Small, anechoic collection behind the uterus (open arrow), demonstrating free abdominal fluid.

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Heller T. FASH: Focused Assessment with Sonography for HIV/TB. A Practical Manual. Munich, Germany. TALC-Teaching Aids at Low Cost. 2013. ISBN: 978-0-9558811-8-3.

Suggested Reading

Heller T. FASH: Focused Assessment with Sonography for HIV/TB. A Practical Manual. Munich, Germany. TALC-Teaching Aids at Low Cost. 2013. ISBN: 978-0-9558811-8-3. Available for order via:
https://healthbooksinternational.org/books/focused-assessment-with-sonography-for-hivtb

19. Ultrasound guided procedures

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Ultrasound guided interventional procedures are widely used as it allows the clinician real time guidance at the bedside or point of care.

Common interventional procedures that carry a significant degree of risk include peripherally inserted central catheter (PICC) lines and draining of fluid collections. Performing these procedures relying on the landmark approach alone for needle entry and target localisation are associated with a greater risk of post-operative complications such as bleeding, pneumothorax, organ injury and procedure failure.

In general there are two types of ultrasound guidance:

– Static guidance: Ultrasound is used to identify a suitable skin entry point and the target, e.g. vessel or largest pocket of fluid. An entry point is marked and depth to target estimated by counting the 1 cm spaced dots on the screen. The procedure is performed without further ultrasound image guidance. Care must be taken that the patient doesn't change position, as even different breathing can move thoracic and abdominal structures significantly.
– Dynamic / real time guidance: Ultrasound is used to identify a suitable skin entry point and the target, e.g. vessel or largest pocket of fluid. Then the tip of the needle can be followed precisely in real time as it advances and reaches the target, minimizing the risk of complications. Dynamic guidance usually requires an assistant during the procedure or higher level of skill. However, it can be beneficial to reduce complications in more complex or higher risk procedures to minimize risk to surrounding anatomy.

19.1 Vascular access

Ultrasound can also be used in any procedures requiring venous access. It can be useful in complicated cases such as patients with large patient body habitus, previous IV drug use, dehydrated patients, those with a history of difficult venous access or it can reveal alternate or deeper lying peripheral veins. It is also useful in paediatric patients.

Clinical conditions will dictate the type of venous access required, but two main types are:
– Peripheral venous access is typically preferred when used for shorter periods with smaller gauge devices. It also is generally associated with fewer complications and is quicker to obtain.
– Central venous access may be indicated for patients who failed peripheral access, when a larger gauge device is required for drug administration, pressure monitoring, blood sampling or when access is known to be required for a longer duration.

Ultrasound guidance should be used as standard for all higher risk interventions such as central venous catheter (CVC) insertion, e.g. PICC, of the internal jugular or basilic vein as it improves the success rate and decreases risk of complications.

19.2 Scanning technique – vascular access

Transducer

A 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is preferred.

If unavailable A 5-2 MHz, curved array abdominal transducer such as the C60X can be used with the depth settings adjusted.

Preparation

Sterile techniques for venous access should be used. An assistant should apply gel to the transducer prior to covering it with a sterile cover.

Note: if there are no sterile covers available a sterile glove can be used. Sterile gel or substitute such as iodine solution should be used in the operative field.

Try to eliminate any air bubbles from the interface between the transducer head surface and the inside surface of the sterile cover or glove. This is accomplished by applying sufficient gel to the cover / glove surface and transducer head immediately prior to insertion of the transducer into the cover, using sterile rubber bands / ties to secure the cover to the transducer head, and by using sterile gel on the skin surface during sonographic guidance.

Patient position

The patient position will typically be lying on their back, i.e. supine, but will be dictated by the location of the target vessel and type of access required. Common veins used include: cephalic, basilica, internal jugular, subclavian (although difficult to visualize with ultrasound) and to a lesser degree the femoral vein.

Scanning steps and technique – vascular access

1. With the transducer in the transverse position, i.e. marker pointing to the patient's right, identify the target vessel and visualize surrounding anatomy to minimize the risk of inadvertent puncture.
2. Confirm target by using compression or colour Doppler to clarify as required (Figure 1).
3. Centre the vessel and estimate the depth required by calculating from dots on the ultrasound screen.
4. If using dynamic guidance (see above), the transducer can be aligned in either the transverse or longitudinal position. A key goal is to avoid the artery that usually accompanies the target vein.
5. The tip of the needle can be followed in real time as it approaches the target vessel, avoiding the accompanying artery.
6. The needle should be visible as it approaches the vessel wall, and can be seen to cause the wall to 'bulge in' prior to puncture, an effect sometimes referred to as 'tenting.' Identification of this effect can be used to minimize the risk of opposite vessel wall puncture.
7. The final position of the catheter can be confirmed within the target vessel. (Figure 2).

Scanning notes for vascular access

– In general:
  • Veins: Thin walled vessels with minimal pulsation, compress easily when minimal pressure is applied with the transducer.
  • Arteries: Slightly thicker wall, pulsating vessel. More difficult to compress when pressure if applied with the transducer.
– Non-compressible veins indicate thrombus, cannulation of these vessels should not be attempted and follow up is required.
– Colour Doppler imaging may be used to differentiate arteries and veins if there is any doubt between vessels, and to confirm thrombosis if relevant.

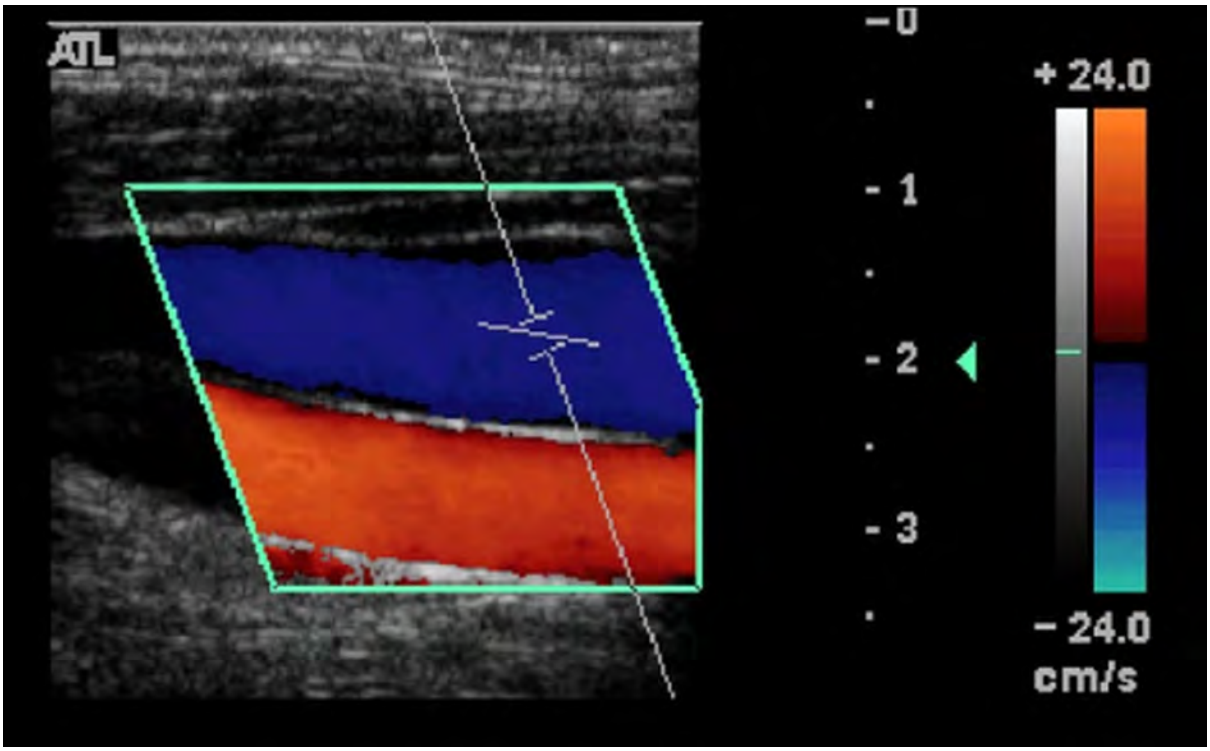

Figure 1: Artery vein Doppler
Colour Doppler image at the top shows the jugular vein in blue
and the carotid artery in red confirming normal blood flow in opposite directions.
Note: The colours blue and red represents the direction of blood flow to identify vessels.

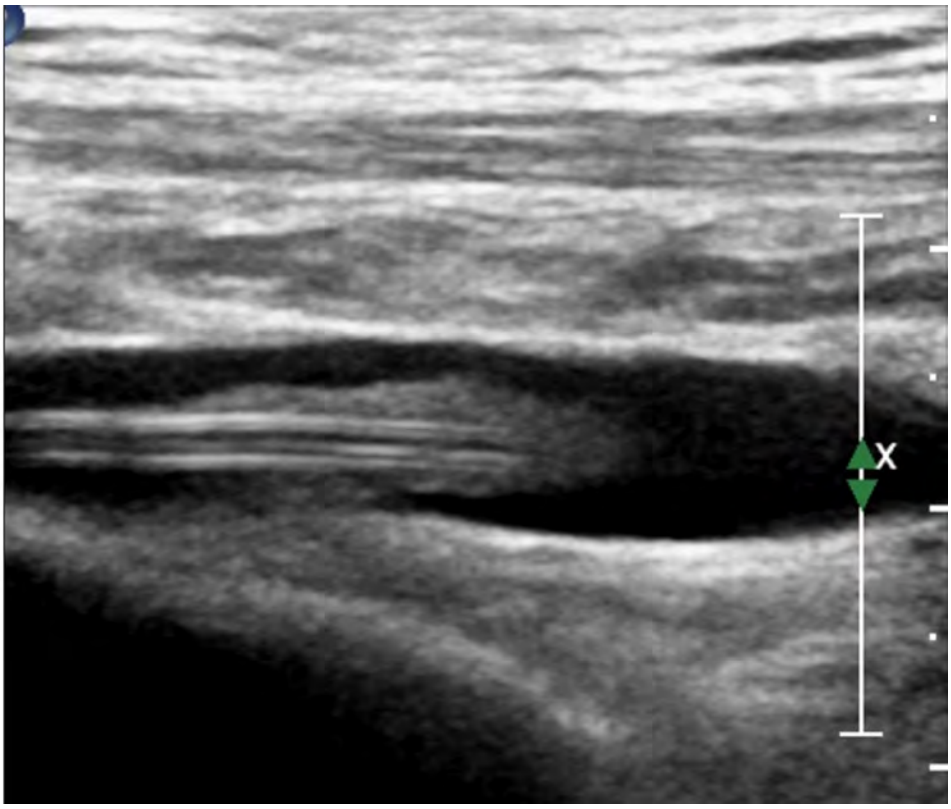

Figure 2: PICC in subclavian vein
An intravenous catheter (PICC) appears as uniformly parallel echogenic lines
within the subclavian vein. In this case thrombus has formed
an echogenic mass partially surrounding the catheter.

19.3 Paracentesis and thoracentesis

Abnormal fluid collections in the pleural space or peritoneal cavity can occur due to a variety of medical conditions including; congestive heart failure, infection, trauma, renal disease, liver disease, cirrhosis, malignancy and tuberculosis.

Removal of these fluid collections from the pleural space, i.e. thoracentesis, or from the peritoneal cavity, i.e. paracentesis, is performed for diagnostic and / or therapeutic indications.

Simple fluid collections such as transudate are hypoechoic with through-transmission and posterior enhancement. Typically these collections accumulate in the dependent areas of the pleural space (Figure 3) or peritoneal cavity (Figure 5), unless loculated (Figure 4).

Complex collections such as abscess may be mostly hyperechoic but contain echogenic debris and can be loculated (Figure 6).

Ultrasound imaging of patients with fluid collections prior to drainage is advantageous as it can identify the largest pocket of fluid, identify if the fluid collection is amendable to drainage, demonstrate surrounding anatomy, identify entry site and estimate target depth to minimize complications and reduce the risk of procedure failure. It can also be used for post procedural assessment of fluid drainage and complications e.g. pneumothorax.

19.4 Scanning technique – paracentesis and thoracentesis

Transducer

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred initially identify the fluid collection and demonstrate the surrounding anatomy. If available it is possible to then switch to a 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo.

Apply gel to the transducer face and / or patient. If no gel is available, use water or sterile iodine solution. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient's position will be dictated by the location of the fluid collection. The entry site and transducer positions will vary accordingly.

– Thoracentesis: The ideal position is with the patient seated, leaning forward and facing in the opposite direction to the clinician. The preferred approach for needle placement is in an intercostal space in the lower back. If this positioning is not possible, a semi recumbent, lateral decubitus or supine position may be used.

  The entry point should be as close to the top, i.e. superior surface, of the nearest rib as possible, to avoid injuring the intercostal vessels. Particularly injuring the intercostal artery is a potential and clinically serious complication of thoracentesis.

  In most cases thoracentesis can be safely performed without direct real-time sonographic guidance of needle placement. Marking the skin, using ultrasound to identify the ideal entry point, is usually sufficient.

– Paracentesis: Is typically performed with the patient supine or in the oblique / lateral decubitus position. If free flowing, the collection will move to the dependent aspect of the peritoneal cavity. Have the patient empty their bladder before the procedure to reduce the risk of complications and of confusing the bladder for a simple fluid collection.

  Again, in most cases paracentesis can be safely performed without direct real-time sonographic guidance of needle placement. Marking the skin, using ultrasound to identify the ideal entry point, is usually sufficient. The most common site chosen in this manner is the right lower quadrant.

Preparation

Sterile techniques for interventional procedures must be used. For ultrasound-guided procedures gel needs to be place on the transducer face then covered with a sterile cover (if there are no sterile covers available a sterile glove can be used). Sterile gel or substitute also needs to be placed on the surface of the cover, otherwise the ultrasound image will be poor. An assistant may be required.

Try to eliminate any air bubbles from the interface between the transducer head surface and the inside surface of the sterile cover or glove. This is accomplished by applying sufficient gel to the cover / glove surface and transducer head immediately prior to insertion of the transducer into the cover; using sterile rubber bands / ties to secure the cover to the transducer head; and by using sterile gel on the skin surface during sonographic guidance.

Scanning steps and technique – paracentesis and thoracentesis

1. With the transducer in the transverse position, identify the target collection and visualize surrounding anatomy to minimize the risk of inadvertent puncture.
2. Centre the collection and estimate the depth required by calculating from dots on the Ultrasound screen (Figure 3).
3. If using dynamic guidance (see above), the transducer can be aligned in either the transverse or longitudinal position.
4. The tip of the needle will create a ‘ring down’ artefact; it can be followed in real time as it approaches and enters the target collection.
5. Perform post procedural assessment of: fluid volume drainage and post-operative complications such as pneumothorax if relevant (see extended FAST - anterior thoracic view - pneumothorax study - Chapter 10, section 10.6).

Scanning notes for paracentesis and thoracentesis

– If using static ultrasound guidance ensure the patient remains in an identical position and replicates respiration in-between entry site identification and performing procedure.

– Limited local anaesthesia is usually adequate for these ultrasound-guided procedures. Once the needle insertion site is determined by careful ultrasound scanning, a small volume of local anaesthetic, usually lidocaine, is injected into the skin to make a small weal. Once the skin is anesthetized a longer thin needle, i.e. 23-25 gauge, is inserted into the weal and advanced along the projected needle course for the procedure. For thoracentesis and paracentesis it is important to adequately anaesthetise the pleural or peritoneal surfaces. Then the procedure can be performed without significant patient discomfort.

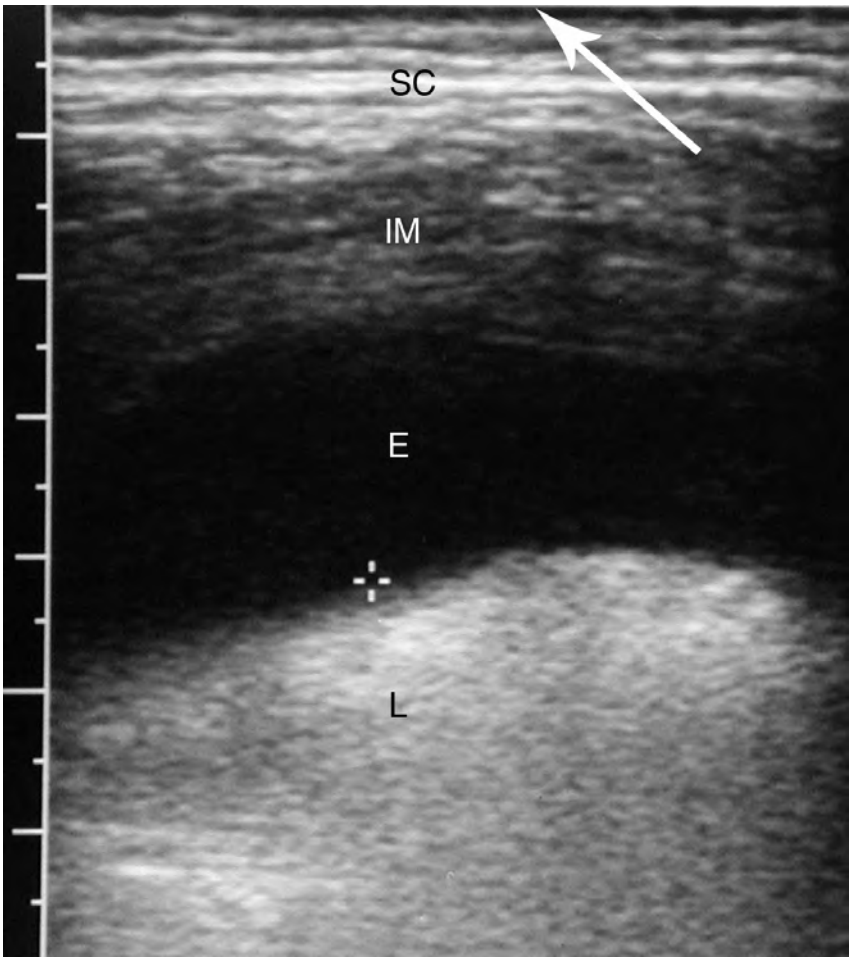

Figure 3: Thoracentesis
This image was obtained by placing a linear array transducer in a lower posterior intercostal space in preparation for thoracentesis. The skin surface is at the transducer face (arrow) at the top of the image. Visualized just deep to the transducer are the echogenic subcutaneous tissues (SC), the hypoechoic intercostal muscle (IM),
and the pleural effusion (E). In this case the effusion is anechoic and likely a transudate. The limit of the effusion is marked by the bright echoes of the aerated lung (L).
The cursors (+) marks the depth of the lung, at 5.3 cm. Centimeter marks are evident along the left side of this image. A needle placed at this location through the intercostal space would encounter fluid at approximately 3 cm depth. The needle should not be advanced more than 5 cm to avoid puncturing the lung and causing a pneumothorax.

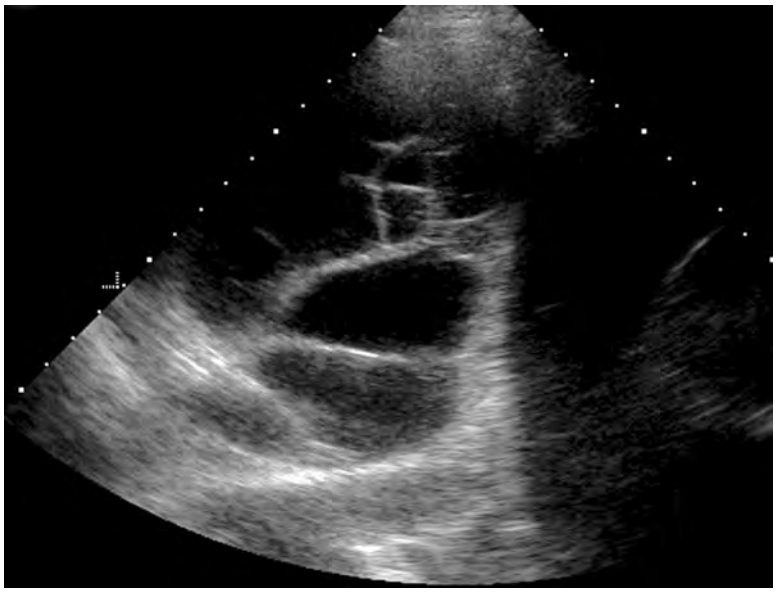

Figure 4: Septated pleural effusion
A transducer placed in a lower intercostal space reveals a pleural effusion with multiple septations. The presence of septations or of echogenic particulate matter within the effusion is indicative of an exudative effusion.
Thoracentesis in this case revealed a tuberculous pleural effusion.
The presence of septations may make thoracentesis more difficult because the fibrous tissue may clog the needle.
Direct sonographic guidance and visualization of the needle / catheter tip in these instances can be helpful in maximizing the amount of fluid that can be removed.

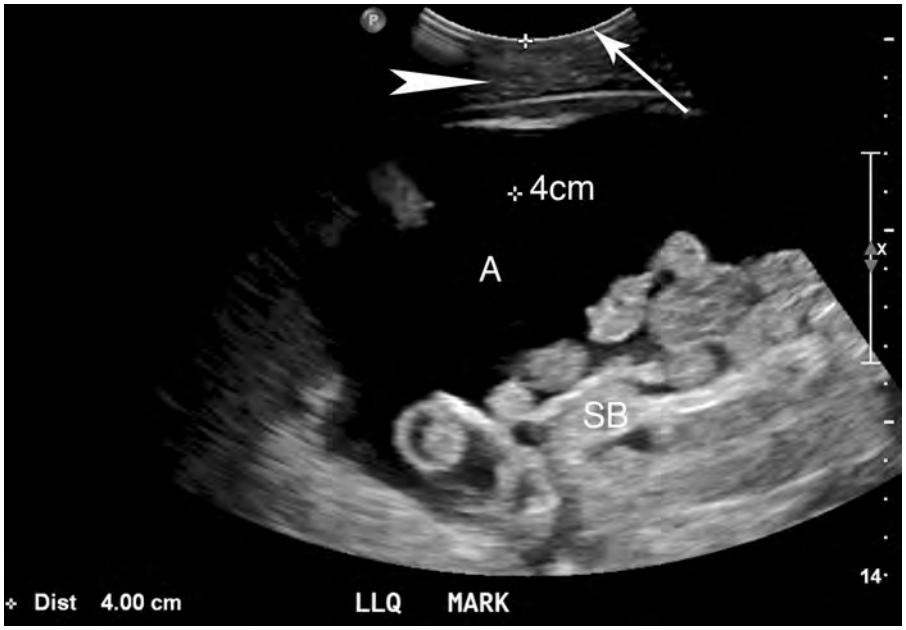

Figure 5: Paracentesis
With the patient in supine position a curved array transducer placed on the left lower quadrant of the abdomen reveals large volume anechoic ascites (A).
Loops of small bowel (SB) are seen floating in the ascites.
The skin surface is at the transducer face at the top of the image (arrow). Just deep to the transducer face is the musculature of the anterior abdominal wall (arrowhead).
The cursors (+) measure a 4 cm depth for accurate and safe needle placement for paracentesis.

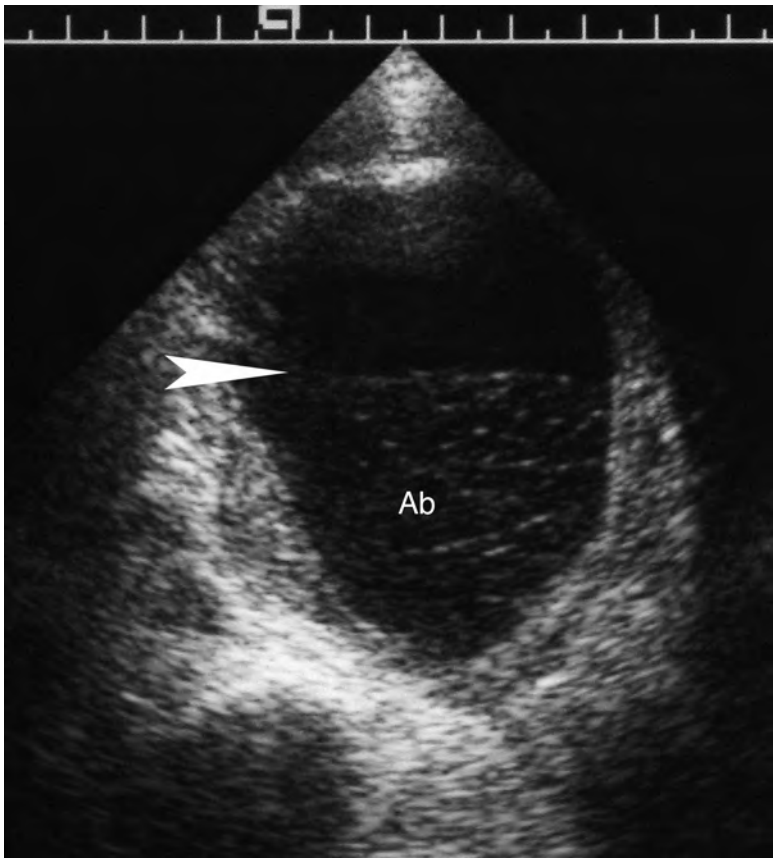

Figure 6: Loculated fluid collection
A transducer placed on the lower anterior abdominal wall reveals a loculated fluid collection (Ab). The collection has thick walls and contains both echogenic particulate matter in its deep portion and clear fluid in its more superficial portion producing a fluid-fluid layer (arrowhead). An abscess was confirmed and treated by ultrasound-guided fluid aspiration and drainage.

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20. Deep vein thrombosis

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Deep vein thrombosis (DVT) is the accumulation of a thrombus in the deep veins of the body, most commonly the legs, i.e. in femoral and popliteal veins (Figure 1). These blood clots carry significant rwisk to the patient if dislodged as they can travel through the venous system to the lungs resulting in pulmonary embolism, a potentially fatal condition. While clots may form in veins below the knee, these are not considered significant as a risk for pulmonary embolism but may propagate into the deep veins of the thigh.

Ultrasound interrogation of the deep veins using the following steps is simple, quick, non-invasive and is an accurate examination that can be performed at the patient's bedside.

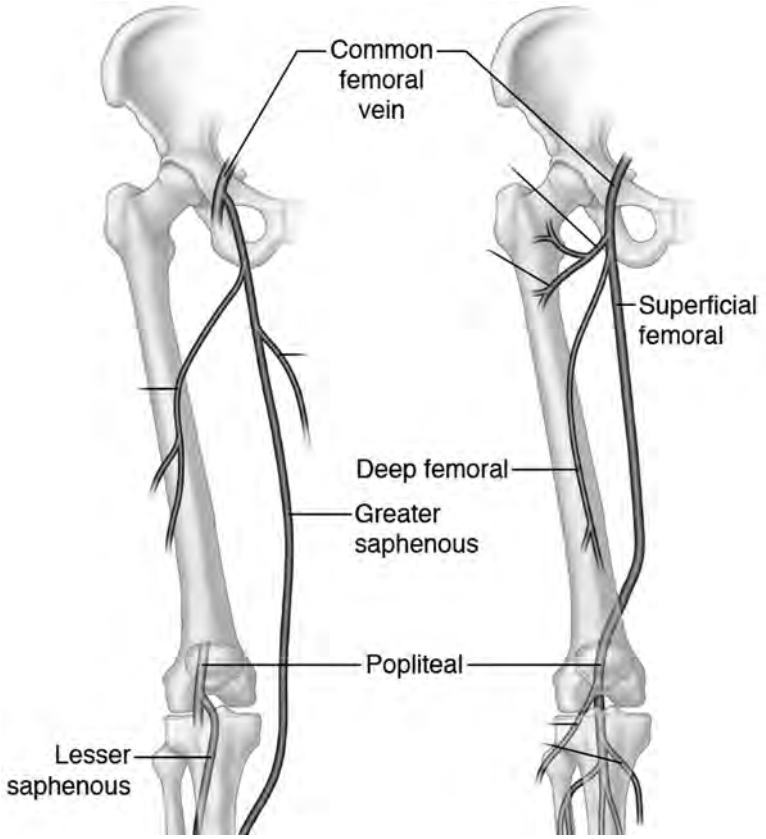

Figure 1: Anatomic drawing of the major leg veins
The figure shows the superficial (saphenous) venous system on the left and the deep venous system on the right. Traditional nomenclature terms the deep veins of the thigh common femoral, deep femoral, and superficial femoral veins. All are considered deep veins and carry a risk of pulmonary embolism when thrombosed.

Compression ultrasound is the imaging procedure of choice for diagnosis of deep venous thrombosis in the lower extremities. A DVT ultrasound study may be indicated in patients with pain, tenderness, redness, warmth or swelling to the extremities. Periods of immobility, post orthopaedic surgical procedures and malignancy also increase the risk of DVT forming and warrant ultrasound investigation.

20.1 Scanning Technique - DVT

Transducer

A 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Position the patient lying on their back, i.e. supine on the examination table, externally rotate the hip and slightly bend the knee of the affected leg. Raising the head of the bed 20-30° promotes blood pooling and venous distension in the legs.

Scanning steps and technique – Femoral veins

1. Start in the groin area and locate the common femoral vein (CFV) prior to the branching of the greater saphenous vein. It is typically found at the crease in the groin on the upper thigh anterior-medial to the common femoral artery (CFA). Confirm with colour Doppler if required. Label with annotations 'R' or 'L' which leg is being examined.
2. Align the transducer in the transverse position, i.e. marker pointing to the patient's right, aligned with the short axis, i.e. cross-section, of the vein. Apply pressure; the amount of pressure will depend on the patient's body habitus. The vein should completely compress so that the opposing walls of the vein touch; creating a 'winking eye' appearance as pressure is applied and relaxed. The proper amount of transducer pressure will compress the patient's vein without compressing the adjacent artery (Figure 2).
3. Slide the transducer distally pausing to repeat the compression assessment every centimetre from the groin through the popliteal fossa.
4. Blood flow can be augmented and the veins distended for improved visualization by gently squeezing the calf. The 'valsalva manoeuvre', i.e. have the patient hold their breath and bear down, can also be used to distend the leg veins.
5. Colour Doppler may be used to assist in identification of the deep veins especially in large patients and when used in combination with venous blood flow augmentation techniques.

Scanning steps and technique – popliteal veins

1. Have the patient flex the affected side knee or move the patient into the prone position to access the posterior medial aspect of the knee.
2. The compression process is repeated for the investigation of the popliteal veins. Less pressure is usually required for the popliteal vein compared to the femoral veins.
3. A Baker's cyst or popliteal cyst can appear similar to a DVT for an inexperienced user, as it is also a non-compressible structure. Baker's cysts are typically larger and can usually be identified without ultrasound, by palpation. A Baker's cyst extends from the posterior medial aspect of the knee joint itself, rather than as a continuation of the superficial femoral vein.

Scanning notes for DVT

– In patients who are obese or very muscular the deep veins of the legs may be difficult to identify. It is best to start the examination in the crease at the groin, which marks the location of the inguinal ligament. The femoral vessels can be reliably located in the mid-portion of the groin

fold. Once identified it can be helpful to turn on colour Doppler to mainÈtain visualization of the flow in the artery while tracing the course of the adjacent vein. A normal vein will compress easily with transducer pressure, much less than the pressure required compressing the artery.

– Be sure to inform the patient of the nature of the examination and that you will be applying pressure to the patient's leg. Ask the patient to inform you if the examination becomes uncomfortable. Acute thrombophlebitis is an inflammatory condition and the affected vein may be quite tender in some patients.
– As the femoral artery and vein descend the thigh, the vessels curve gradually medially around the upper leg to their normal posterior position in the popliteal fossa at the back of the knee.
– While the femoral and popliteal veins are normally a single continuous vessel in some patients these deep veins are duplicated. Duplicated deep veins are smaller than normal and tend to course on either side of the artery. Thrombus may occur in only one of the duplicated veins. This is a pitfall to accurate diagnosis.
– The greater saphenous vein is a superficial vein that courses in the superficial tissues of the anterior thigh. The greater saphenous vein empties into the femoral vein about 3 cm below the inguinal ligament. Thrombosis of the greater saphenous or other superficial veins is usually painful but is not associated with risk of pulmonary embolism. Varicose veins refer to abnormal dilatation and loss of valvular competence of the superficial venous system of the leg.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

20.2 Diagnosis of DVT

The inability to compress the vein wall-to-wall is diagnostic of venous thrombosis (Figure 3). DVT may be acute or chronic, and can be difficult to differentiate with ultrasound; however the following characteristics guide diagnosis.

– An acute thrombus is hypoechoic and is commonly hard to differentiate from flowing blood without using transducer compression.
– The vein is usually distended, i.e. larger in diameter, when the thrombus is acute. Compare to the same vein at the same level in the opposite leg.
– When a thrombus is present, colour Doppler may confirm complete occlusion, i.e. absence of blood flow, in the vein, or may show a trickle of blood flow around the thrombus.
– Deep venous thrombosis is slow to resolve and is prone to recur. Thrombosed veins return to normal appearance and compressibility in only 50 % of cases by 12-24 months.
– Chronic thrombus appears more echogenic and is more likely to be only partially occlusive. A chronic clot shrinks with time and is commonly attached only partially to the vessel wall.

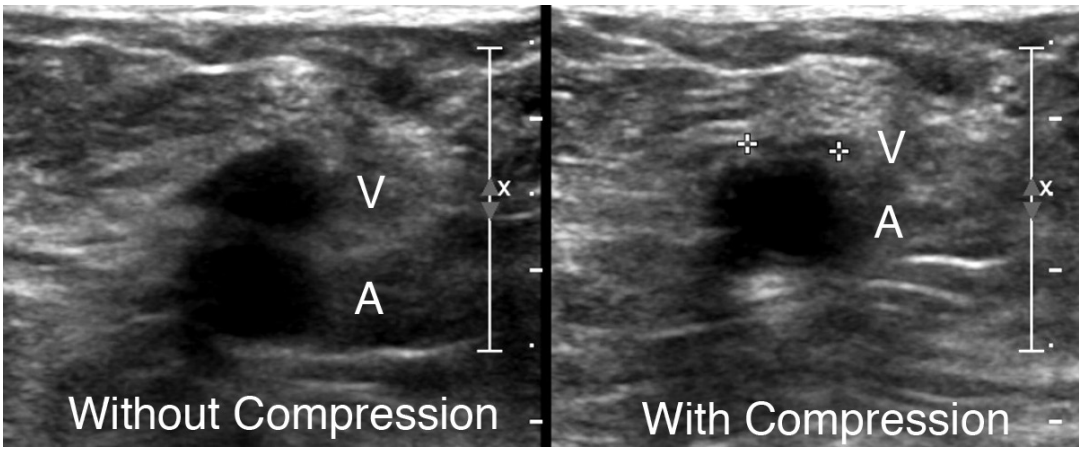

Figure 2: Femoral artery and vein with and without compression
Ultrasound images of the femoral artery (A) and vein (V) obtained in a transverse plane are shown without (on the left) and with (on the right) transducer compression. The vein compresses completely with opposing walls touching. Normal wall-to-wall transducer compression confirms the absence of thrombus within the vein.

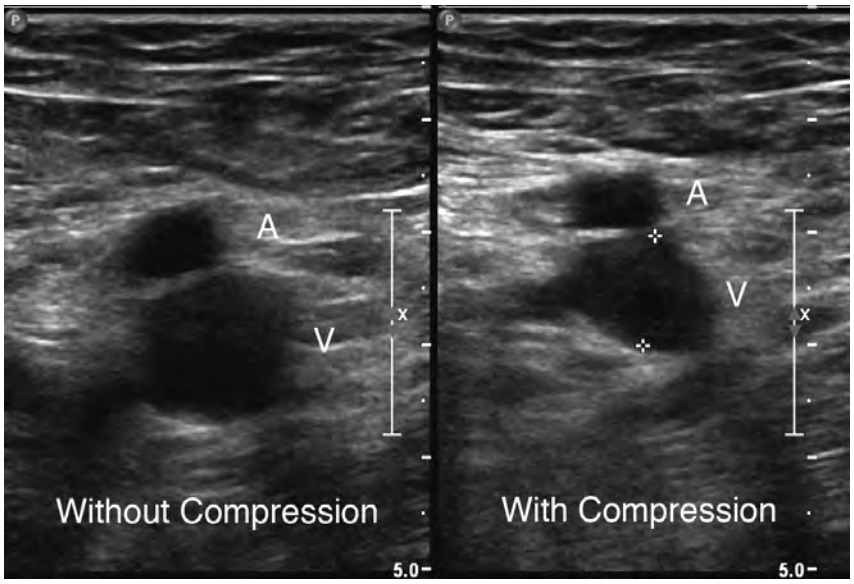

Figure 3: Distal femoral artery and vein with and without compression
Ultrasound images of the distal common femoral artery (A) and vein (V) obtained in a transverse plane are shown without (on the left) and with (on the right) transducer compression. The blood clot within the common femoral vein is echolucent but causes enlargement of the vein compared to the artery. The presence of thrombosis is confirmed by using transducer compression. Firm compression fails to compress the thrombosed vein. The amount of compression used is less than would be required to compress the adjacent artery.

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21. Ultrasound in paediatrics

Ultrasound is an extremely useful and recommended imaging tool in paediatrics because it carries no radiation risk to growing children and because it can be performed real-time on a moving child without compromising the image quality significantly. It is particularly useful in MSF sites because it can be used at the point-of-care including the bed side or even in an incubator for neonates.

Ultrasound imaging of paediatrics can be complex and detailed. It requires expertise but it can also be used to answer very simple management influencing questions like:
– Is there hydrocephalus?
– Is there an effusion?
– Is there hydronephrosis?
– Is there lymphadenopathy to suggest TB (FASH)?

The following are short descriptions of realistic indications for the use of ultrasound in MSF sites but users are advised to seek training to use these adequately. The chapters 22-26 are dedicated to ultrasound applications in paediatrics.

Head

Neonatal ultrasound can be performed relatively easily through the anterior fontanelle to yield coronal and sagittal images. Even though advanced imaging can elicit detailed information about the presence and grade of germinal matrix haemorrhage and degree of white matter injury in hypoxic premature neonates or structural and vascular information, the inexperienced ultrasound user is more likely to find use in detecting hydrocephalus. Identification of symmetrically or asymmetrically dilated ventricles is something that can be managed surgically, through ventricular drainage, and may prompt referral to an advanced centre.

Chest

Chest ultrasound is a useful for diagnosing pleural effusion, consolidation, interstitial syndrome and pneumothorax. Chest imaging with ultrasound can differentiate causes for 'white out' of a lung, i.e. opaque hemithorax, on a chest radiograph (Figure 1) and direct management appropriately. Differentiating effusion from consolidation in children with an opaque hemithorax has direct implications on management.

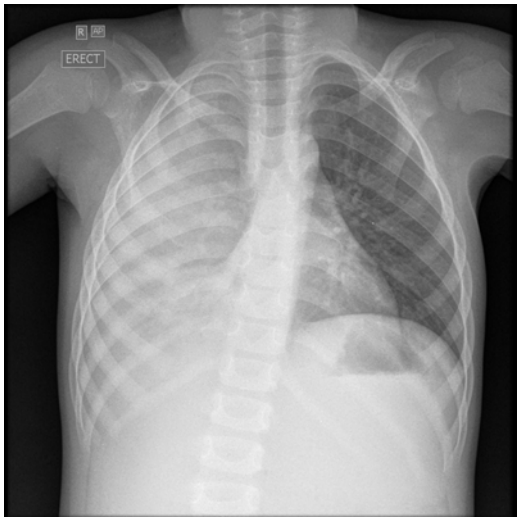

Figure 1: 'White out'
Chest radiograph of a 3 year old with near complete opacification ('white out') of the right hemithorax.

Renal / urinary

Detailed renal imaging may be complex and require expertise but identification of the presence of a kidney and detection of hydronephrosis are relatively simple techniques that can help with management decisions at the point-of-care.

Abdominal

Abdominal sonography for organ evaluation requires expertise and training but may be useful for clinicians working in areas with a high prevalence of infectious diseases. Detection of intra-abdominal lymphadenopathy and / or organ lesions may be the only clue to a diagnosis of tuberculosis. In addition, the detection of intraperitoneal fluid can assist in the diagnosis of TB and can motivate the clinician to tap this either for diagnostic and / or therapeutic purposes.

Caution: FAST sonography in children is contentious. The management of blunt abdominal trauma in children is conservative even in the presence of abdominal fluid, when there is haemodynamic stability. Emergency surgery should be undertaken in children who are hemodynamically unstable without the need for imaging. The use of FAST sonography in children does not address the issue of renal pedicle injuries. When there is significant blunt abdominal trauma and paediatric patients are not for immediate surgery, the goal of imaging remains to identify any renal vascular pedicle injury and any organ lacerations that may require surgery if the blood pressure suddenly drops. More importantly, clinical decisions take precedence over imaging.

Mediastinal TB

Mediastinal ultrasound to detect TB lymphadenopathy has been reported in the literature and a standardised technique for performing this has recently been described. The simplest mechanism for doing this is with a small footprint high-resolution curved array transducer such as the C11x (see Annex 2) through the suprasternal notch. Distinguishing lymphadenopathy, which is oval and more echogenic than the echo free vessels or the homogenous thymus is the goal. Lymphadenopathy does not equate to TB but is highly suggestive in the correct clinical setting, and treatment can be initiated while awaiting confirmatory tests.

22. Neonatal head

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The neonatal brain ultrasound allows for rapid evaluation of the infant brain through the unique sonographic window of the anterior fontanelle. The fontanelle is diamond shaped and located between the frontal and parietal bones and typically closes between 4 months and 1 year of age. This window allows for non-invasive, rapid evaluation of the brain in infants without the need for sedation or radiation.

There are many indications for neurosonology in the preterm and term neonate and older infant in which the fontanelle has remained open:
- Evaluation of haemorrhages or infarctions in the preterm and term infant
- Evaluation of hydrocephalus
- Evaluation of congenital malformations such as agenesis of the corpus callosum, Dandy Walker malformation, holoprosencephaly
- Evaluation of extra-axial surface collections either from trauma (subdural hematomas) or infection (meningitis, empyema)
- Evaluation of congenital or acquired brain infections
- Follow up of previously documented abnormalities (including prenatal abnormalities)

22.1 Scanning technique – neonatal head

Transducer

The 8-5 MHz C11x curved array or the P21X 5-1 MHz phased array which are compatible with the MSF standard M-Turbo are preferred if available.

As an alternative the transvaginal transducer such as the ICTx provides excellent imaging but can be more difficult to use.

A 13-6 MHz linear array vascular transducer such as the HFL38x, can be used to assess superficial structures. In premature infants it can provide excellent detail as well.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Supine patient on the examination table or at the bedside. The mother can hold the infant in her arms while scanning if needed.

Scanning steps and technique – neonatal head

1. Place the transducer at the anterior fontanelle utilizing a generous amount of gel and avoid pressure on the underlying 'soft spot'.
2. Start in the coronal, i.e. transverse view. Representative coronal views should be obtained by sweeping through the entire brain from anterior to posterior.
3. The transducer should be positioned to demonstrate symmetric right and left hemispheres (Figure 1). Carefully ensure that imaging remains symmetrical of each half of the brain. At least five images in the coronal scanning plane tilting from anterior to posterior should be obtained, as illustrated in Figures 3-7.
4. The images should demonstrate:
   - The frontal lobe anterior to the frontal horns of the lateral ventricles with orbits visualized deep to the skull base (Figure 3).
   - Frontal horns or bodies of the lateral ventricles and interhemispheric fissure (Figure 4, Figure 5, Figure 6).
   - Lateral ventricles at the level of the lateral and third ventricles (Figure 4).
   - Include interhemispheric fissure, corpus callosum, septum pellucidum, caudate nuclei, putamina, globi pallidi, and sylvian fissures. The foramina of Monro should also be depicted, outlining the course of the choroid plexus from the lateral into the third ventricles (Figure 4 and Figure 5).
   - Lateral ventricles slightly posterior to the foramina of Monro where the lateral and third ventricles communicate.
   - Level of the quadrigeminal plate cistern and cerebellum. Include the cerebellar vermis, lateral ventricles bordered by caudate nuclei and thalami, and temporal horns (Figure 5).
   - Choroid plexus at the posterior aspect of the lateral ventricles. Periventricular white matter lateral to posterior horns of the lateral ventricles (Figure 5).
   - Area posterior to the occipital horns. Include parietal and occipital lobes and the posterior interhemispheric fissure (Figure 9).
   - Extra-axial fluid spaces should be imaged as needed using a linear high frequency transducer such as the HFL38x to obtain a coronal magnification of the extra-axial fluid space, including peripheral brain structures.

Figure 1: Coronal plane images
Transverse transducer position at the anterior fontanelle.
Tilt the transducer back to front to image anterior to posterior.

Figure 2: Coronal plane
Tilt the transducer initially angling to the front
then angling to the back to image anterior to posterior.

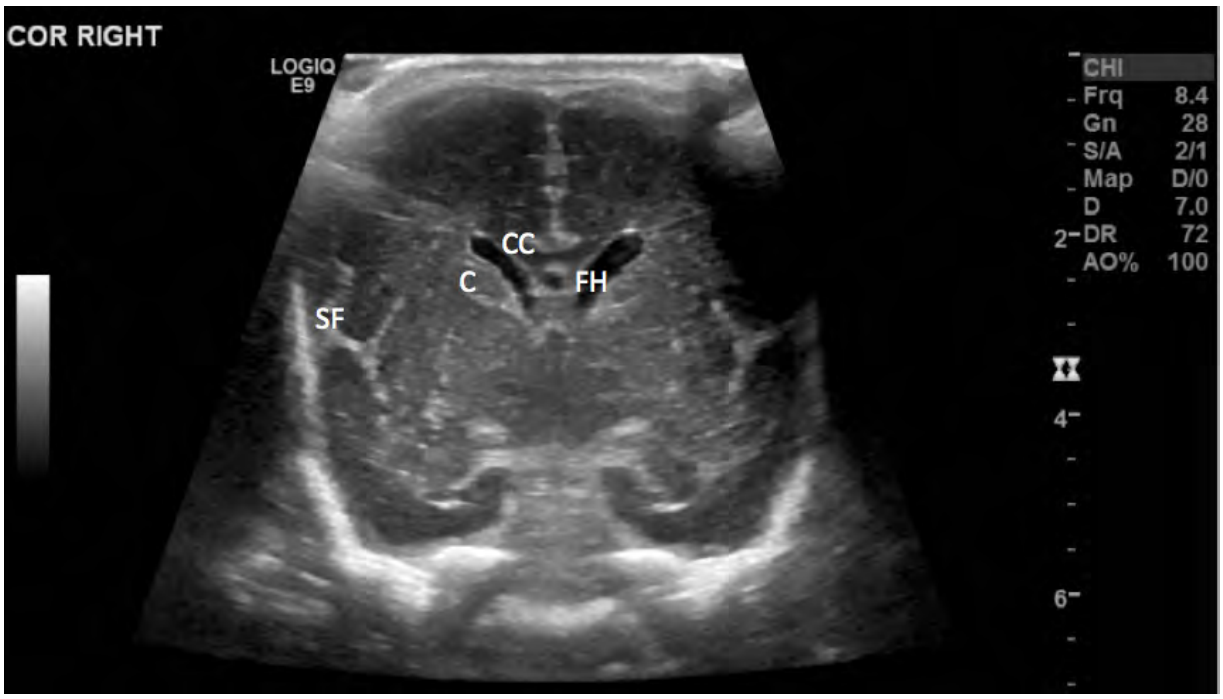


Figure 3: Normal Brain at 34 weeks gestation, coronal image through frontal horns
CC = Hypoechoic corpus callosum; C = Caudate nucleus;
FH = Frontal horns of the lateral ventricles; SF = Echogenic Sylvian fissure.

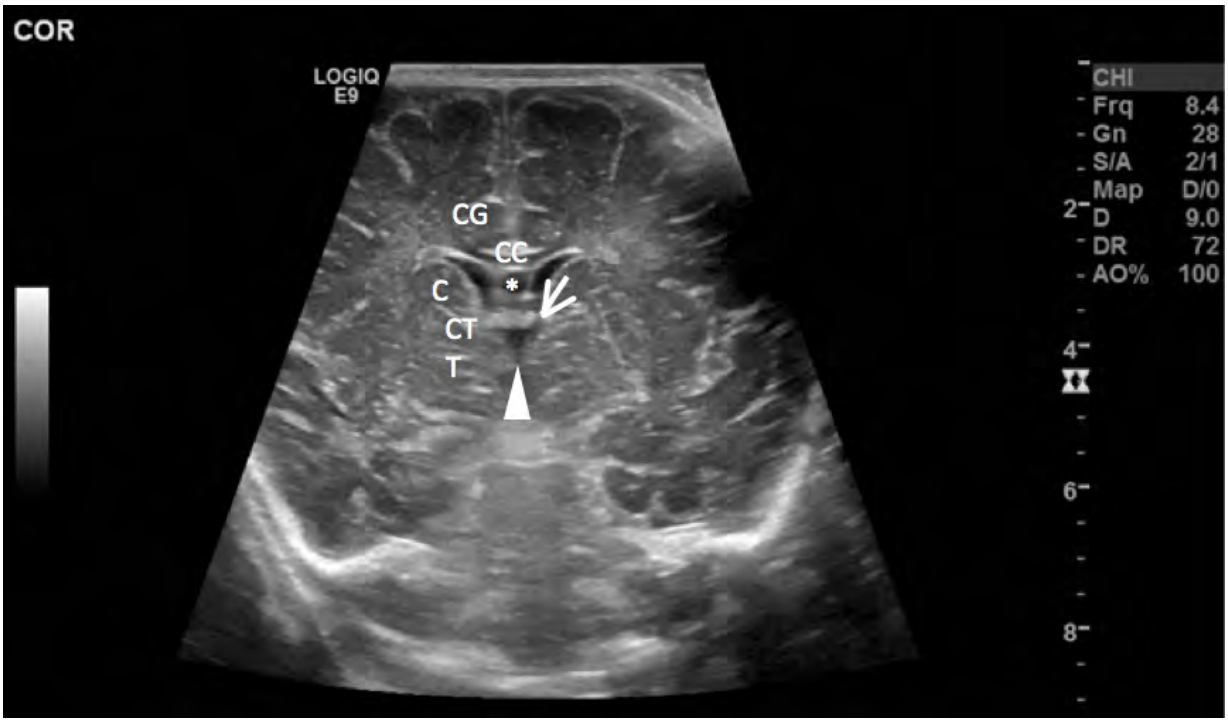


Figure 4: Normal Brain at 34 weeks gestation in the same patient
Coronal image through caudothalamic grooves.
CG = Cingulate gyrus; CC = Corpus callosum; Asterix (*) = Cavum septum pellucidum;
C = Caudate nucleus; CT = Caudothalamic groove; T = Thalamus;
Arrow = Foramen of Monroe; Arrowhead = Anterior third ventricle.

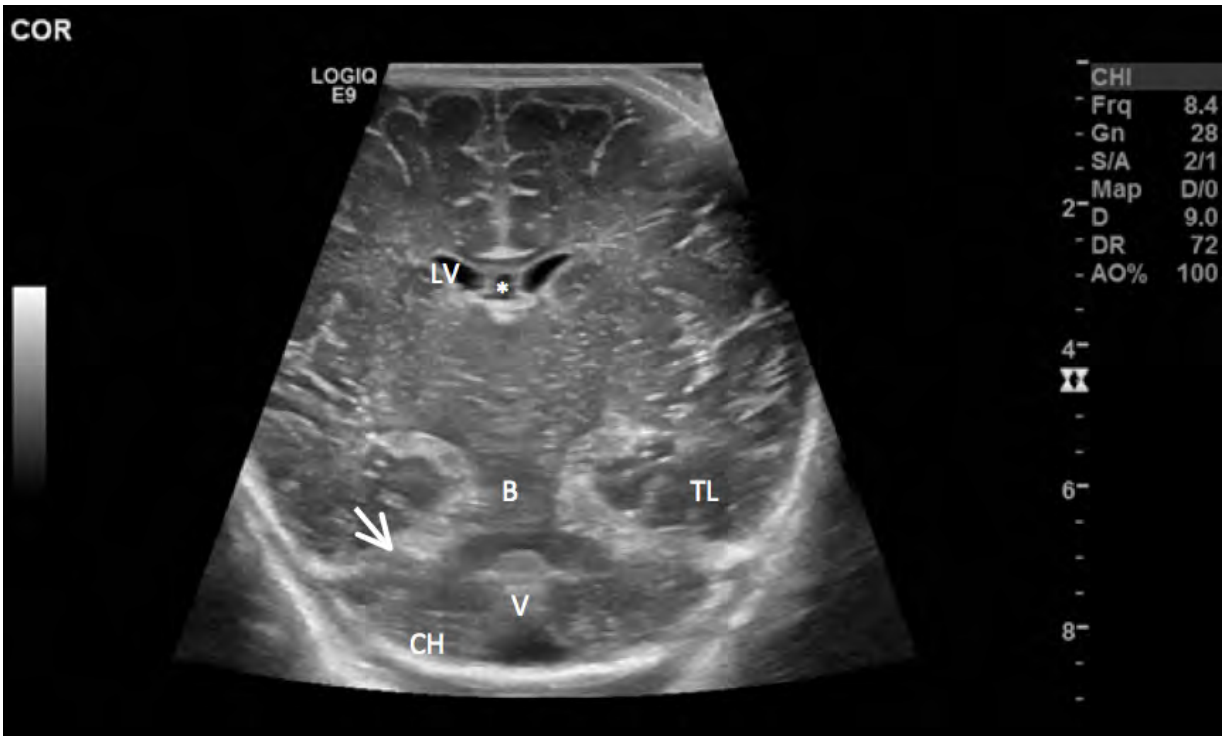


Figure 5: Normal Brain at 34 weeks gestation in the same patient
Coronal image through midbrain.
LV = Lateral ventricle; Asterix (*) = Cavum septum pellucidum; B = Brainstem; TL = Temporal lobe;
Arrow = Echogenic tentorium; V = Vermis; CH = Cerebellar hemisphere.

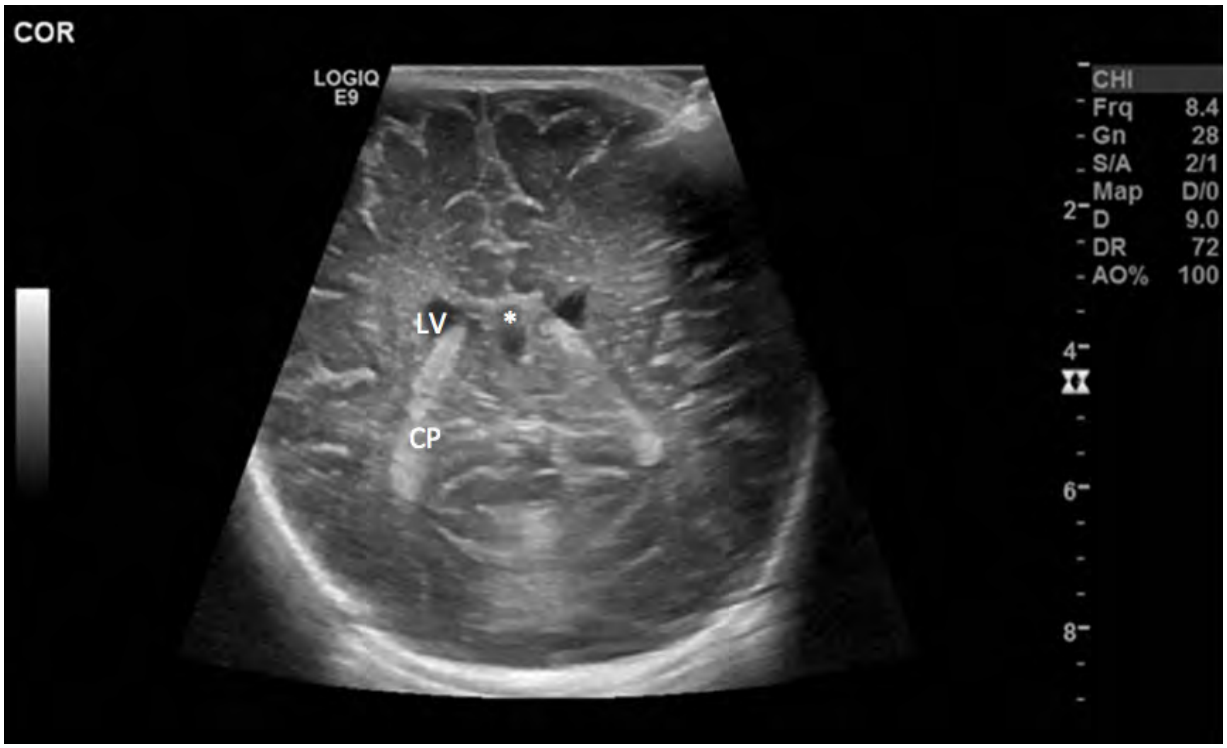


Figure 6: Normal Brain at 34 weeks gestation in the same patient
Coronal image through atria of lateral ventricle.
LV = Lateral ventricle; Asterix (*) = Posterior third ventricle;
CP = Glomus of choroid plexus in trigone of lateral ventricle.

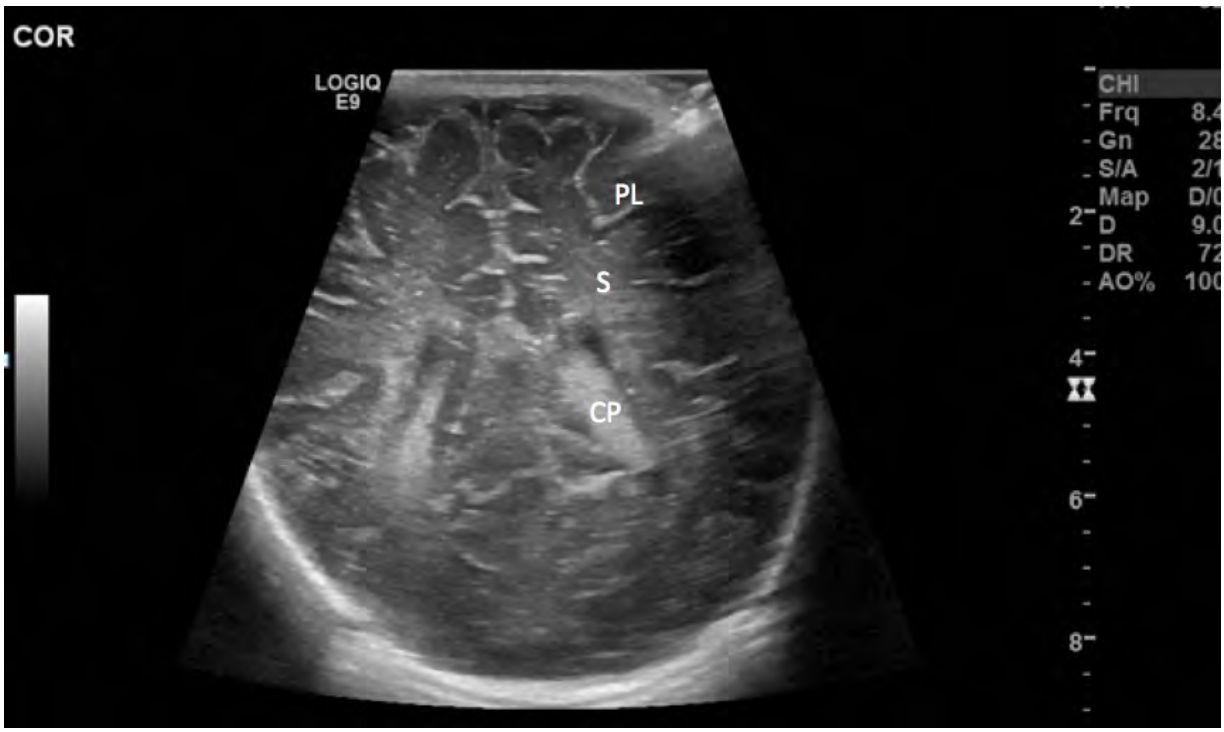


Figure 7: Normal Brain at 34 weeks gestation in the same patient
Coronal image through occipital horns of lateral ventricles.
PL = Parietal lobe; S = Centrum semiovale;
CP = Choroid plexus in the occipital horn of lateral ventricle.

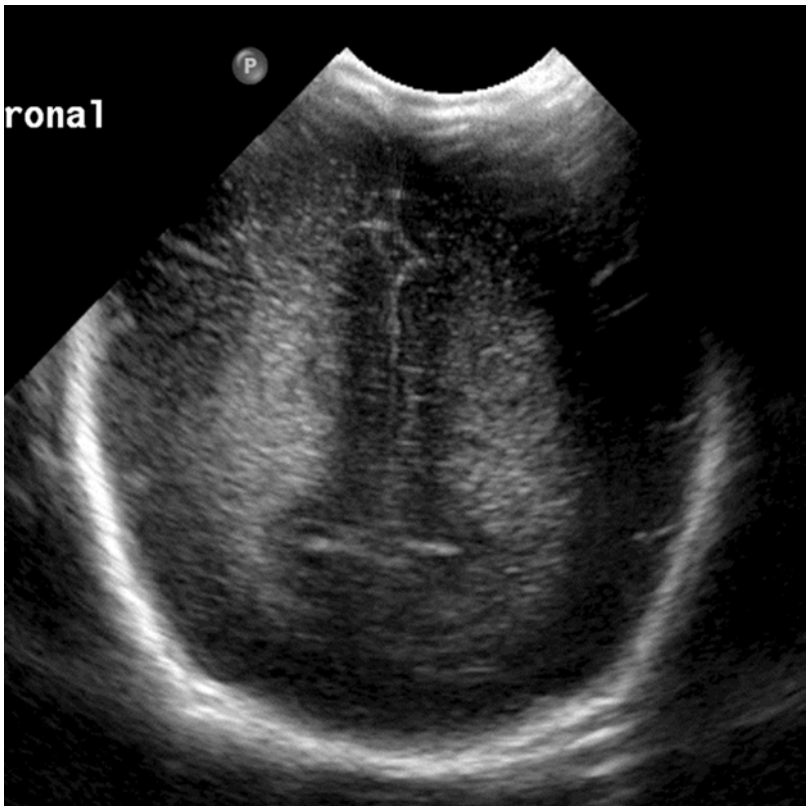


Figure 8: Normal Brain at 34 weeks gestation in the same patient
Coronal image through the occipital periventricular white matter

5. The sagittal, i.e. longitudinal, view by convention should place the anterior aspect of the brain on the left side of the image. The right or left side needs to be clearly annotated. Sequential sagittal views with tilting of the transducer allows for imaging of the parasagittal regions with appropriate degree of transducer angulation (Figure 9). At least five images in the bilateral parasagittal and sagittal planes, as illustrated below (Figure 10,Figure 11,Figure 12), should be obtained. These views should demonstrate
   - Right and left parasagittal views of the lateral ventricles, including the caudothalamic groove (Figure 10).
   - Steeper right and left parasagittal views of the lateral ventricles showing the choroid plexus (Figure 11).
   - Steeper right and left parasagittal to demonstrate the Sylvian fissure.
   - Midline sagittal views to include the corpus callosum, cavum septi pellucidi and cavum vergae if present, third and fourth ventricles, aqueduct of Sylvius, brain stem, cerebellar vermis, cisterna magna (Figure 12).

A

B

Figure 9 A and B: Longitudinal transducer position at the anterior fontanelle for sagittal plane images. Tilt the transducer left and right to obtain parasagittal images.

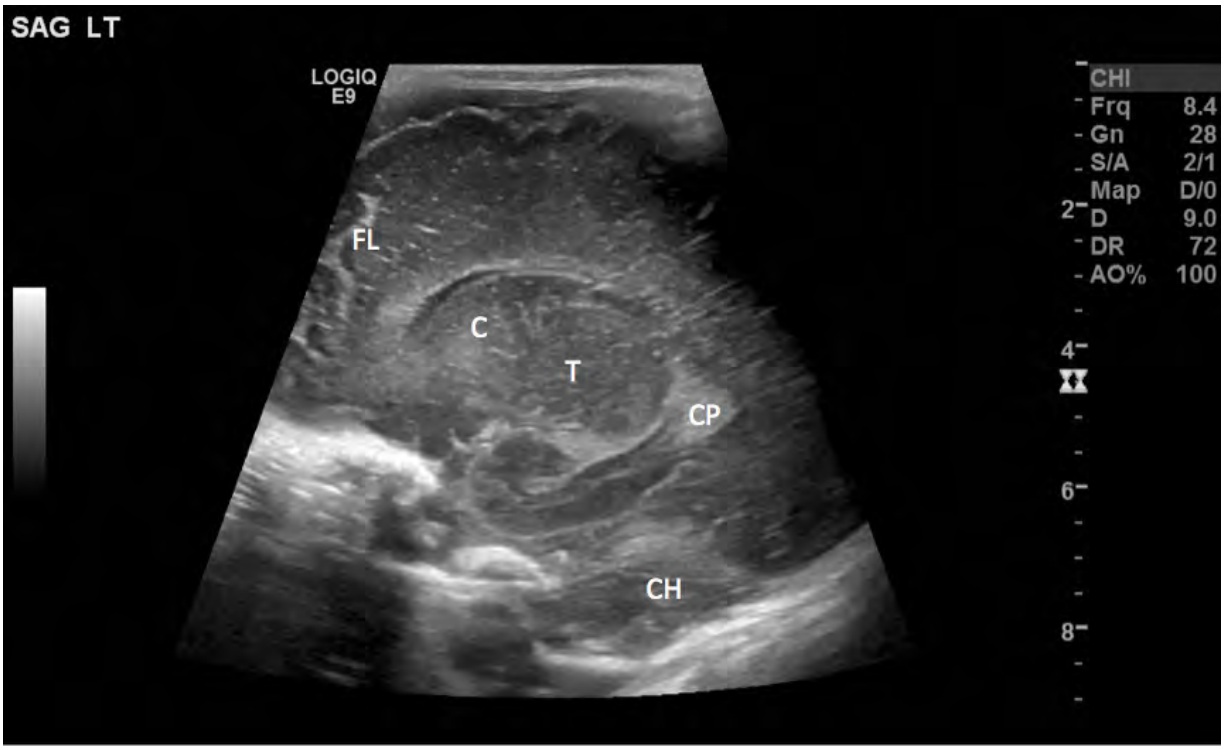


Figure 10: Normal Brain at 34 weeks gestation in the same patient
Parasagittal image of the trigone of the lateral ventricle.
FL = Frontal lobe; C = Caudate nucleus; T = Thalamus; CP = Glomus of choroid plexus in atrium of the lateral ventricle; CH = Cerebellar hemisphere.

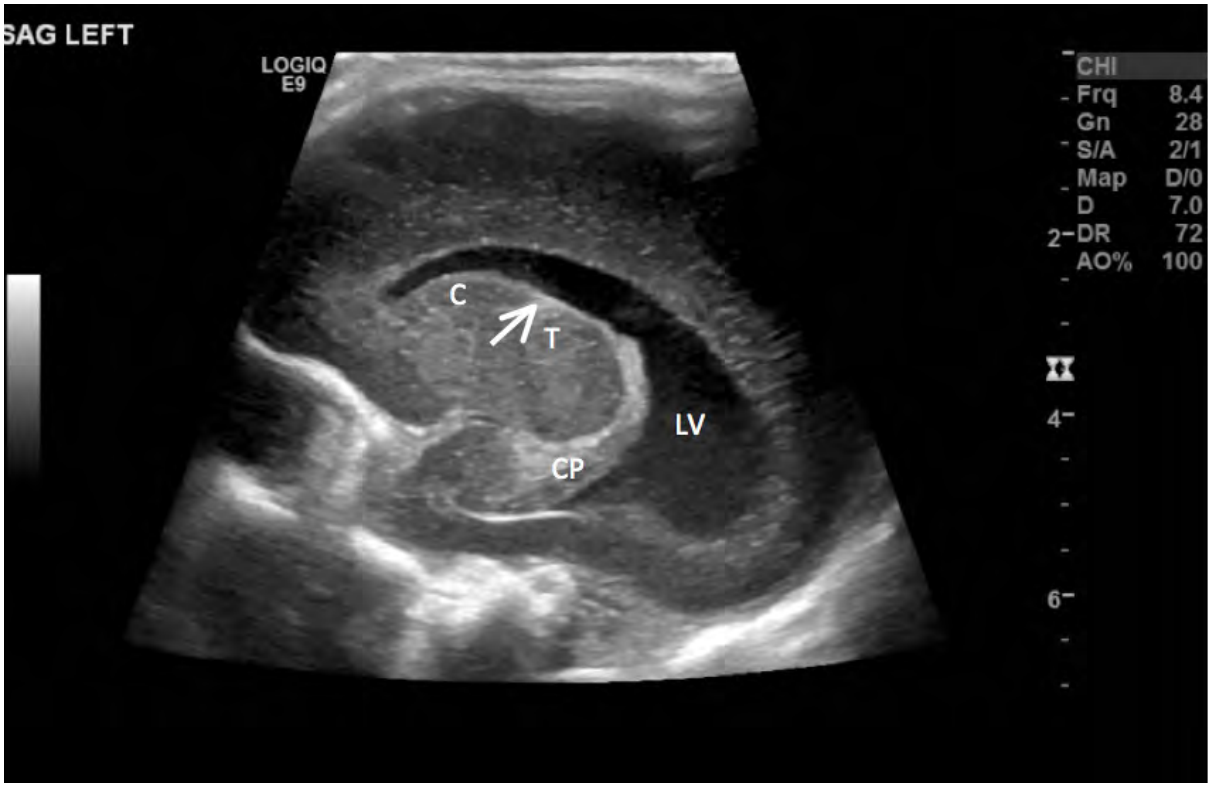


Figure 11: Normal Brain at 34 weeks gestation in the same patient
Parasagittal image of the caudothalamic grooves.
C = Caudate nucleus; T = Thalamus; Arrow = Caudothalamic groove; LV = Body of lateral ventricle; CP = Choroid plexus.

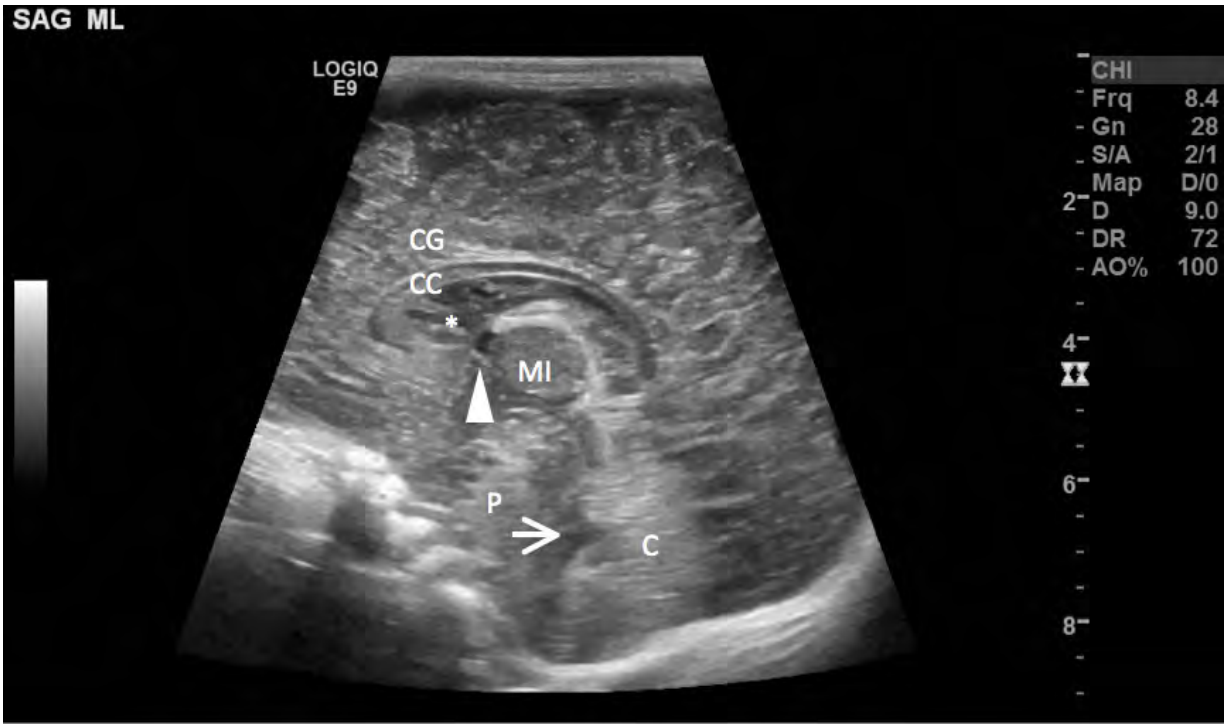


Figure 12: Normal Brain at 34 weeks gestation in the same patient
Midline sagittal image of the brain.
CG = Cingulate gyrus; CC = Corpus callosum, Asterix(*) = Cavum septum pellucidum;
Arrowhead = third ventricle; MI = Massa intermedia; P = Pons;
Arrow = Fourth ventricle; C = Cerebellum.

Additional views, if necessary, may be taken through the posterior or mastoid fontanelles the foramen magnum, any open suture, a craniotomy defect, or thin areas of the temporal and parietal bones.

Scanning notes for the neonatal head

– Carefully document which side is truly right and left while scanning.
– Midline sagittal view can be tricky to get due to the oblique positioning of the transducer. Careful attention to visualizing the corpus callosum and vermis can help ensure a well-positioned midline image.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

22.2 Germinal matrix haemorrhage

The germinal matrix is the site of neuronal and glial precursors which migrate peripherally during brain development. It is located along the lateral ventricles and caudothalamic groove. This highly cellular and vascular region is most active from 8 to 28 weeks gestation involuting typically by 32 weeks gestation.

A preterm neonate born at less than 32 weeks gestation is at highest risk for a germinal matrix haemorrhage, with about 90 % of the bleeds occurring within the first three days of life. After the onset of bleeding, the haemorrhage reaches a maximum around the fifth day. Ultrasound of the head can stage the bleed at onset and evaluate for sequela of germinal matrix haemorrhage, such as hydrocephalus and porencephaly (tissue loss).

Four grades of germinal matrix haemorrhage are distinguished:

– Grade 1: restricted to subependymal region / germinal matrix which is seen in the caudothalamic groove
– Grade 2: intraventricular haemorrhage without ventricular dilatation; extension of grade 1 into normal sized ventricles
– Grade 3: intraventricular haemorrhage with extension into dilated ventricles
– Grade 4: intraventricular rupture and haemorrhage into the surrounding white matter

Germinal matrix haemorrhage typically originates at the caudothalamic groove. When the blood is contained in the subependyma it is called a subependymal haemorrhage (SEH) (Grade 1 SEH). If the blood extends into the ventricles it is call an intraventricular haemorrhage (IVH) with or without hydrocephalus. At times venous infarction is associated with the germinal matrix haemorrhage and a periventricular haemorrhagic infarction / intraparenchymal haemorrhage (IPH) (Grade 4 IPH) can develop.

Subependymal haemorrhage (Grade 1 haemorrhage) presents as a homogeneous echogenic mass in the caudothalamic groove (Figure 13). There is no extension into the ventricle. As the hematoma ages the clot becomes less echogenic with its centre sonolucent.

Intraventricular haemorrhage may occur without ventriculomegaly (Grade 2 haemorrhage) or with ventriculomegaly (Grade 3 haemorrhage). When a SEH breaks into the lateral ventricle, blood can fill a portion of the ventricular system. The clot may block the ventricle with a chemical ventriculitis causing thickening and increased echogenicity of the subependymal lining of the ventricle. Post haemorrhagic hydrocephalus may develop require shunting if it progresses. Follow-up scans are needed to follow progressive hydrocephalus week to week.

Intraparenchymal haemorrhage (Grade 4 haemorrhage) typically develops in the frontal or parietal lobes secondary to venous infarction (Figure 14). These periventricular haemorrhagic infarctions are typically asymmetric and appear as echogenic masses in the brain parenchyma. As the clot retracts the centre becomes sonolucent. Two to three months later an area of porencephaly, i.e. loss of tissue, can be seen with cystic regions communicating with the ventricle (Figure 15).

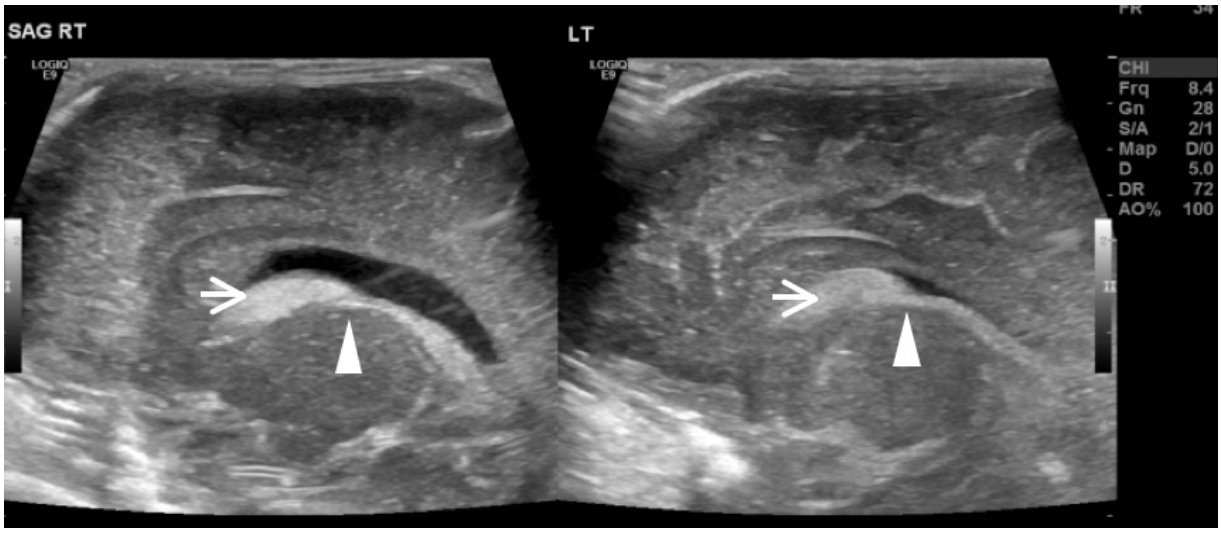


Figure 13: Bilateral Grade 1 germinal matrix haemorrhage
Parasagittal images demonstrate echogenic material consistent with blood products (arrows) extends anterior to the caudothalamic grooves (arrowheads) bilaterally.

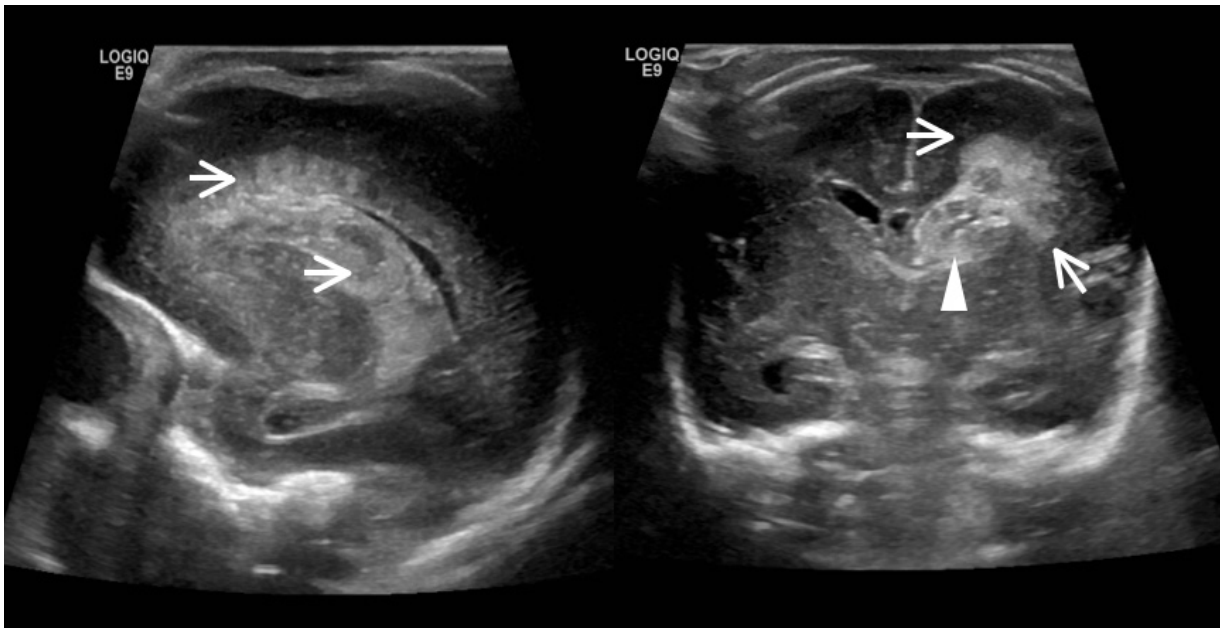


Figure 14: Left Grade 4 germinal matrix haemorrhage
Parasagittal and coronal images demonstrate heterogeneous echogenic material consistent with blood products is present
in the left caudothalamic region (arrowhead) and the adjacent left parietal lobe and left lateral ventricle (arrows).

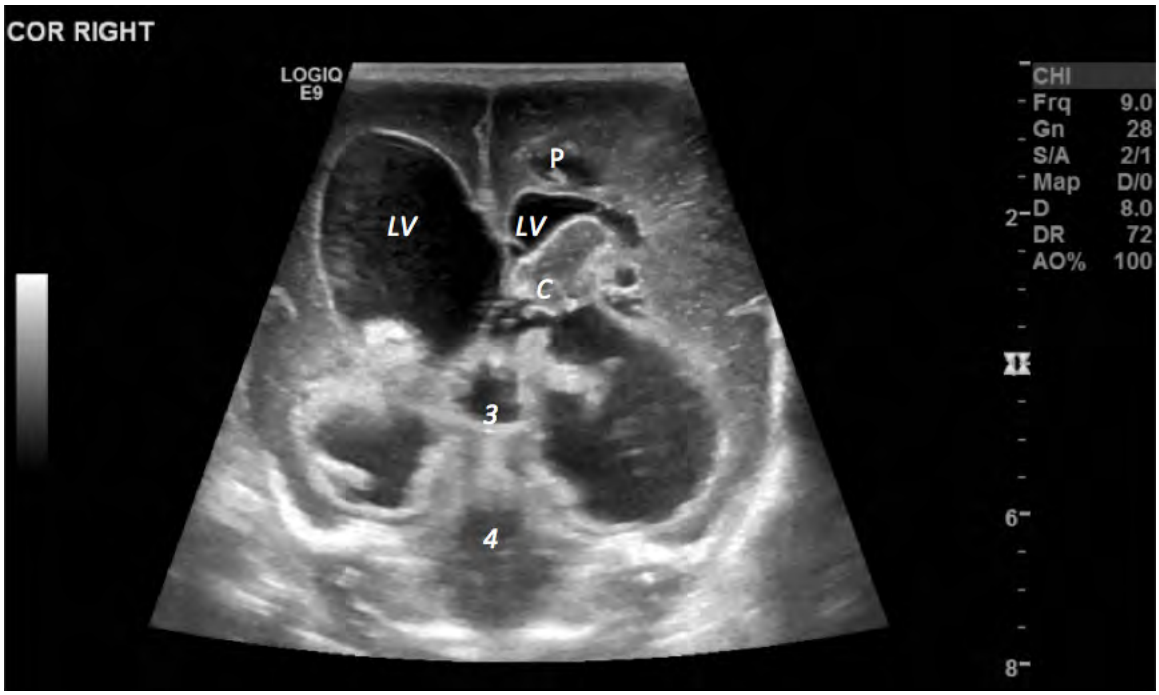


Figure 15: Follow up of Grade 4 haemorrhage with development of hydrocephalus and porencephaly. Coronal image demonstrates echogenic, retractile clot in the body of the left lateral ventricle (C).

22.3 Ventriculomegaly / hydrocephalus

Ventriculomegaly is the term used when the ventricles appear larger than normal. Prenatally, an upper limit of 10 mm for the transverse diameter of the atria of the lateral ventricles has been commonly accepted as the cut off for an enlarged ventricle.

Postnatally, hydrocephalus is one of the most common referrals for paediatric head ultrasound. It is important to remember that large ventricles (ventriculomegaly) do not always mean an infant has hydrocephalus. Ventriculomegaly simply means the ventricles are enlarged which can be from hydrocephalus, i.e. imbalance between cerebrospinal fluid production and drainage by the arachnoid villi, or atrophy, i.e. loss of tissue with normal intracranial pressure. Both can present with large ventricles. If clinically the aetiology is not known, ventriculomegaly is the more appropriate term to use. Hydrocephalus may be due to obstructed outflow, decreased absorption, or rarely overproduction of cerebrospinal fluid, such as in the case of a choroid plexus tumour.

There is no consensus cut-off measurement for the ventricular size in the neonate above which hydrocephalus should be diagnosed. There are a few key points to keep in mind to help distinguish between hydrocephalus and the normal sized ventricles:

– Serial scanning and measurements of the lateral and third ventricles is the most sensitive assessment of hydrocephalus. Standard measurements of the lateral ventricles include the largest measurable transverse diameters and widths of the frontal horns; all in the coronal plane (Figure 16). The third ventricle should also be measured in the coronal plane at its largest transverse diameter (Figure 17).
– The temporal horns of the lateral ventricles and the third ventricle are normally diminutive in the neonate. Dilatation of the temporal horns or the third ventricle suggest hydrocephalus (Figure 17).
– The choroid plexus in the atrium of the lateral ventricles should be adherent to the ventricular wall on a parasagittal image. Cerebrospinal fluid surrounding the echogenic choroid plexus, called ‘hanging choroid’, suggests hydrocephalus of the lateral ventricle (Figure 17).

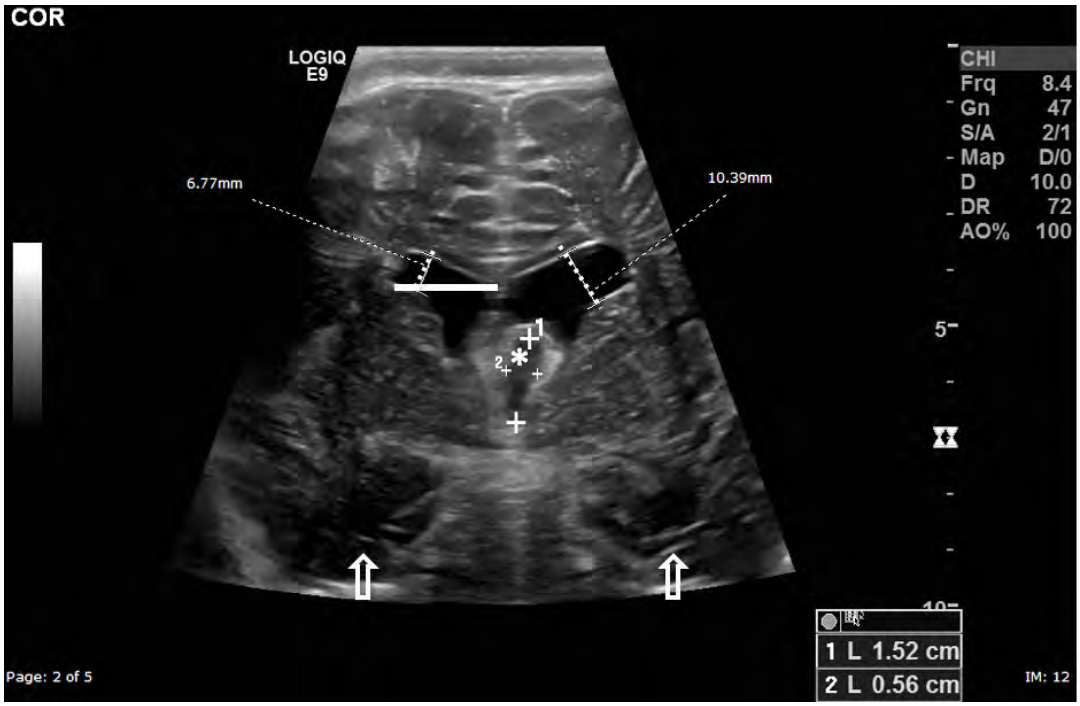


Figure 16: Asymmetric obstructing hydrocephalus of the lateral ventricles, left larger than right, secondary to choroid plexus cyst in the region of the foramen of Monroe. Coronal image demonstrates several ways to measure the frontal horns.

Standard ventricle measurements include of the transverse diameter of the frontal horn of the lateral ventricles from the falx to the most lateral aspect (horizontal, solid line in the right ventricle) and the width of the frontal horns between the ventricular walls (dashed, oblique lines in both frontal horns: 6.77 mm right frontal horn and 10.39 in left frontal horn). The obstructing choroid plexus cyst is also measured on the image (*). Note the dilated temporal horns (arrows).

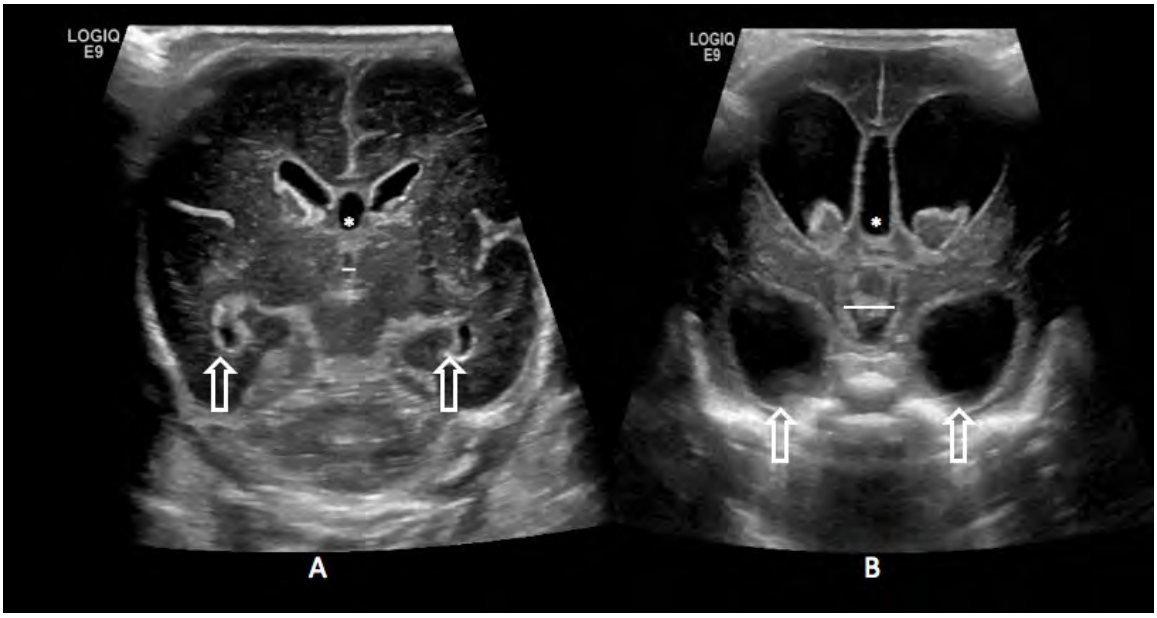


Figure 17: Hydrocephalus
Mild hydrocephalus in patient A and severe in patient B.
The temporal horns are dilated in both images (arrows). The third ventricle is measured in the coronal plane at its widest transverse diameter (white horizontal line). There is echogenic clot present within the third ventricle in patient B. Note the cavum septum pellucidum in both patients (*) should not be mistaken for the third ventricle.

22.4 Extracranial subarachnoid versus subdural haemorrhages

Extracranial subarachnoid and subdural collections can be missed by ultrasound if not looked for carefully by an experienced user. These collections around the superficial convexity of the brain parenchyma are best seen using 13-6 MHz linear array vascular transducer such as the HFL38x if available. Identifying these collections is helpful in the evaluation of subarachnoid haemorrhage, post traumatic subdural haemorrhage, infections and subdural empyema (Figure 18, Figure 19).

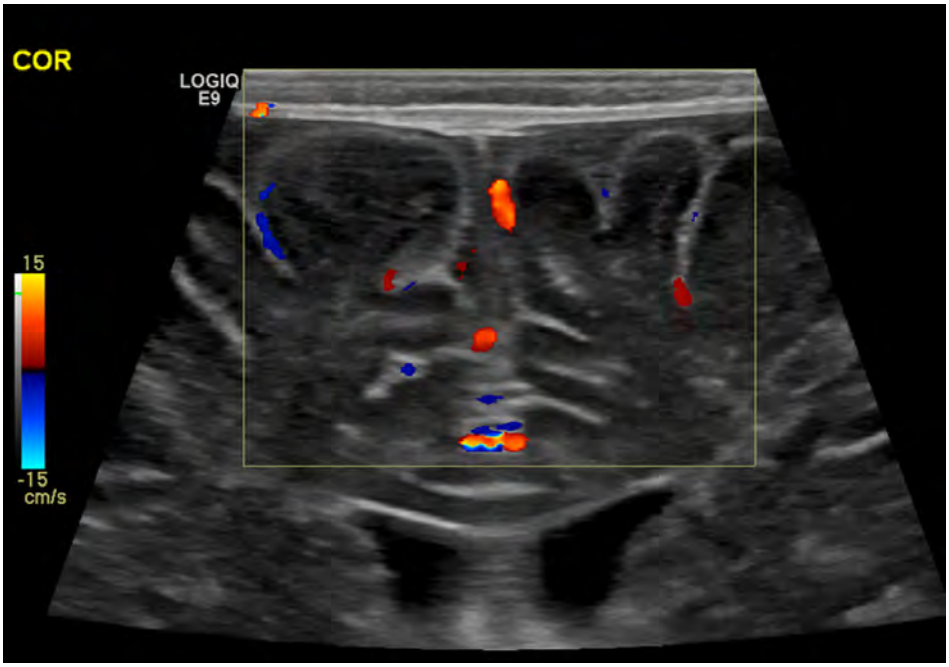


Figure 18: Normal subarachnoid space
Coronal image using a high resolution linear transducer demonstrating a normal subarachnoid space.

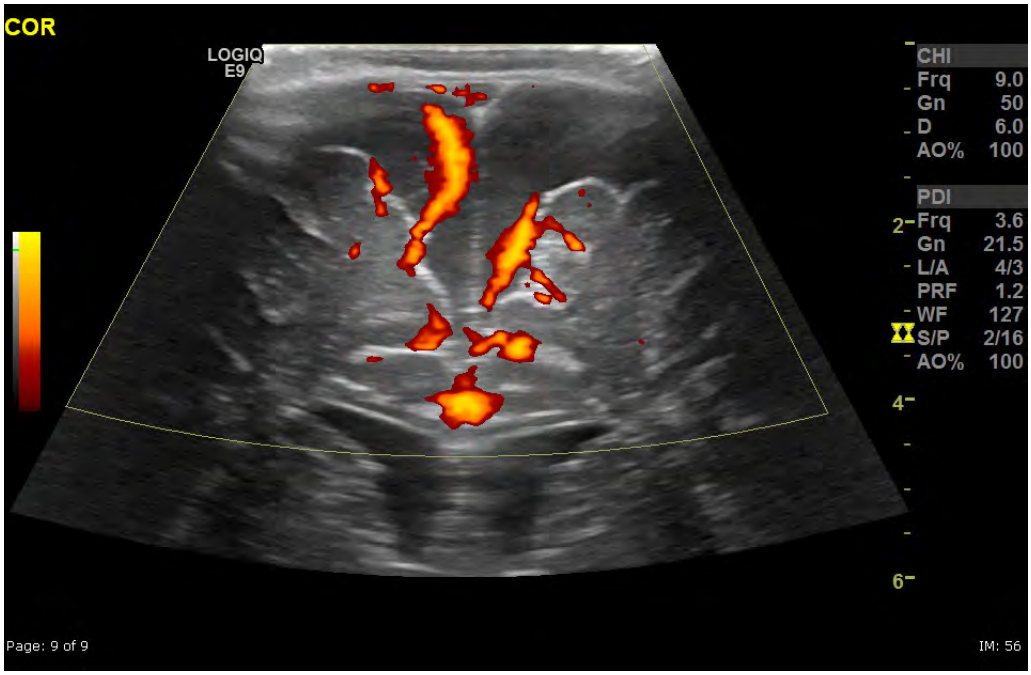


Figure 19: Prominent subarachnoid space
Coronal image using a linear transducer with Colour Doppler demonstrates crossing vessels confirming the fluid is subarachnoid

Subarachnoid haemorrhage

The presence of large interhemispheric and Sylvian fissures with thick increased echogenicity can suggest the present of subarachnoid haemorrhage (SAH). SAH can occur in neonates with asphyxia, trauma, or coagulation disturbances. Meningitis with debris within the subarachnoic space can have a similar appearance and should be considered in the differential – see below.

Subdural and epidural haemorrhage

Subdural and epidural haematomas can be difficult to identify by ultrasound. These haematomas present as unilateral or bilateral hypoechoic fluid collections surrounding the brain parenchyma (Figure 20, andFigure 21, Figure 22). Small amounts of fluid may be difficult to see due to near field artefact. This is less of a problem with high frequency linear transducers such as the HFL38x. Magnified coronal sections are particularly helpful in evaluating the convexities.

If colour Doppler is available, displacement of vessels can help differentiate subarachnoid from subdural fluid based on the displacement of vessels on the brain surface. With subdural collections the vessels are flattened along the convexity. The vessels cross through subarachnoid fluid.

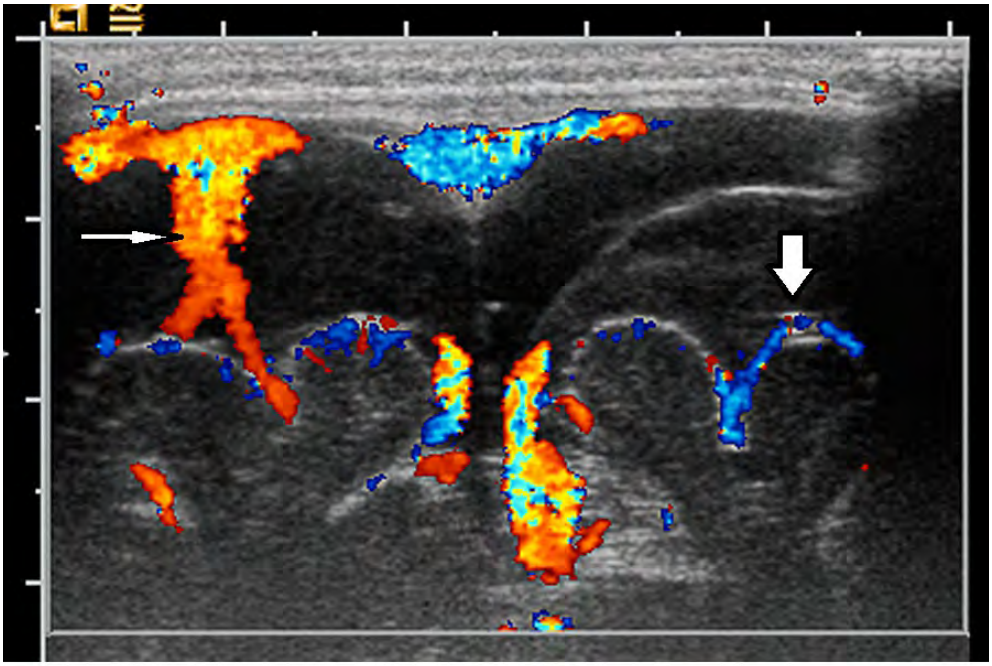


Figure 20: Subarachnoid vs subdural fluid
Coronal image using a linear transducer with colour Doppler demonstrates vessels crossing subarachnoid fluid (horizontal thin arrow) versus vessels hugging the convexity (horizontal thick arrow) confirming the presence of a subdural collection. This was a 4 month old status post non-accidental trauma with an evolving subdural hematoma.

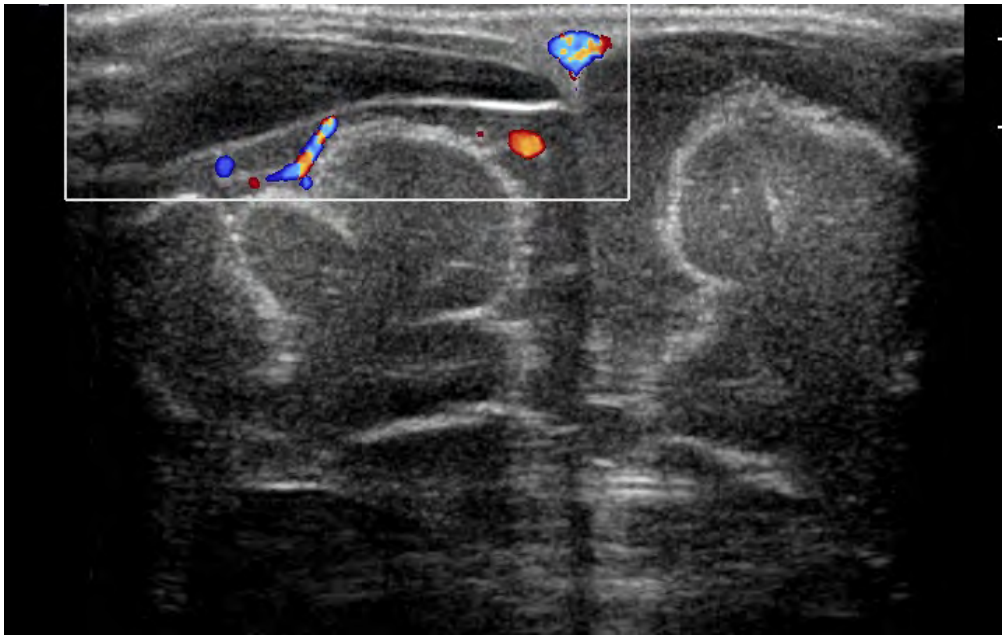


Figure 21: Subdural hematoma
Coronal image using a linear transducer with colour Doppler demonstrates vessels along the convexity confirming the presence of a subdural collection.

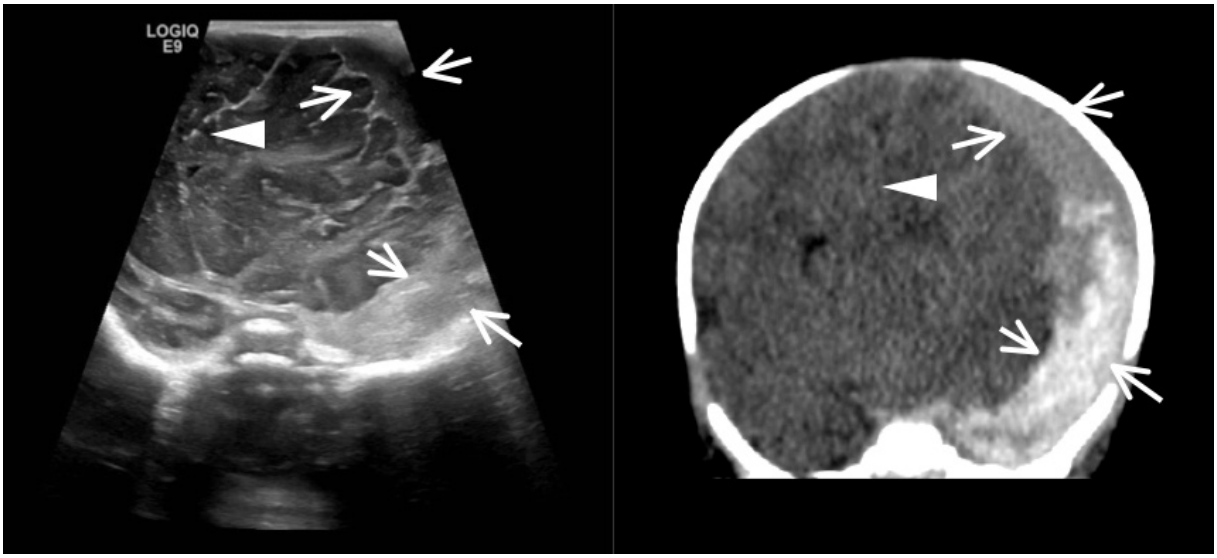


Figure 22: Coronal ultrasound on the left and corresponding CT image on the right.
Large left subdural hematoma (arrows) with mass effect on the left cerebral hemisphere and associated midline shift (arrowhead) in an infant with haemophilia.
Heterogeneity of the subdural blood products on both US and CT corresponds to clotted and unclotted blood.

22.5 Meningitis

Ultrasound can be useful in cases of meningitis. Thick subarachnoid fluid may be secondary to infection rather than blood. The presence of subdural fluid can suggest the present of an empyema (Figures 23, Figure 24 and 25).

Cerebritis abscess formation and venous sinus thrombosis are additional complications that can be seen by ultrasound in infants with meningitis (Figure 26).

Infarctions can occur from arterial vasculitis or venous obstruction with regions of increased or decreased echogenicity of brain parenchyma.

Ventriculitis can be suggested by the presence of hydrocephalus, echogenic debris in the ventricles, or fibrous septa in the ventricles (Figure 27).

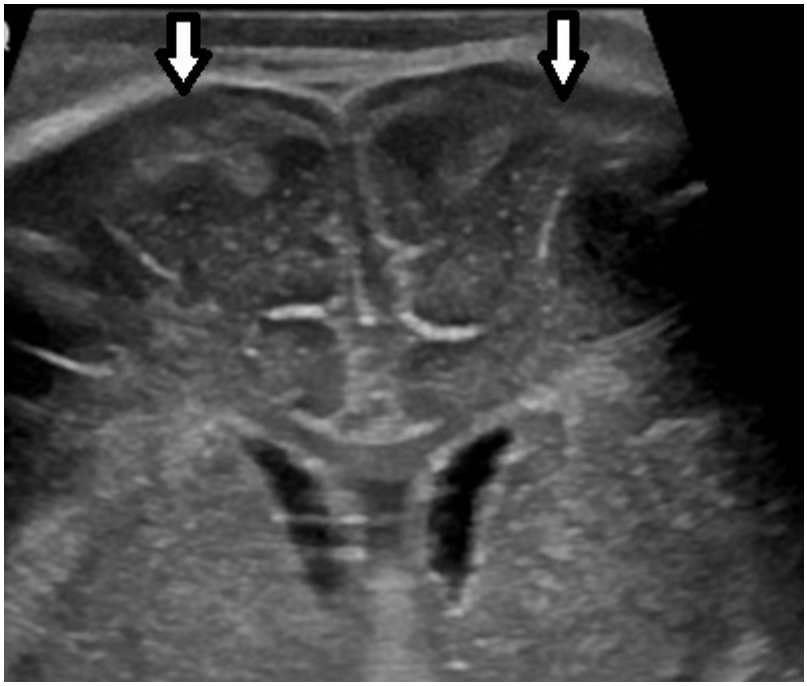


Figure 23: Meningitis
Coronal image using a linear transducer demonstrates extra-axial echogenic subarachnoid fluid over the convexities (arrows) in this infant with meningitis.

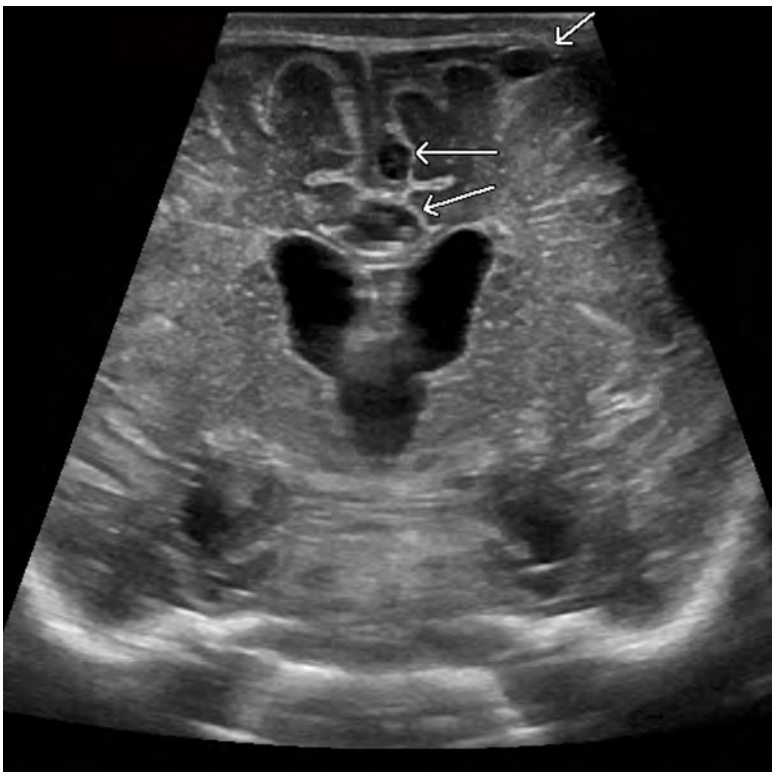
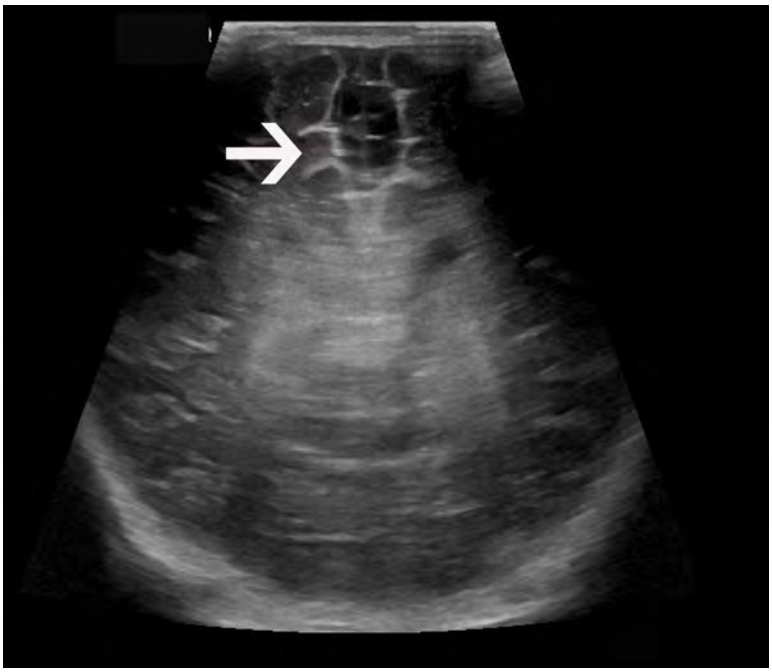


Figure 24: Meningitis
Coronal image demonstrates extra-axial echogenic fluid with loculated hypoechoic collections in the interhemispheric fissure and left convexity (arrows) in this infant with empyemas. The third ventricle and temporal horns are dilated indicating hydrocephalus is present as well.

A



B

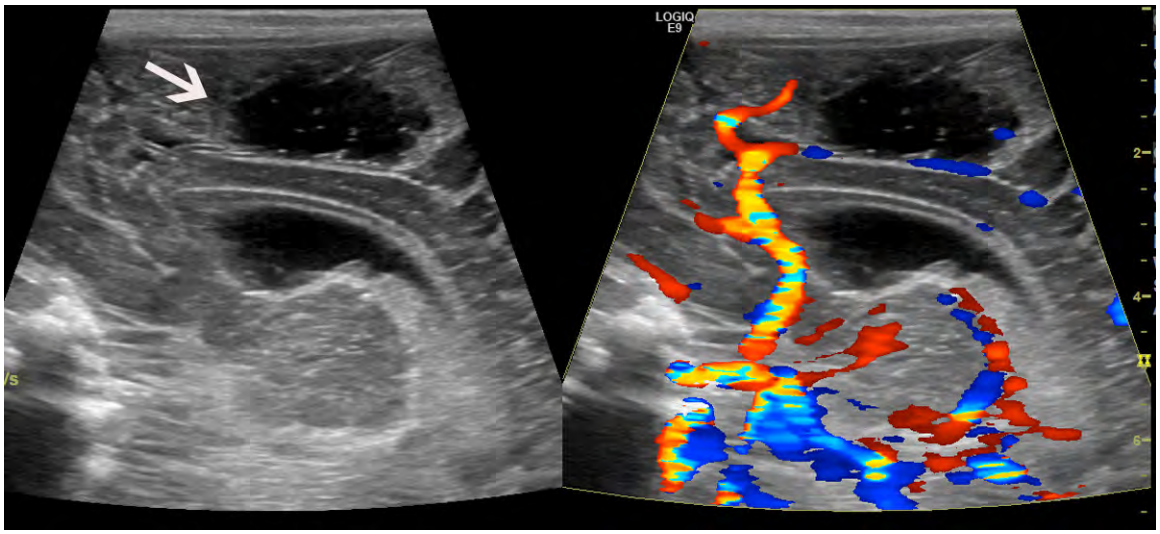
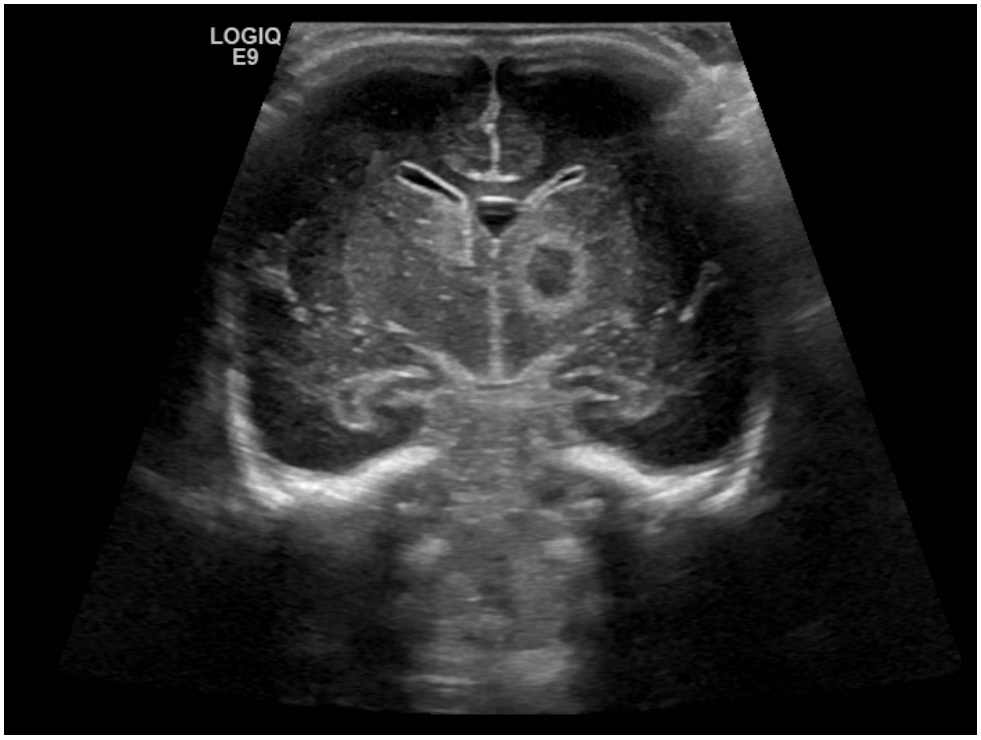


Figure 25: Meningitis
Coronal (A) and sagittal (B) with and without colour Doppler (B) ultrasound images demonstrate septated extra-axial interhemispheric collections (arrows) in an infant with empyemas.

A



B

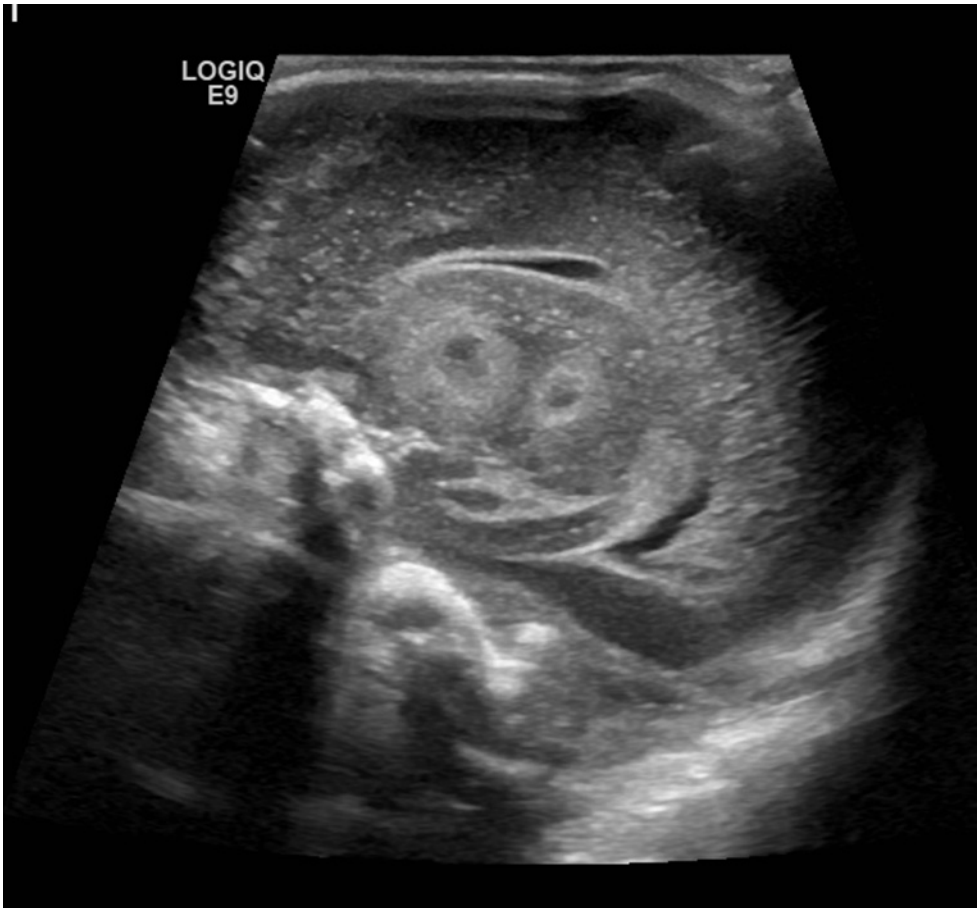


Figure 26: Candida
Coronal (A) and parasagittal images (B) demonstrate hypoechoic circular lesions with echogenic rims in an infant with multiple intracranial Candida abscesses.

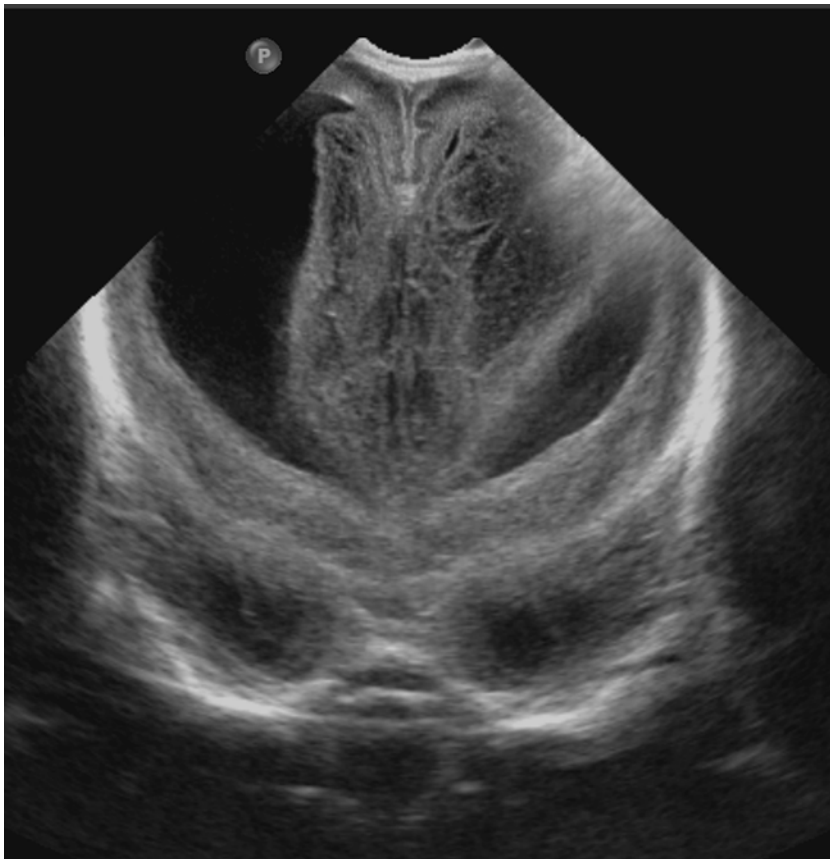


Figure 27: Three month old with Serratia Marcescens meningitis
Coronal image demonstrates severe ventriculomegaly with cobweb septations within the dilated ventricles.

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Suggested Readings

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23. Paediatric chest ultrasound

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The lung is a voluminous organ and standardised areas can therefore be defined anteriorly, antero-laterally and posteriorly corresponding to the different lobes in the left and right lungs. Thus an ultrasound transducer can be directly applied to the intercostal space to view the corresponding lung lobe underneath.

A chest ultrasound can be performed in any child with symptoms and signs of respiratory disorders (cough, difficulty in breathing, wheezing) or a child who is suspected of having pneumonia, heart failure, pneumothorax, and pleural effusion. It's useful to identify or exclude a variety of pathologies including consolidation, pleural effusion, interstitial syndrome and pneumothorax.

23.1 Scanning technique – paediatric chest

Transducers

A 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is preferred.

A 5-2 MHz, curved array abdominal transducer such as the C60X, which is compatible with the MSF standard M-Turbo, is preferred to identify pleural effusions.

Either transducer can be used to demonstrate consolidation.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Chest ultrasound can be done with the patient lying supine, prone or seated. Lying supine is preferred in the evaluation of pneumothorax and pleural effusion due to the preferential accumulation in non-dependant and dependant areas respectively. Young children can be held to the carers' chest, exposing the back for imaging initially, can be turned after this for further imaging.

Scanning steps and technique – paediatric chest

1. The scan is done along anatomical lines:
   - Mid-clavicular
   - Anterior axillary
   - Mid-axillary lines
   - Mid-scapular (in children held to the chest)
2. Start by positioning the transducer in the anterior axillary line (Figure 1). Then move the transducer from the head to the feet.
3. The lower lobes and costophrenic angles are best visualised by sliding the transducer antero-posteriorly in the lower intercostal spaces. Position the transducer as shown below in the intercostal space and move it antero-posteriorly: anterior (left image) and posterior (right image) in Figure 2.
4. The posterior lung segments can be scanned in the interscapular areas and the posterior portion of the lower lobes bilaterally are scanned in the infra-scapular areas with the patient lying prone or seated.
5. Range of scanning: Each intercostal space should be evaluated along the different anatomical lines (see point 1). On the right side, each intercostal space should be evaluated in a cephalo-caudal, i.e. head to feet, direction until the liver is visualised. On the left side, the same is done until the spleen is visualised below the diaphragm.

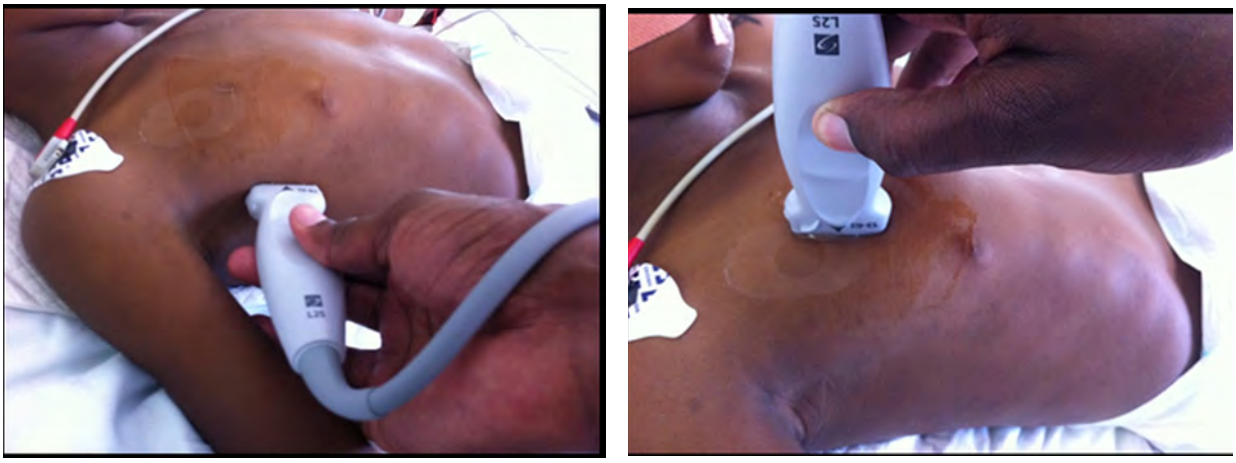


Figure 1: Scanning along anatomical lines
Showing scanning along the anterior axillary line (left) and the mid-clavicular line (right) using a high frequency linear transducer in a patient who is lying supine.
The transducer is moved in the cephalo-caudal direction along the anatomical lines.

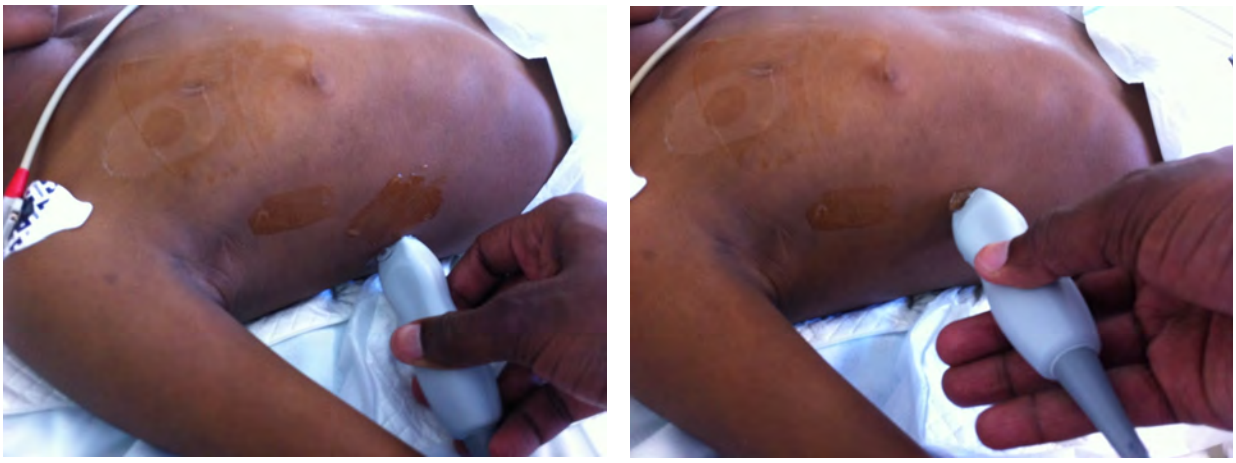


Figure 2: Scanning lower lobes
Showing the use of a low frequency curvilinear transducer when scanning the lower lobes and the costophrenic angles.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

23.2 Normal findings – paediatric chest

Normal aerated lung is poorly visualised with ultrasound but has a specific pattern as a result of the artefacts produced by air. Changes in the appearance of these artefacts are used to identify areas of pathology. The following are seen in normal aerated lung:

Pleura

Pleura appears as a shimmering, bright, i.e. hyperechoic, line (the pleural line) between the rib shadows (Figure 3).

Lung sliding

Lung sliding refers to the movement seen at the pleural line during inspiration and expiration (akin to a row of moving ants). This is due to the visceral and parietal pleura sliding against each other during inspiration and expiration.

A-lines

A-lines are horizontal lines which are reflections of the pleural line (Figure 3). They are seen in normal aerated lung but also in a pneumothorax!

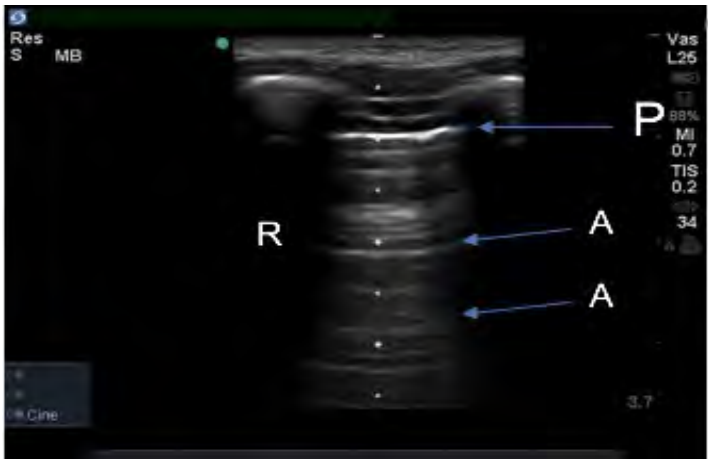


Figure 3: A-lines
Showing the bright (hyperechoic) pleural line (P) between the two rib shadows (R). It is at this pleural line that lung sliding is demonstrated with the sliding appearing like a row of ants. A-lines (A) are reflections of the pleural line.

B-lines

B-lines are bright, well defined lines that resemble comet tails (hence the name 'comet tail artefact') that arise from the pleural line to the bottom of the screen without fading. Their appearance varies between inspiration and expiration and they erase the A-lines. Up to 2 B-lines per field are considered normal, while more than 2 B-lines or confluence of B-lines into sheets are abnormal findings indicating thickened interstitial septa (Figure 4). See Chapter 23.3.3 Interstitial Syndrome for more information.

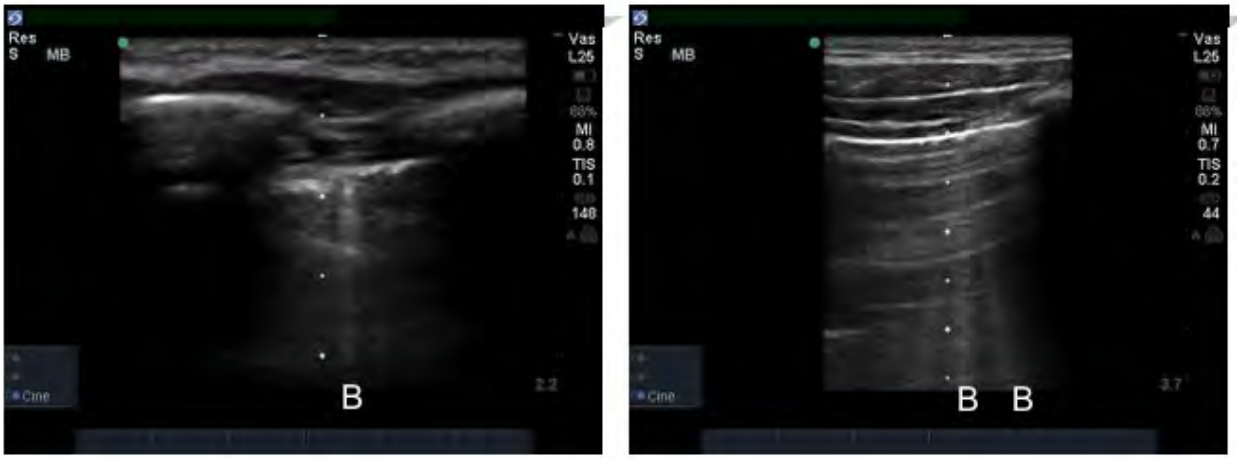


Figure 4: B-lines
B-lines are vertical lines that arise from the pleural line to the bottom of the screen without fading ('B').

Curtain sign

The diaphragm separates the chest and abdominal cavities. Lung tissue is seen above the diaphragm while the liver and spleen are visualised below the diaphragm. During respiration, normal lung tissue partially occludes the view of the liver and spleen as the lung expands and collapses in a manner akin to the opening and closing of a theatre stage curtain, hence the name 'curtain sign' (Figure 5 and Figure 6).

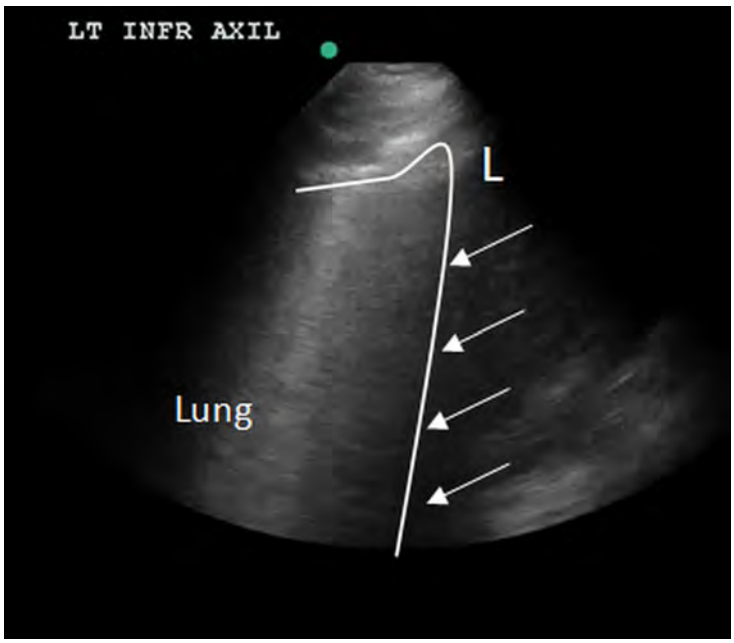


Figure 5: Curtain sign
Figure above showing curtain sign with the arrows and white margin showing the edge of the curtain (lung tissue) and the liver below that (L).

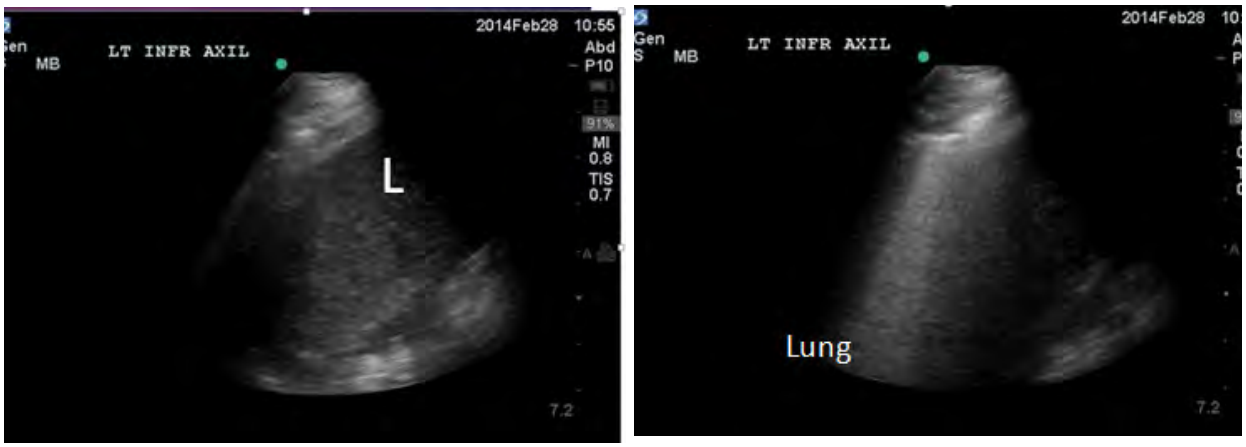


Figure 6: Curtain sign
The same image above is shown below with respiratory variation of the 'curtain' (lung tissue) during expiration (left) and inspiration (right). Note the appearance and disappearance of the liver (L) as it is shielded by the inflated lung.

23.3 Pathological findings – paediatric chest

Identification of pathology depends on a few principles, namely:

- In the pleural space, air, i.e. pneumothorax, and fluids, i.e. effusions, have opposite gravitational directions; air within the pleural space will rise (non-dependant) whereas a pleural effusion is dependant.
- If fluid is present within lung parenchymal tissue, it is in very close proximity to the air in the alveoli with minimal gravitational effect as is seen in interstitial (pulmonary) oedema and produces a distinct pattern on ultrasound.
- Nearly all acute disorders border the pleural line.
- Pathological conditions are associated with changes in the appearance of the artefacts seen in normal lung as described in Chapter 22.2.
- A number of lung ultrasound findings, both normal and abnormal depend on the presence of moving lung tissue (and will thus be absent in the apnoeic patient).

23.3.1 Pleural effusion

Pleural effusions are seen in the dependent lung areas and are delineated by the chest wall and the diaphragm. They are always above the diaphragm.

Scanning technique – pleural effusion

1. Adjust the depth to optimise the view.
2. The transducer is placed in the intercostal space with its long axis parallel to the adjacent rib.
3. The effusion predominantly appears as dark, i.e. anechoic and usually homogenous fluid in the dependent areas above the diaphragm.

Scanning notes for pleural effusion

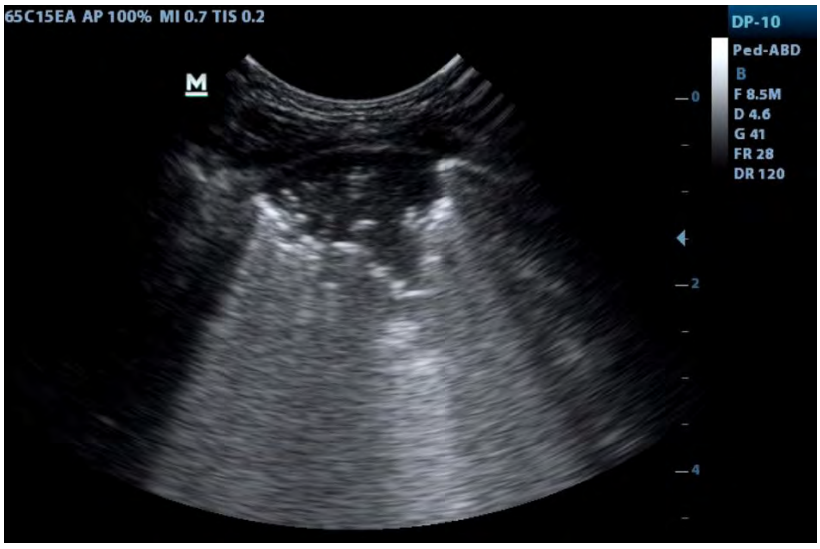
- The effusion may not be homogenous if it is an empyema or is loculated.
- Depending on the size of the pleural effusion, it can track more superiorly within the chest cavity. If complicated the effusion may contain hyperechoic septae and fluid of differing echogenicities indicating loculation (Figure 7). The effusion does not vary with inspiration and expiration.

Figure 7: Pleural effusion
Images showing a right sided pleural effusion (P) lying between the edge of the aerated lung and the diaphragm / liver below. The diaphragm (D) delineates the thorax from the abdominal cavity and liver. The right image shows a septated / loculated pleural effusion.

23.3.2 Consolidation

Alveolar consolidation appears as an area of poorly defined dark, i.e. hypoechoic, lung tissue resembling liver called hepatisation. Within the consolidation, hyperechoic punctate areas can be seen corresponding to air in the bronchi: a so called ultrasound air bronchogram. Collapsed lung segments can resemble consolidation sonographically and may not have air bronchograms.

A



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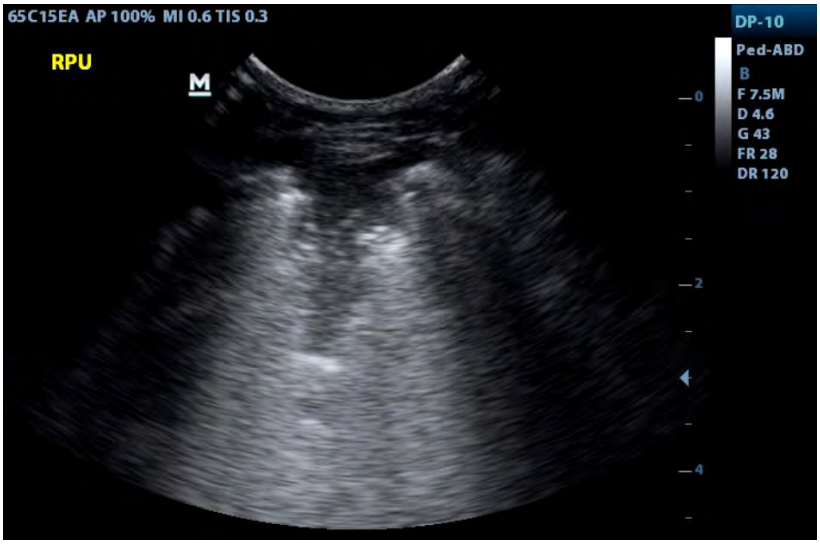

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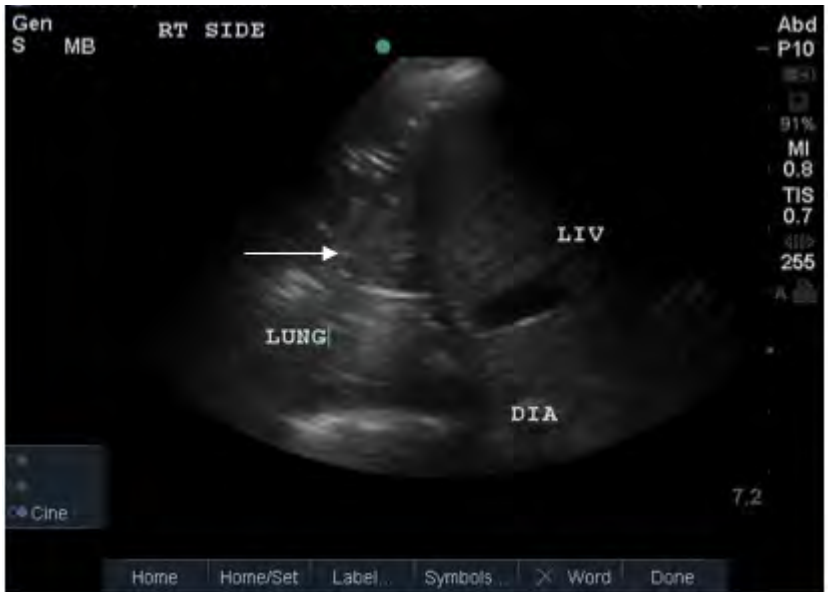

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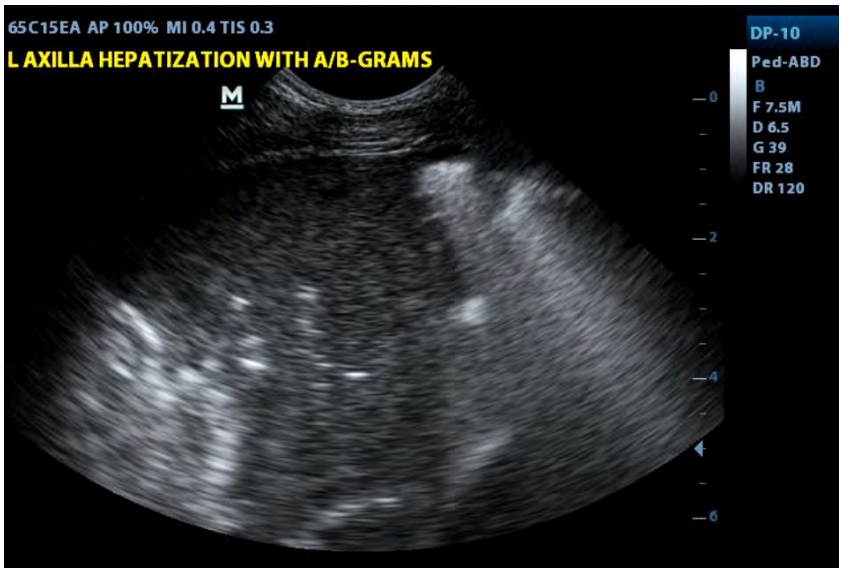


Figure 8: Consolidation
Images (A) and (B) shows smaller subpleural consolidations surrounded by confluent B-lines. Images (C) and (D) shows large areas of consolidation also referred to as 'hepatization' due to the liver-like appearance. In (C) the arrow marks the consolidated right lower lobe (LUNG), clearly demarcated from the liver (LIV) by the domed diaphragm (DIA).
Note the resemblance in appearance between consolidated lung (with bright area = bronchograms) and the liver.

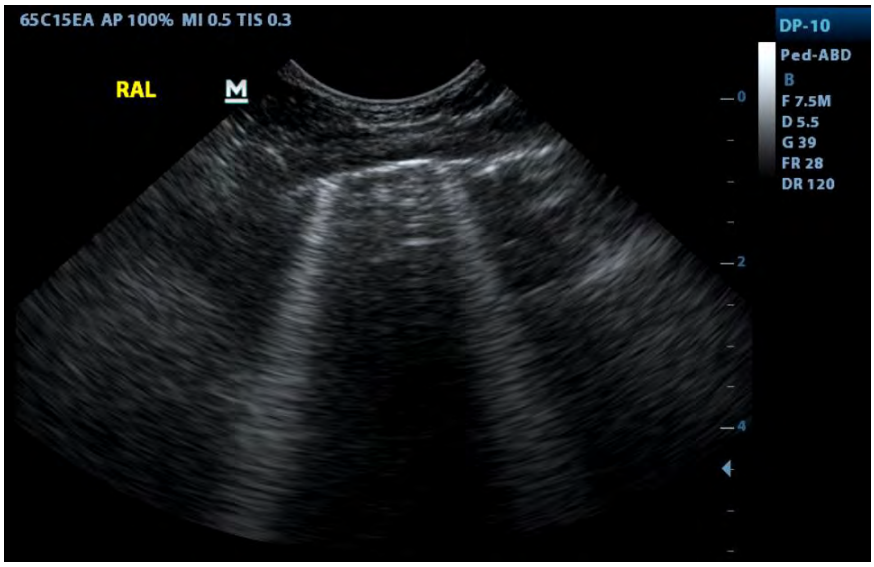
Caution: It is very easy to mistake the liver or spleen for consolidation located close to these organs and vice versa. Hence, the thorax should be clearly identified with the ultrasound by locating the diaphragm and visualizing the consolidated lung above and the liver or spleen below the diaphragm.

23.3.3 Interstitial syndrome

Occasional B-lines can be seen in normal lungs, especially at the bases. Up to two B-lines in an intercostal space are considered normal whereas three or more are pathological. The commonest causes are pulmonary oedema and viral infections (Figure 9 and Figure 10).

B-lines can be localised, disseminated, confluent, homogenous or in-homogenous depending on the pathology and are present in any disease affecting the interstitium.

A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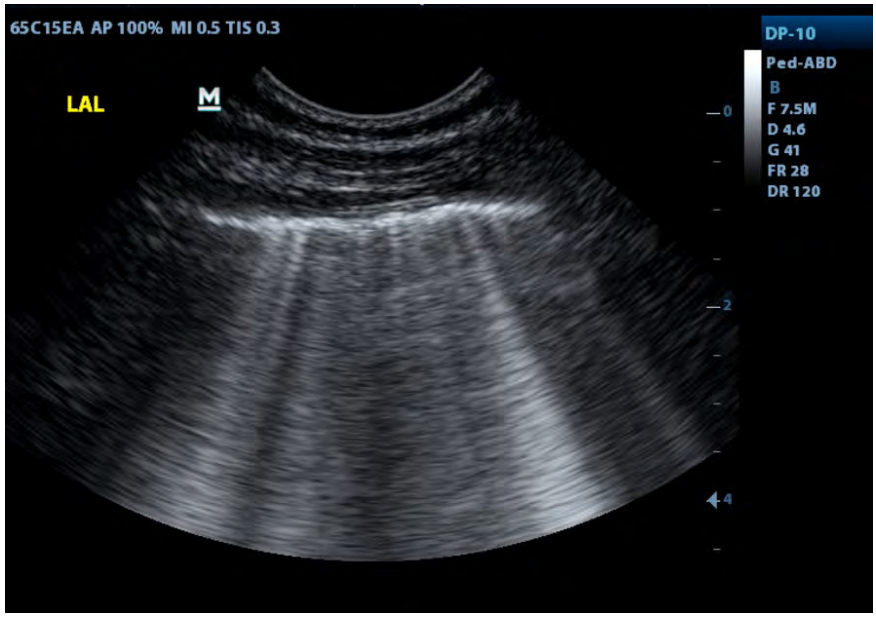
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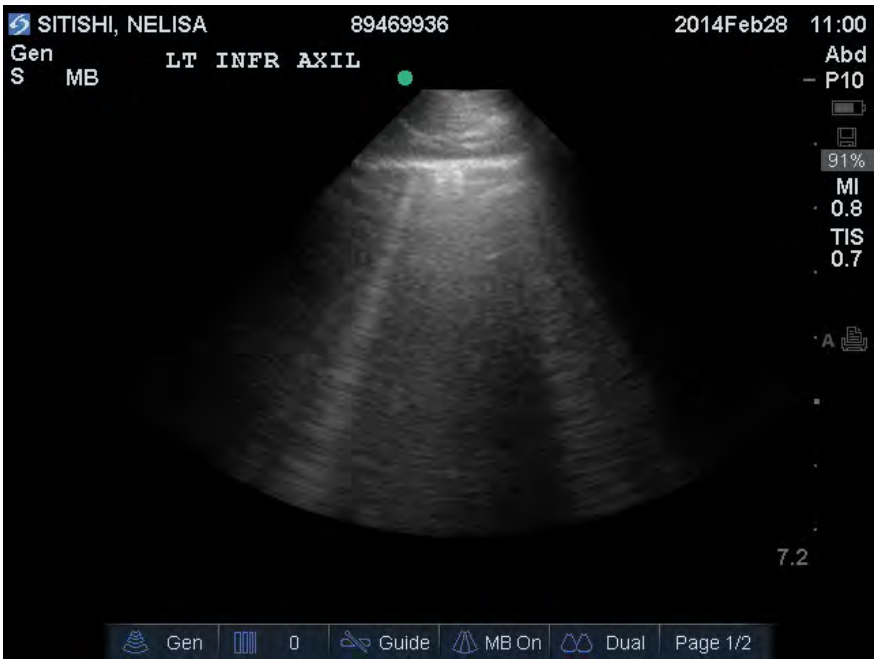
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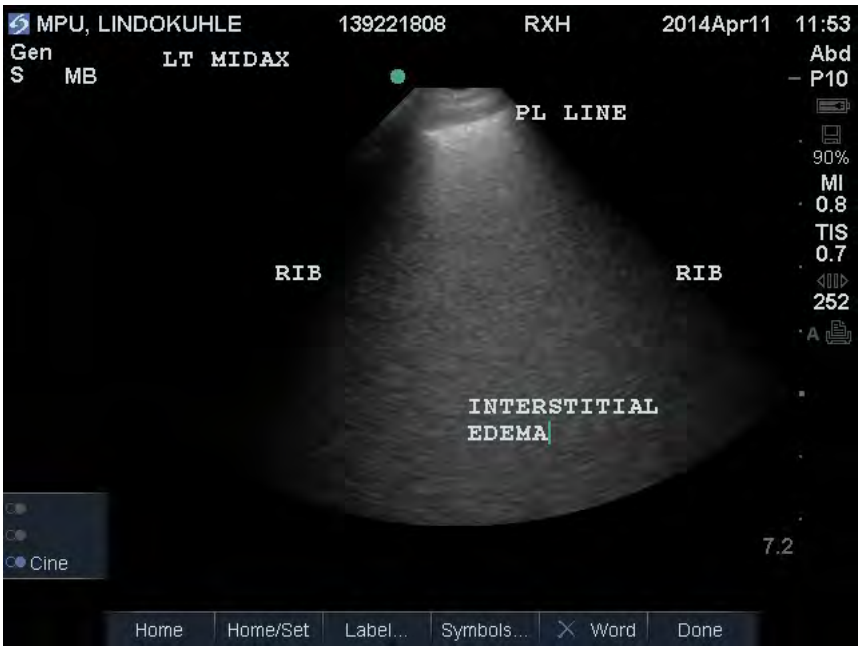


D

Figure 9: Interstitial syndrome
The images above show the progression of interstitial syndrome with the appearance of two B-lines in (A) indicating normality to multiple lines in (B). In (C), the B-lines are becoming more confluent indicating more severe pulmonary oedema while in (D) there is complete confluence (solid) B-lines.

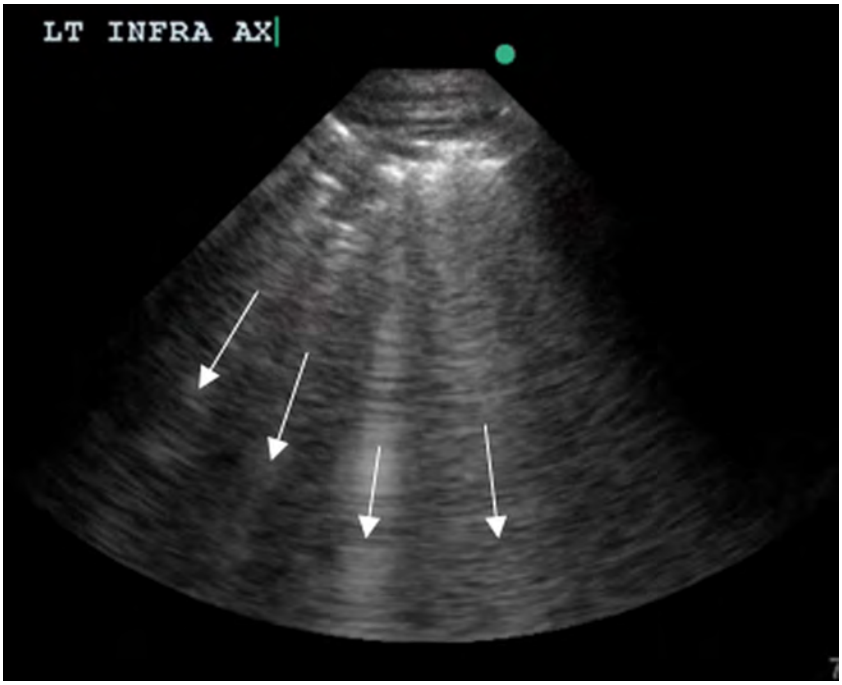


Figure 10: Interstitial syndrome
The figure shows the other appearance of the interstitial syndrome with multiple B-lines (indicated by white arrows) in a child with severe pneumonia evidenced by the consolidation (bronchograms) seen in the top left of the image.

The explanation for these pathological B-lines is that they represent thickened interlobular septae surrounded by alveolar air. In pulmonary interstitial oedema the juxtaposition of air in the alveoli and fluid in the interlobular septa causes the sound to reverberate 'to and fro' between the septa creating a line for each reverberation which combine to form B-lines. When oedema becomes more severe, the mixing of fluid and air causes more B-lines to be generated and they become closer together. Very severe oedema can cause the B-lines to fuse with a hyperechoic confluent pattern that fills the space between 2 ribs.

23.3.4 Pneumothorax

Three signs should be looked for to diagnose a pneumothorax:
– Absent lung sliding on dynamic scanning during respiration
– Presence of A-lines
– Visualisation of the 'lung point'.

It is important to remember the basic anatomy that is visualised with the ultrasound machine during chest sonography and a review of this basic anatomy is shown in Figure 11 below. The important anatomy to identify include the skin and subcutaneous tissues, the rib shadows, the pleural line and below that the lung tissue.

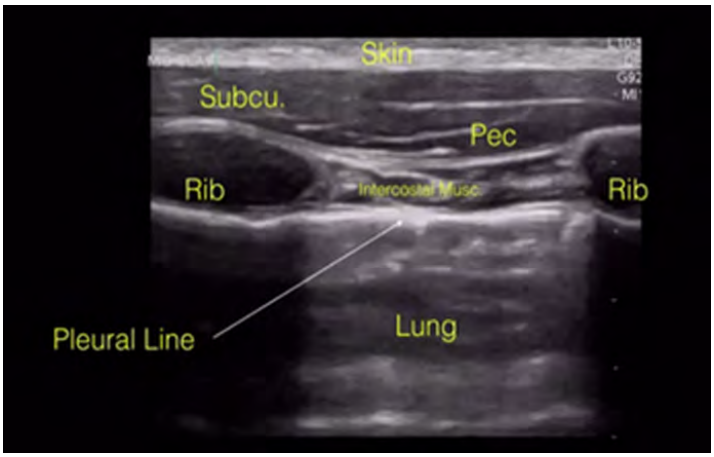


Figure 11: Showing the basic anatomy as visualised in the sagittal plane during chest sonography The anatomy includes skin, subcutaneous tissue (subcu), muscle (pec and intercostal musc), rib shadows on either side (rib), the luminescent pleural line and the lung tissue beneath that.

The pleural line is extremely important because this where lung sliding is demonstrated. Absence of lung sliding with absent B-lines and multiple A-lines gives rise to a pattern suspicious of pneumothorax as shown in Figure 12 below.

Absence of B-lines is non-specific but may point to a pneumothorax. It is important to remember though, that the presence of a single B-line rules out a pneumothorax, since B-lines are generated from lung tissue (refer to Figure 4: B-lines.).

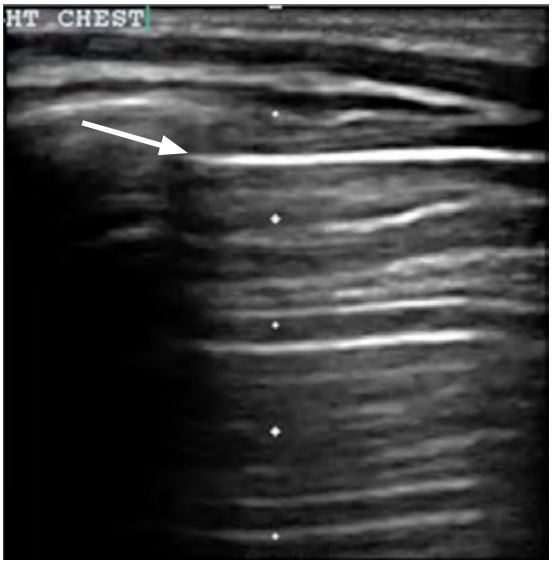
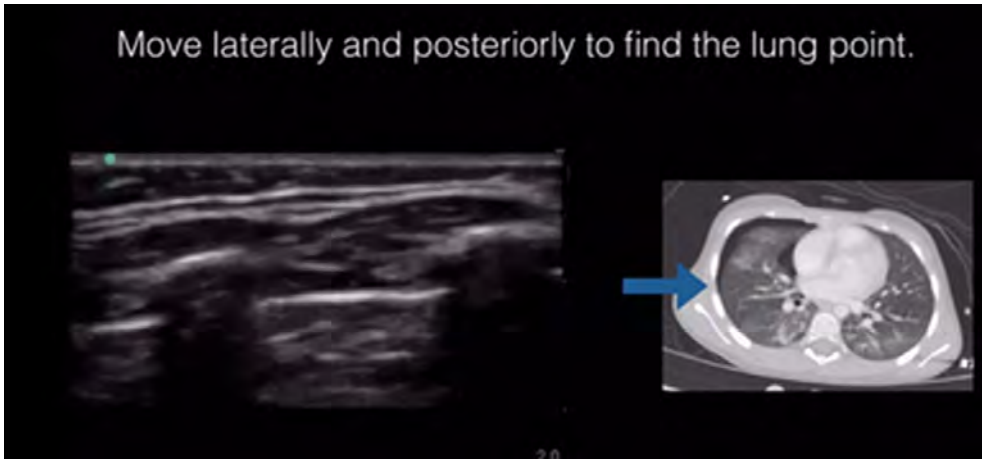


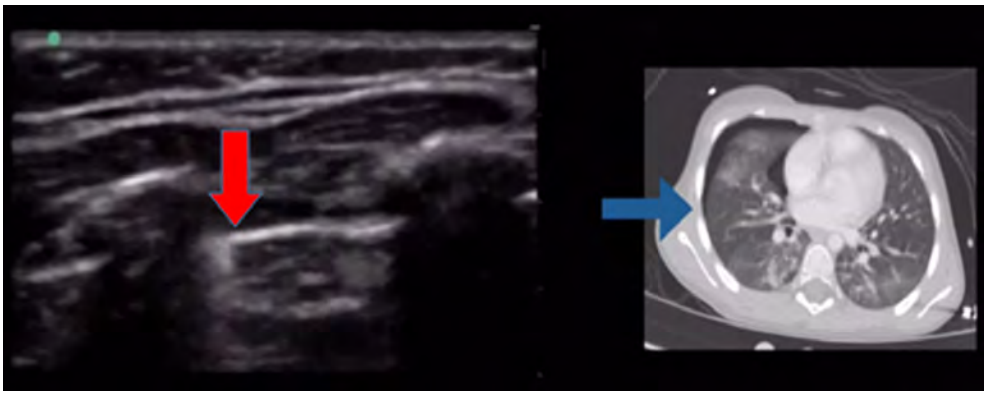
Figure 12: Showing the appearance of a pneumothorax with numerous A-lines and absent B-lines (absence of lung sliding must be confirmed while performing the ultrasound scan). Notice the luminescent pleural line (arrow) and absent lung tissue beneath that.

Lung point

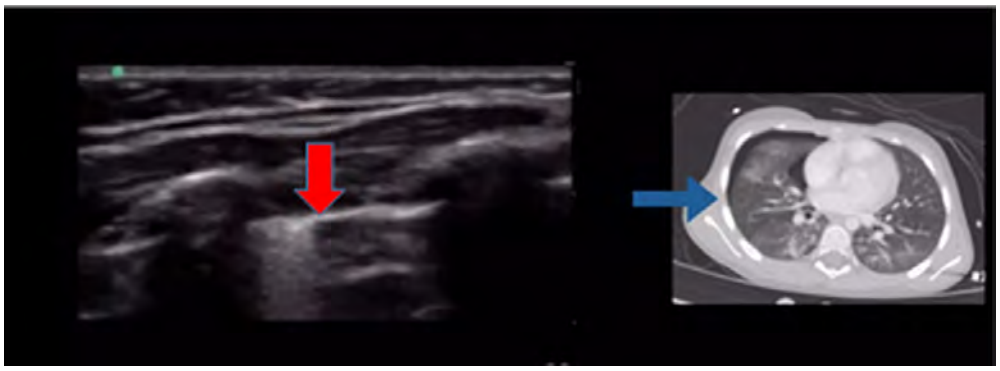
In the presence of a pneumothorax there is a point, usually in the lateral regions where the lung and air may be visualized in the same view. This is the 'lung point'. In the supine patient the air in the pleural space moves anterior and the lung collapses to a dependent position posteriorly. On moving from anterior to lateral, a pneumothorax pattern gives way to a fleeting appearance of lung pattern in a particular location of the chest wall.



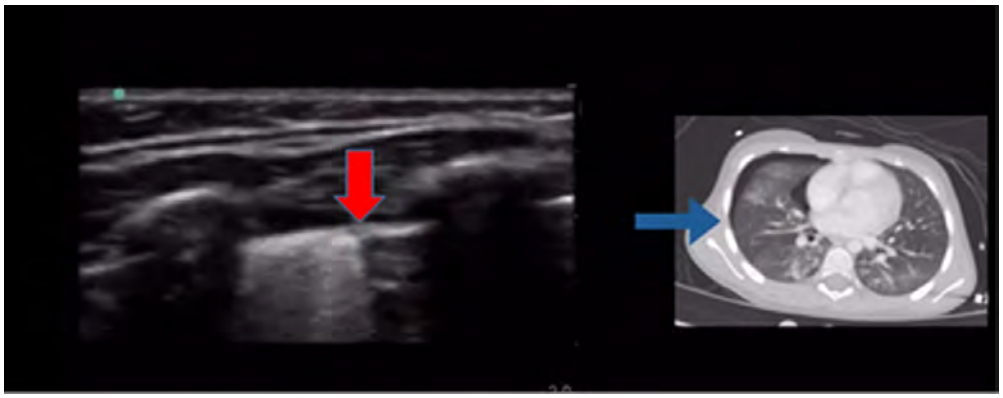
A) No lung point visualised. Only pneumothorax seen in the intercostal space. Blue arrow in CT image shows position of ultrasound probe.



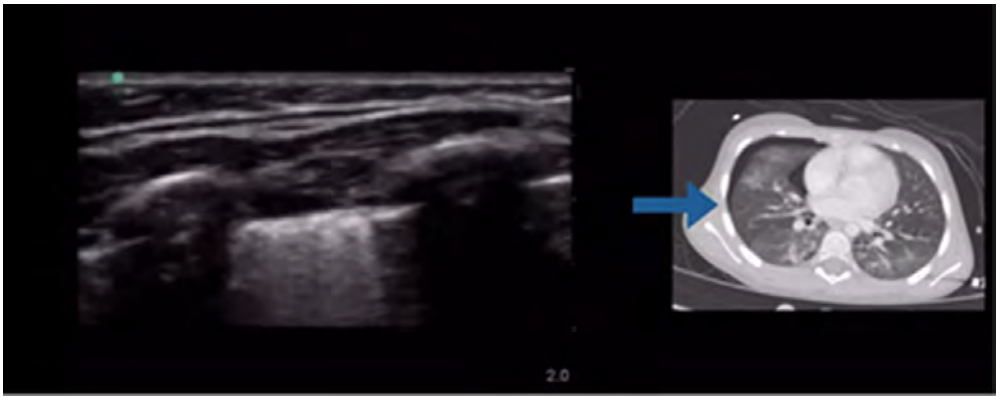
(B) Lung point visualised (red arrow) with pneumothorax visible on the right of the image



(C) Lung point visualised (red arrow) while more aerated lung appears from the left of the image



(D) – Lung point visualised but there is more aerated lung than pneumothorax



(E) Aerated lung almost fills intercostal space but small pneumothorax is still visible on the far right

Figure 13 A-E: Demonstration of the lung point
The lung point (red arrow) is the point between the two rib shadows at which the normal lung and the pneumothorax are seen in the same intercostal space.
The pneumothorax pattern in (A) gives way to the lung pattern appearing in (B) – (E).

* Figures 11, 13 (A-E) courtesy of Nate Lane, MD, UCIMC Emergency Department Ultrasound Director from https://www.youtube.com/watch?v=P1tRdw2rDcE

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24. Mediastinal ultrasound in children

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Ultrasound has been shown to be a useful tool in demonstrating mediastinal lymphadenopathy in children with suspected TB and can either supplement standard radiographs or act as a replacement in scenarios where X-ray is not available. In children, the imaging diagnosis of pulmonary TB relies on the identification of intrathoracic lymphadenopathy irrespective of the modality used to image the child.

24.1 Scanning technique - mediastinal ultrasound

Transducer

A 8-5 MHz micro curved array transducer such as the C11x which is compatible with the MSF standard M-Turbo, is preferred.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The child should be positioned supine with arms to the side and a small pillow / blanket should be placed between the shoulder blades to allow the head to be tilted slightly backwards to expose the suprasternal notch. The patient can be encouraged to turn the head to left to improve access.

Scanning steps and technique – mediastinal ultrasound

Transverse view

1. The ultrasound transducer is placed at the suprasternal notch and oriented perpendicular to the axis of the neck.
2. Start with the transducer in a neutral position and then manipulate it towards the patient's feet making a sweeping movement to allow a view into the mediastinum.
3. The transverse view demonstrates the following normal vascular anatomy (Figure 1):
   - The right and left brachiocephalic veins (Rt BCV and Lt BCV)
   - The superior vena cava (SVC)
   - The aorta
   - The pulmonary artery (Pulm).

   Enlarged lymph nodes are mainly visualized in zone A, B and C (Figure 1).

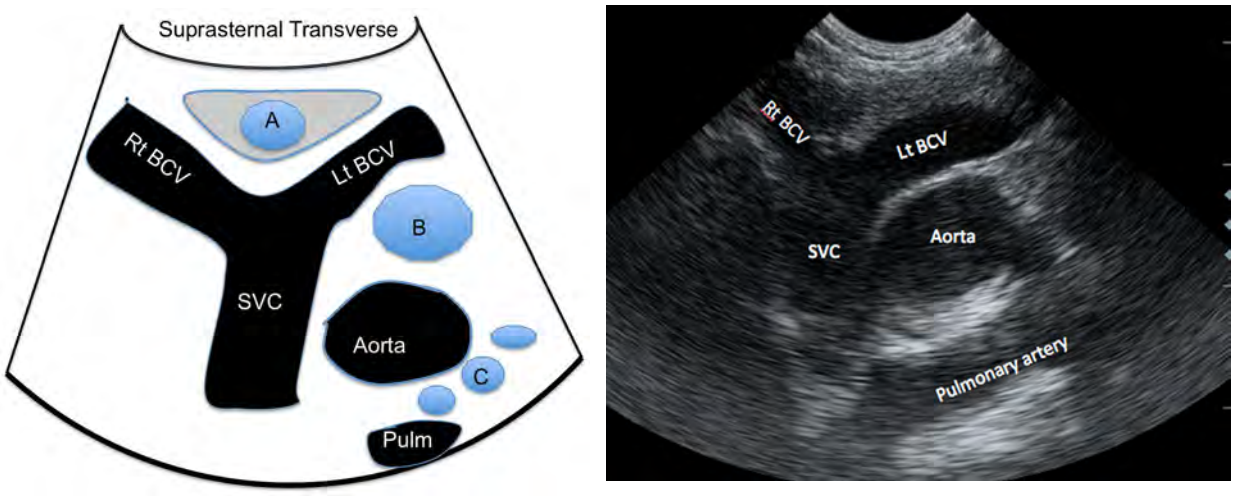

Figure 1: Suprasternal transverse view
This view demonstrates the venous structures (Rt BCV = right brachiocephalic vein and, Lt BCV = left brachiocephalic vein and SVC = superior vena cava) in the more superficial position (but just deep to the thymus). The aorta is seen in cross section deep to the left brachiocephalic vein while the pulmonary artery is seen as a more linear structure deep top aorta. All vessels are anechoic. The associated schematic demonstrates the same anatomy but also indicates the sites where lymphadenopathy may be seen in cases with primary tuberculosis, as oval structures A - C.

Sagittal oblique view

1. Rotate the probe anti-clockwise so that the probe notch is oriented obliquely to face the child's right nipple to follow the orientation of the aortic arch / ascending aorta.
2. Again start in a neutral position, keep the probe notch pointing towards the right nipple and sweep the probe to look into the chest to allow a full view of the area around the aortic arch.

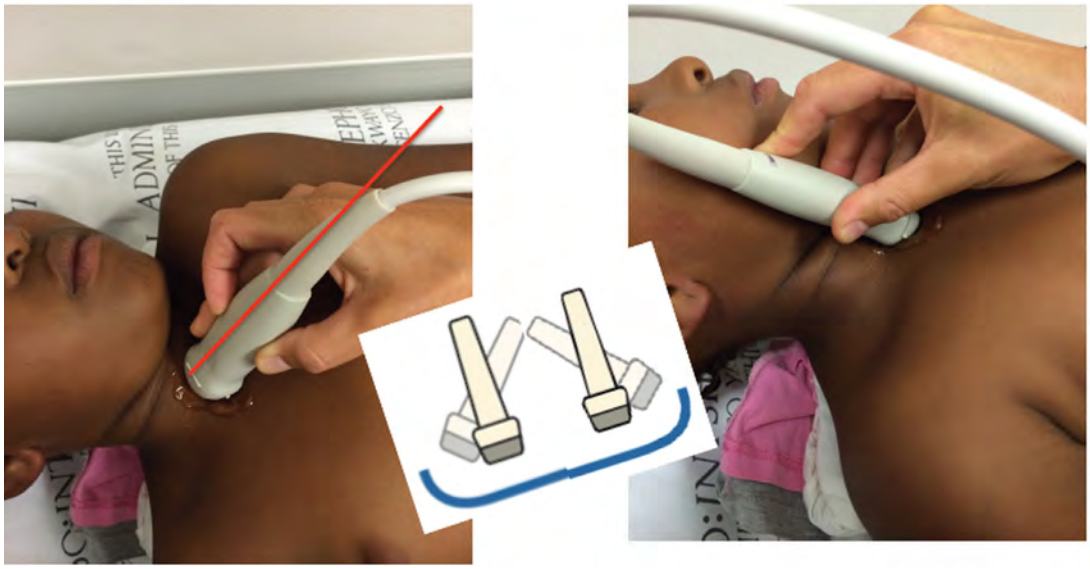

Figure 2: Sagittal oblique view

3. The sagittal oblique view demonstrates the following normal vascular anatomy (Figure 3):
   - The left brachiocephalic vein (Lt BCV)
   - The aortic arch with
   - The left common carotid artery (Lt CCA) and
   - The left subclavian artery (Lt SCV).

   Enlarged lymph nodes are mainly visualized in zone D, E and F (Figure 3).

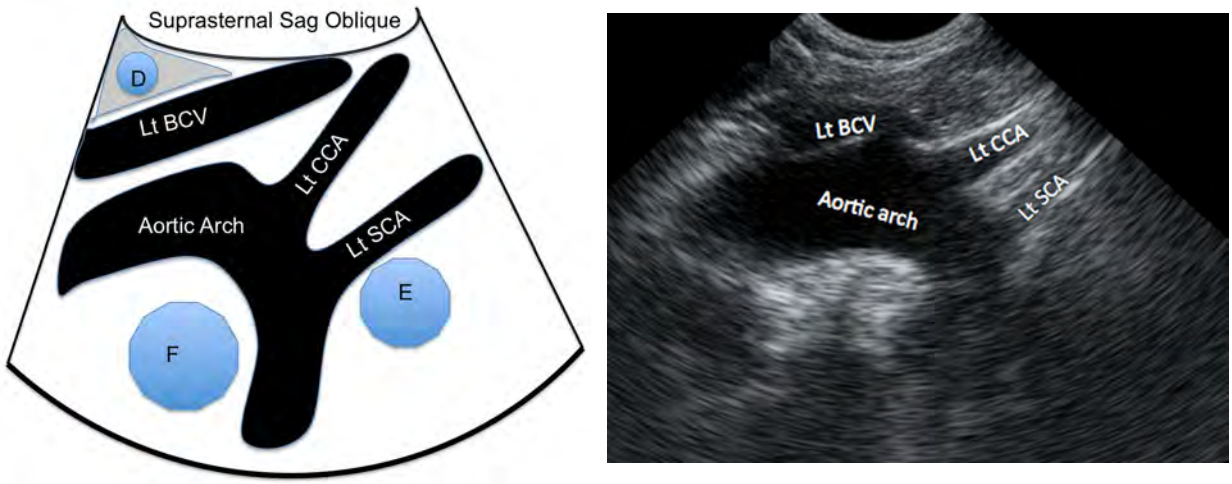

Figure 3: Sagittal oblique view.
This view demonstrates the left brachiocephalic vein (Lt BCV = left brachiocephalic vein) as a linear structure in the more superficial position (but just deep to the thymus). The aorta is as an arch deep to the left brachiocephalic vein while the linear structures arising from it represent the main arterial branches into the neck. All vessels are anechoic. The associated schematic demonstrates the same anatomy but also indicates the sites where lymphadenopathy may be seen in cases with primary tuberculosis, as oval structures D - F.
Lt CCA = left common carotid artery; Lt SCA = left subclavian artery.

Scanning notes for mediastinal ultrasound

– Detection of lymphadenopathy in the correct clinical setting is diagnostic of TB even though there are a multitude of causes for lymphadenopathy.
– The thymus is a normal structure that may be visualized in zones A and D. The normal thymus is homogenous, does not cause mass effect and usually appears rhomboid in the transverse plane or triangular in the sagittal plane as opposed to lymph nodes, which are oval, more hypoechoic and cause mass effect.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

24.2 Lymphadenopathy

Lymphadenopathy is relatively hypoechoic (but not echo free); oval in all planes and often displaces structures. It is identified distinctly from normal vessels, which are echo free, situated in characteristic locations, become elongated structures in at least one plane and often have branches. Enlarged lymph nodes are commonly seen in zone A, B, C, D, E and F (see above images).

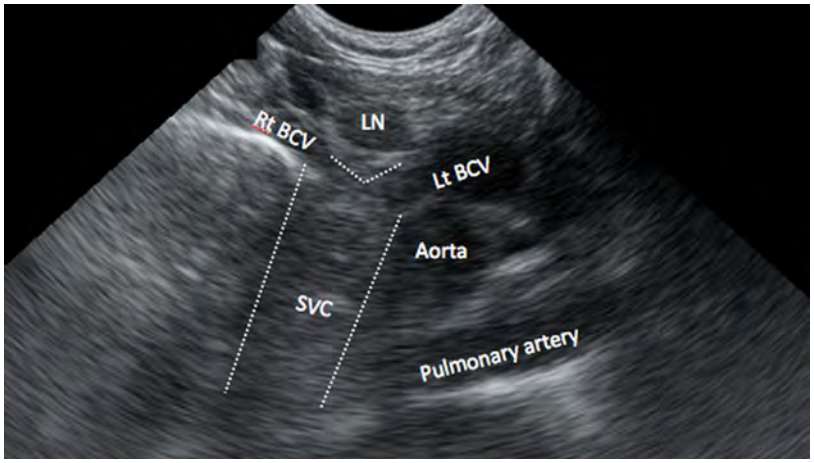

Figure 4: Transverse view
Transverse view of a an oval lymph node (LN) in zone A which has an oval appearance and is more echogenic than the vascular structures, by hypoechoic compared to the thymic tissue which is superficial to it. The superior vena cava (SVC) position is assumed based on the other vascular structures. Rt BCV = right brachiocephalic vein; Lt BCV = left brachiocephalic vein.

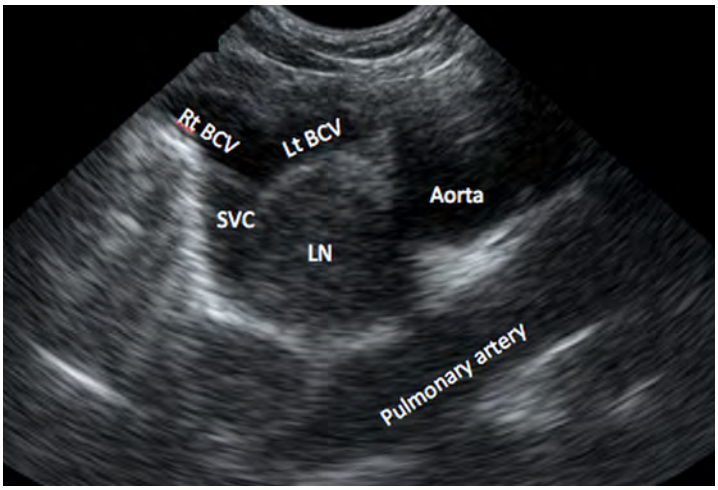

Figure 5: Transverse view:
Transverse view of an oval, large, relatively echogenic lymph node (LN) in zone B, compressing the superior vena cava (SVC) and displacing the aorta.
Rt BCV = right brachiocephalic vein; Lt BCV = left brachiocephalic vein.

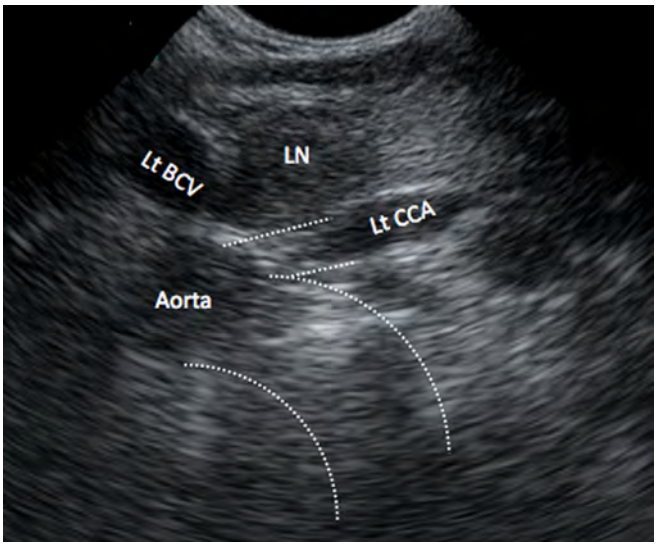

Figure 6: Sagittal oblique view
Sagittal oblique view does not demonstrate the full aortic arch because of malpositioning, but does demonstrate an oval lymph node (LN) in zone D, superficial to the vascular structures. It is hypoechoic compared to the thymic tissue seen inferior to it, but more echogenic than the anechoic vessels. Lt BCV = left brachiocephalic vein; Lt CCA = left common carotid artery.

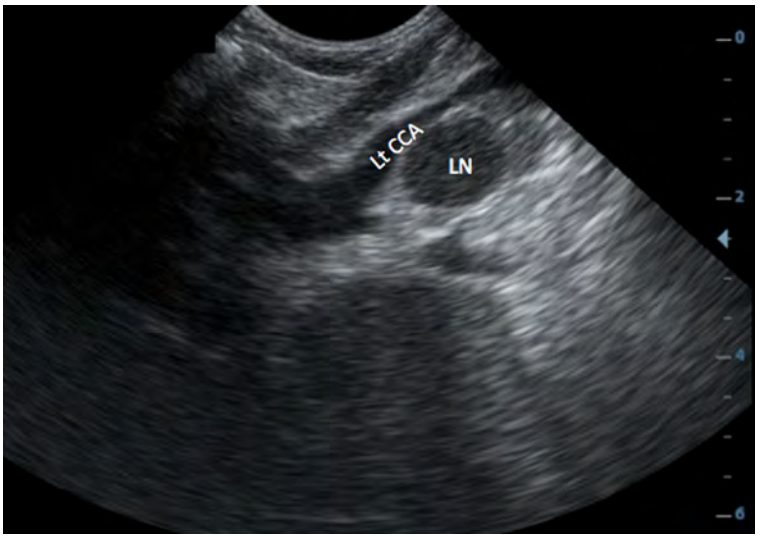

Figure 7: Sagittal oblique view
Sagittal oblique view demonstrates an oval hypoechoic lymph node (LN) in zone E, compressing the left common carotid artery (Lt CCA). The lymph node is more echogenic than the surrounding curvi-linear vessels.

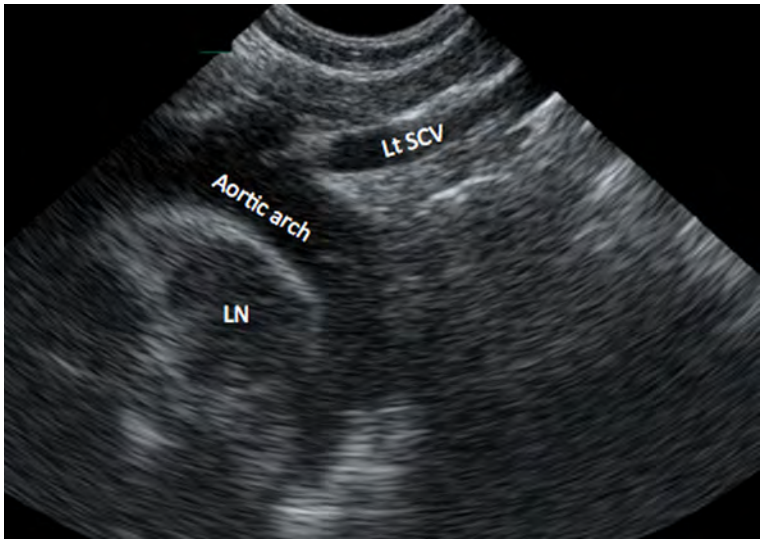

Figure 8: Sagittal oblique view
Sagittal oblique view demonstrates the aortic arch, which is anechoic compared to the oval lymph node (LN) in zone F (the aorto-pulmonary window).
Lt SCV = left subclavian artery.

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25. Paediatric urinary system

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The urinary tract comprises the urinary bladder, ureters and the kidneys. It has a complex embryology leading to many congenital anomalies. It is also commonly affected by acquired conditions such as infection, trauma and malignancy.

Ultrasound is the principal imaging modality for the diagnosis, assessment and follow up of most urinary tract conditions. It is a rapid, efficient, can be taken to the patient, and does not utilise ionising radiation making it ideal for children, particularly when repeated examinations are required.

A structured approach to performing ultrasound of the urinary tract will maximise the information obtained from each examination and will make comparison with earlier and follow up studies much easier.

Urinary tract conditions which can be evaluated with ultrasound include: urinary tract sepsis, trauma, masses, stone disease, congenital malformations and renal failure (acute or chronic).

Ultrasound of the abdomen performed for other reasons, e.g. pain or vomiting, may also lead to the detection of abnormalities of the urinary system.

25.1 Scanning technique – paediatric urinary system

Transducer

Select the transducer according to age and size of the patient.

In a neonate or infant a 8-5 MHz curved array abdominal transducer such as the C11x which is compatible with the MSF standard M-Turbo, would be suitable.

In older children the C60X 5-2 MHz, curved array abdominal transducer is preferred.

The HFL38x, 13-6 MHz linear array vascular transducer will have a large enough footprint to be used in small infants and neonates, and can also be used to obtain supplemental views in older children.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

The patient's position should be supine. Some infants will have to be scanned in the arms of parents or lying beside or on top of them to gain adequate cooperation.

In toilet trained children the urinary bladder should be full at the start of the examination. This enables the assessment of bladder wall thickness, detection of dilated ureters behind the bladder, identification of intraluminal abnormalities (e.g. ureterocoele, stones, debris, masses), bladder emptying and its effect on any renal collecting system dilatation.

If the bladder is only partially full or even empty, e.g. in babies and those who are not toilet trained, consider repeating the scan after an interval to fully evaluate the bladder.

Scanning steps and technique – bladder and ureters

1. Starting in the suprapubic area, scan the urinary bladder first, especially in babies and children who are not toilet trained. If you do not, then it may have emptied by the time you have finished looking at the kidneys. If it is not full you can always come back to it later.
2. Assess the bladder lumen for masses with the transducer in both transverse and longitudinal planes, scanning side to side and up and down. If a 'mass' is seen, continue scanning whilst patient is rolled from one side to the other to see if it is fixed, e.g. tumour, or mobile, e.g. blood clot or calculus.
3. Look for ureteric dilatation posterior to bladder. It is normal to see minor transient dilation <5 mm. If you are not sure whether what you are seeing is a ureter or vessel colour Doppler can be useful.
4. Try to confirm the ureters in two planes: longitudinal and transverse. If it is found to be dilated follow the ureter proximally toward the kidney after fully evaluating the bladder.
5. At the end of the examination (after the evaluation of kidneys), toilet trained children should be asked to empty their bladder. An assessment of any post-void residual should be made: either measured with scanner software or visually, e.g. none, small, moderate, large. Measurements are preferred.
6. In addition, any change in the appearance of the ureters / renal collecting systems should also be assessed following bladder emptying. Mild degrees of renal pelvic and calyceal dilatation can be caused by a very full bladder and often resolve when the bladder is empty.

Scanning notes for bladder and ureters

– Adjust gain controls, depth and focus to obtain an optimal image. Use the automatic gain controls on the keypad.
– Assess bladder wall thickness only if the bladder is well filled. The normal thickness is <3 mm. The lateral wall should be measured on an axial view to avoid an exaggerated measurement of the posterior wall due to increased transmission through the urine and to avoid measuring the muscular trigone on the sagittal view. Wall thickening may be caused by outflow obstruction, e.g. in posterior urethral valves, neuropathic causes, infection and by some drugs.

Scanning steps and technique – kidneys

1. The kidneys can be imaged from anterior, lateral (coronal) and posterior approaches. Generally a coronal approach is adequate in neonates, infants and small children, and in patients who cannot be turned prone. Such views have the benefit of allowing comparison of renal cortical echogenicity with that of the liver and spleen.
   In older children coronal views should be supplemented by imaging with the patient prone as the kidneys are generally better seen using a posterior approach. A plan of approach can also be made if intervention such as nephrostomy or biopsy is being considered.
2. Assess contour of the kidney; it should be smooth although in infancy foetal lobulation may be prominent.
3. Longitudinal and transverse views of the kidney should be obtained. Scan each kidney from side to side longitudinally and from upper to lower pole transversely.
4. Ensure there are two kidneys present and that both are correctly located in the upper retroperitoneum.

5. Check the peri-renal tissues; particularly if there is a history of trauma or infection. Look for subcapsular or peri-renal fluid and collections.
6. If assessed, the renal pelvic diameter should be measured on transverse images. The anterior posterior (AP) diameter of the renal pelvis on transverse images should be measured if >5 mm. It should be measured at the renal hilum (Chapter 23.3).
   If there is also a prominent dilated extrarenal pelvis the transverse diameter of this should also be measured in the transverse plane. Dilatation of the renal collecting system has a number of causes including obstruction and vesico-ureteric reflux. The anatomic location may help with diagnosis and serial measurements can be useful in monitoring progress.
7. Check renal parenchymal echogenicity (compare to liver / spleen) and assess corticomedullary differentiation. Renal echogenicity is slightly less than that of the liver and spleen in older children. Renal medullary echogenicity is less than that of the renal cortex, i.e. the medullary pyramids are hypoechoic with respect to the cortex. This difference is often very prominent in infants and young children, and may initially look like calyceal dilatation. It becomes less obvious with age. Renal echogenicity greater than the liver generally indicates diffuse parenchymal disease, except in neonates and young infants where it is normal.
8. Look for collecting system dilatation involving the renal pelvis and calyces. To ensure that you are detecting dilated calyces rather than prominent medullary pyramids make sure that the calyces communicate with each other during scanning.
9. Assess if renal collecting system is simplex or duplex. This may be easier if only one moiety, i.e. part, is dilated; often the upper pole.
   The majority of ureterocoeles, i.e. congenital dilatation of the distal portion of the ureter, are associated with renal collecting system duplication (see Chapter 23.2).
10. If Doppler is available then make a global assessment of renal vascularity, particularly in acute presentations. Check that the renal artery and vein are patent, but there is no need to calculate indices of flow (such as resistive index) unless patient is hypertensive.

Scanning notes for kidneys

1. Anomalies such as a horseshoe kidney are often only detected using the axial imaging plane scanning anteriorly. In a horseshoe kidney the most inferior part of the kidney continues across the midline to fuse with the inferior pole of the contralateral kidney. This may be overlooked when only scanning coronal or with the patient prone. See 25.3.3 Congenital Anomalies for more information.
2. Large masses should be obvious but smaller masses can be subtle. Look for a focal contour bulge, displacement of calyces, and displacement of vessels with colour Doppler.
3. Small renal cysts can be difficult to see without a high resolution transducer, but if identified should be documented and measured. If bilateral or multiple, then the liver, pancreas and spleen should be evaluated to look for any cysts in these organs - considering various polycystic renal conditions.
4. Adjust gain and time gain controls to get an optimal image. Use any automatic gain controls that are present for same reason.
5. Adjust gain controls, depth and focus to obtain an optimal image. Use the automatic gain controls on the keypad.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

25.2 Bladder and ureters

25.2.1 Normal bladder in paediatrics

The normal paediatric bladder is located in the pelvis but when distended can extend superiorly into the abdomen. Its wall should be well defined and smooth and the mucosa and muscle can usually be resolved. Bladder wall thickness should only be measured when the bladder is full. The bladder wall will look thickened when the bladder is not full. The contained urine should be anechoic, i.e. black, and clear (Figure 1 and Figure 2).

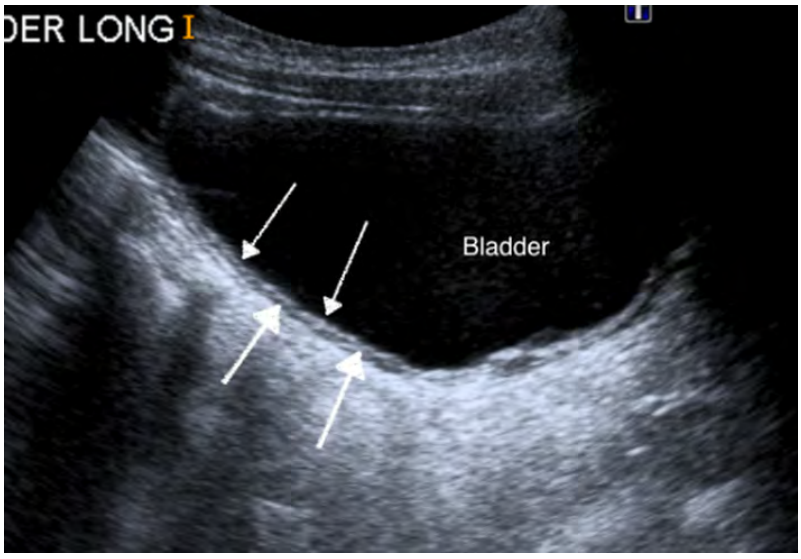

Figure 1: Normal paediatric urinary bladder - longitudinal view
The bladder is well filled. The inner echogenic mucosa (thin arrows) and the outer hypoechoic muscle (thick arrows) can be differentiated.
The wall is smooth with no evidence of trabeculation. If the bladder is well filled, wall thickness should not exceed 3mm.

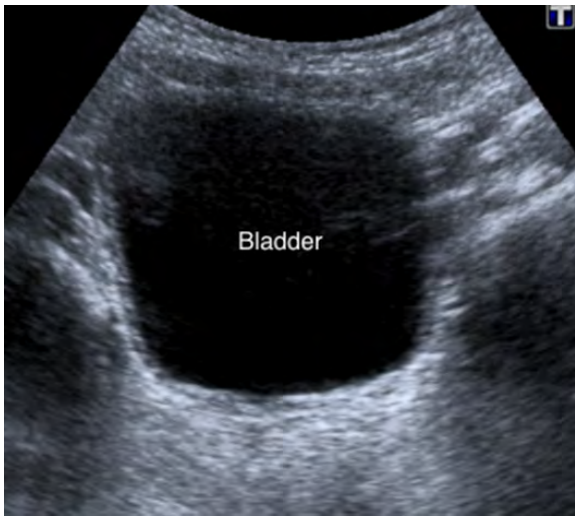

Figure 2: Normal bladder - transverse view
The bladder is well filled. The inner (echogenic) mucosa and the outer (hypoechoic) muscle can again be differentiated. The wall is smooth with no evidence of trabeculation.
If the bladder is well filled, wall thickness should not exceed 3 mm.

25.2.2 Bladder abnormalities

The lumen of the bladder should contain urine which is anechoic, i.e. black. Urinary debris, i.e. fine mobile echogenic particles, is a non-specific finding. Debris may be seen with urinary stasis, e.g. caused by incomplete emptying. Infection may lead to prominent intraluminal debris (Figure 3), which is sonographically indistinguishable from unclotted blood. Blood clot will appear echogenic and may be clumped, though is usually mobile (Figure 4). Dilatation of the distal ureters is best identified using the full bladder as an acoustic window (Figure 5 and Figure 6). The ureters may be seen to peristalse during the examination and may occasionally contain debris or a calculus.

Focal intravesical lesions should be assessed for mobility, size, location and any relationship to the ureterovescical junction. These may all help narrow the differential diagnosis. Causes of intravesical 'masses' include: debris (e.g. infection, stasis, blood, blood clots), calculus, ureterocoele (Figure 7 and Figure 8). Ureterocoeles are almost invariably closely associated with ureteric dilatation. Tumour (e.g. rhabdomyosarcoma) is suggested by a mass that does not move when the patient is turned from side to side and which may contain internal vascularity on colour Doppler (Figure 9).

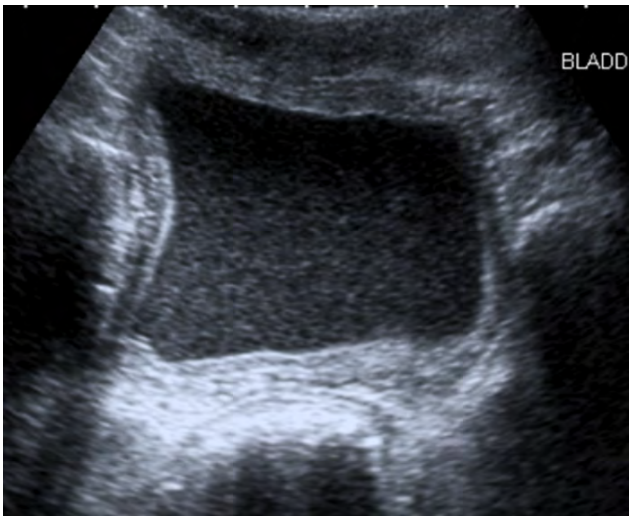

Figure 3: Pyonephrosis, urinary debris - transverse view
There are fine particulate echoes within the bladder lumen, which moved with patient movement and tended to settle posteriorly. This infant had a urinary tract infection and the appearances were felt to represent pus. Similar appearances may be seen when there is urinary stasis e.g. from poor bladder emptying with residual urine, and from haemorrhage (haematuria).

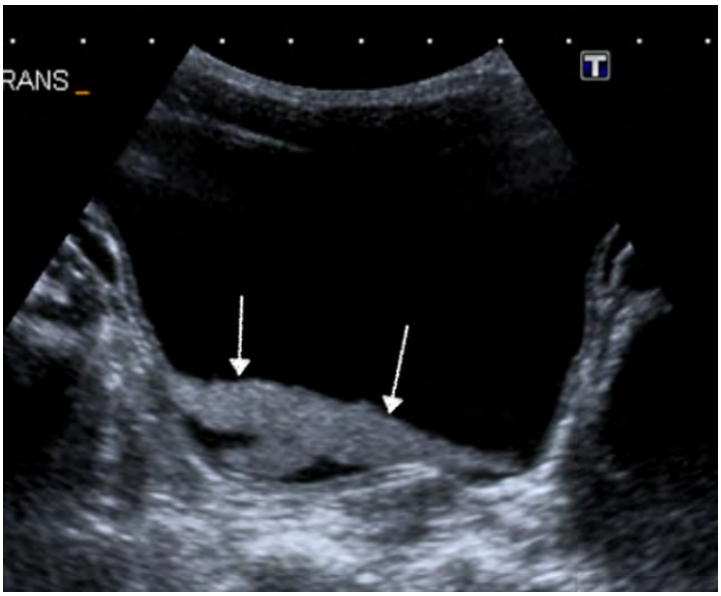

Figure 4: Intravesical blood clot - transverse view
There is a relatively well defined echogenic filling defect lying posteriorly within the bladder (arrows). It moved with patient movement but remained intact (as opposed to particulate debris). The patient had marked haematuria due to a fractured kidney following blunt abdominal trauma.

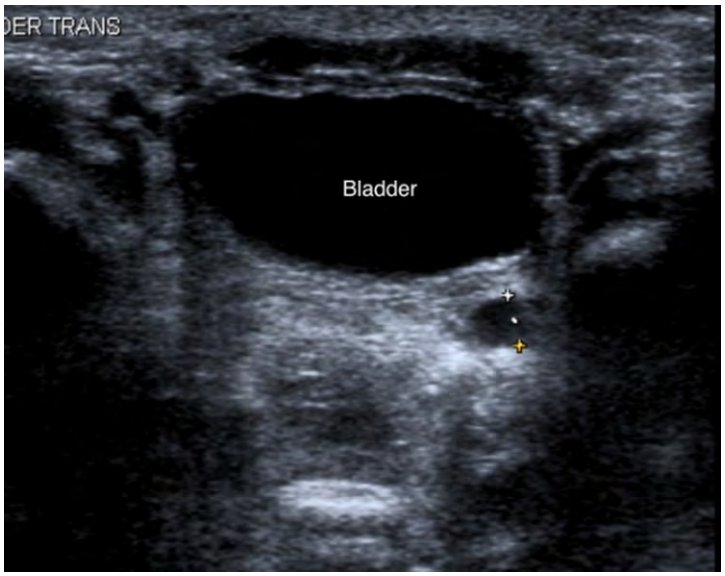

Figure 5: Mild dilatation of distal ureter posterior to the bladder - transverse view
The urinary bladder is normal. The round anechoic structure posterior to the bladder on the left is a dilated left distal ureter. Dilated ureters are more easily seen on transverse images and their diameter should be measure on this view in their longest diameter as shown (between cursors). Transient minor dilatation of the distal ureter (<5 mm) is relatively common and not specific for vesico-ureteric reflux.

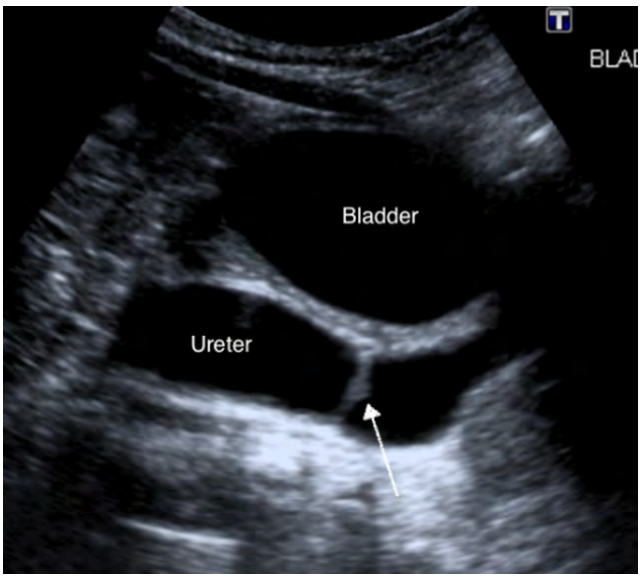

Figure 6: Mild dilatation of distal ureter - longitudinal view
A markedly dilated distal ureter is seen posterior to the bladder on this longitudinal view. There is a mild kink in the distal ureter giving rise to the echogenic band partly crossing its lumen (arrow).

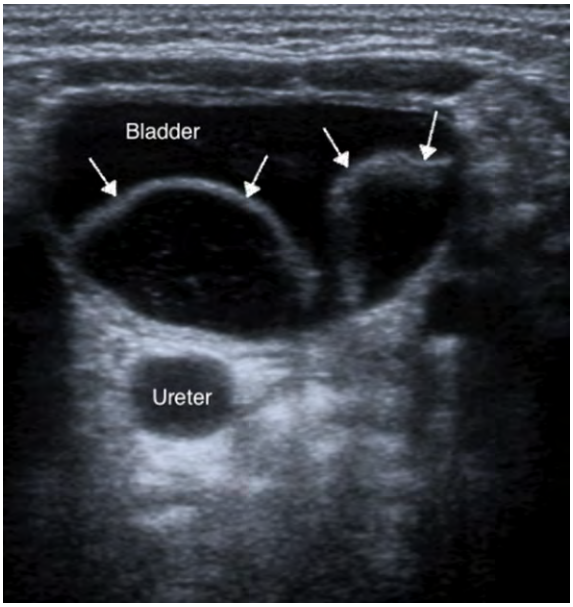

Figure 7: Bilateral ureterocoeles and dilated ureter - transverse view
There are two thin-walled cystic intraluminal filling defects (thin arrows) within the bladder representing bilateral ureterocoeles. The one on the right is slightly larger than the left. There is prominent dilatation of the right distal ureter posterior to the bladder.

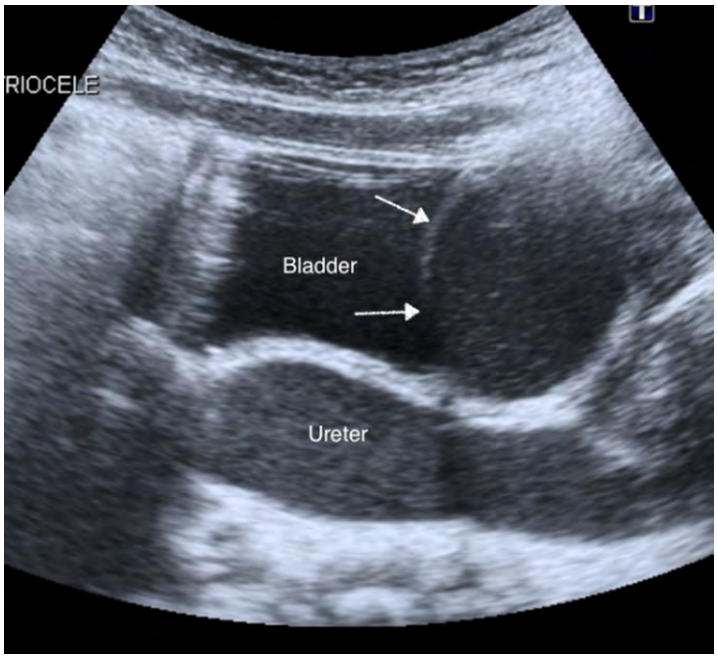

Figure 8: Ureterocoele with debris and dilated ureter - longitudinal view
This longitudinal image shows a large ureterocoele at the base of the bladder (arrows). It is thin walled and cystic. There is dilatation of the distal ureter posterior to the bladder. The distal ureter and the ureterocoele contain fine (mobile) echoes representing debris (pus) in this patient with a urinary tract infection.

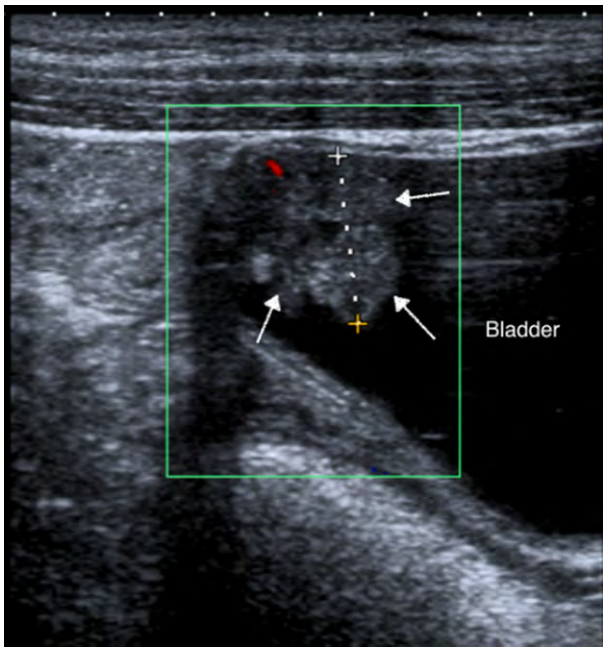

Figure 9: Intraluminal bladder tumour (rhabdomyosarcoma) - transverse view
There is a lobular and rather echogenic filling defect arising from the dome the bladder (arrows) and extending into the lumen. It did not move with change in patient position and colour Doppler showed some internal vascularity.

25.3 Kidneys

25.3.1 Normal kidneys in paediatrics

Renal size depends on the age of the child, and also on other factors such as height and weight. There are charts showing mean and standard deviations for renal lengths related to age (and height and weight). As a general rule the kidneys of a new-born term infant should be approximately 4.5 cm in length (Figure 10). Renal length increases steadily throughout childhood to an average adult size of 11-12 cm in the mid-teenage years (Figure 11-14). For more information please see suggested readings 'Normal Liver, Spleen, and Kidney Dimensions in Neonates, Infants, and Children: Evaluation with Sonography'.

The kidney also changes appearance slightly with growth:
- There is gradual deposition of fat around the renal pelvis leading to increased renal hilar echogenicity.
- Foetal lobulation will tend to resolve with age.
- Cortical echogenicity and corticomedullary differentiation become less prominent with age.

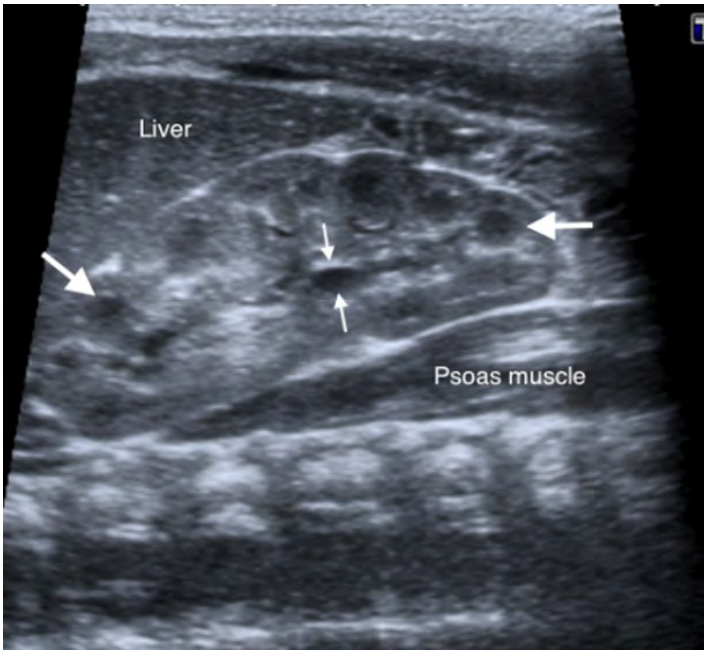

Figure 10: Normal neonatal kidney - longitudinal view
The kidney has a slightly lobular contour representing residual foetal lobulation. There is very slight separation of the renal sinus echoes centrally (thin arrows) though dilatation should only be measured on a transverse image. Cortical parenchymal echogenicity is similar to that of the adjacent liver (normal in the neonatal period). The renal pyramids (medulla) are clearly visible and are of reduced echogenicity compared to the cortex (thick arrows). There is no significant renal sinus fat. The size of a term infant's kidney is about 4.5 cm in length.

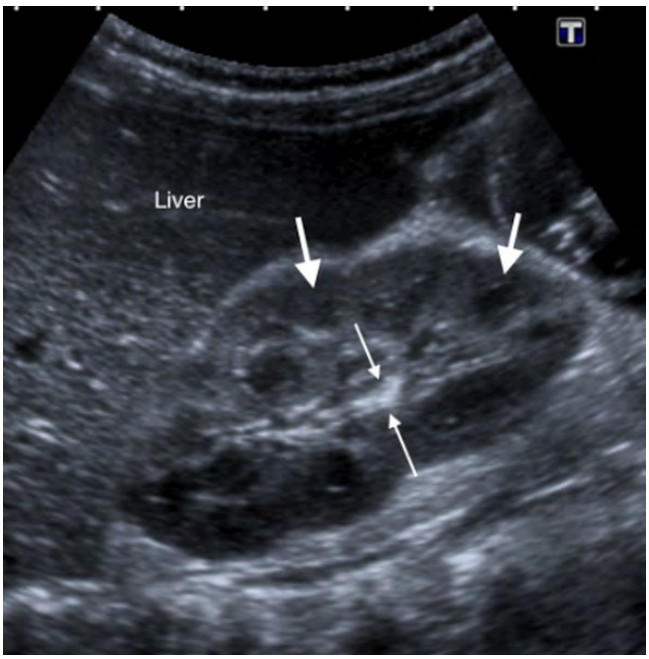

Figure 11: Normal infant kidney - longitudinal view
Corticomedullary differentiation is visible with low echogenicity, (dark) pyramids which is normal (thick arrows). There is no collecting system dilatation. There is still some lobularity of the renal contour and there are increased (bright) renal sinus echoes in keeping with some renal sinus fat (thin arrows), which become more echogenic with age.

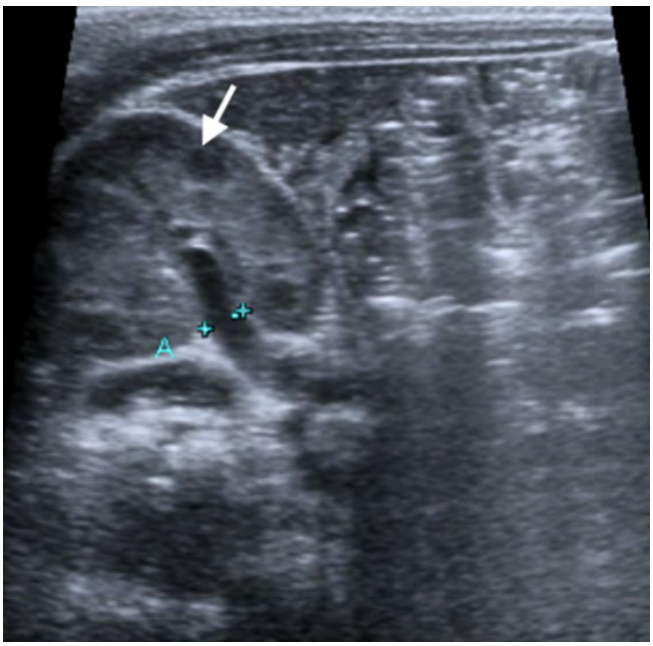

Figure 12: Normal neonatal kidney - transverse view
The lobular contour of the kidney is less apparent than on the longitudinal view. Corticomedullary differentiation is present with the renal pyramids of lower echogenicity compared to cortex (arrow). There is minor separation of the intrarenal sinus echoes indicating mild prominence of the intrarenal pelvis.
This is considered normal if less than 5 mm renal pelvic dilatation is measured at the renal hilum as shown between the cursors (+).

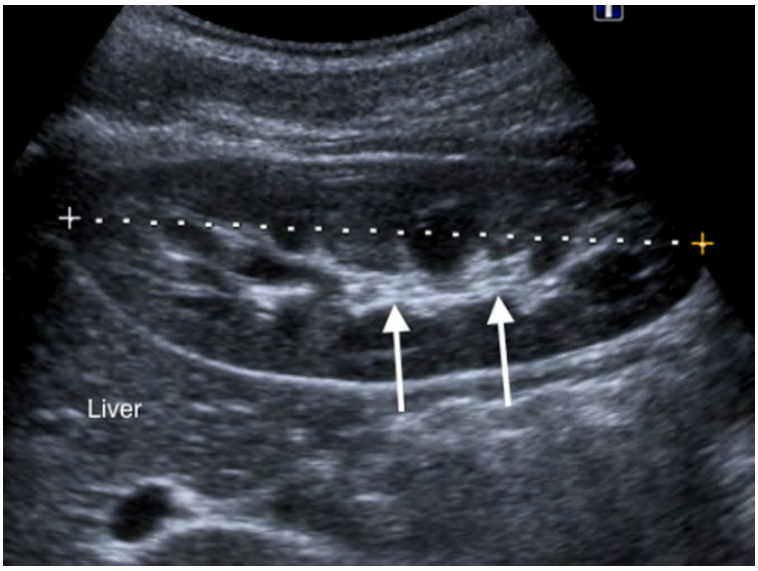

Figure 13: Normal kidney in 13 year old child - prone longitudinal view
Corticomedullary differentiation is present but less clearly seen than in infants and neonates. Renal parenchymal echogenicity is less than that of the adjacent liver. There is prominent echogenic renal sinus fat which develops throughout childhood (thick arrows). There is no collecting system dilatation. The renal length has been measured from upper to lower pole (dotted line between cursors). Foetal lobulation has resolved.

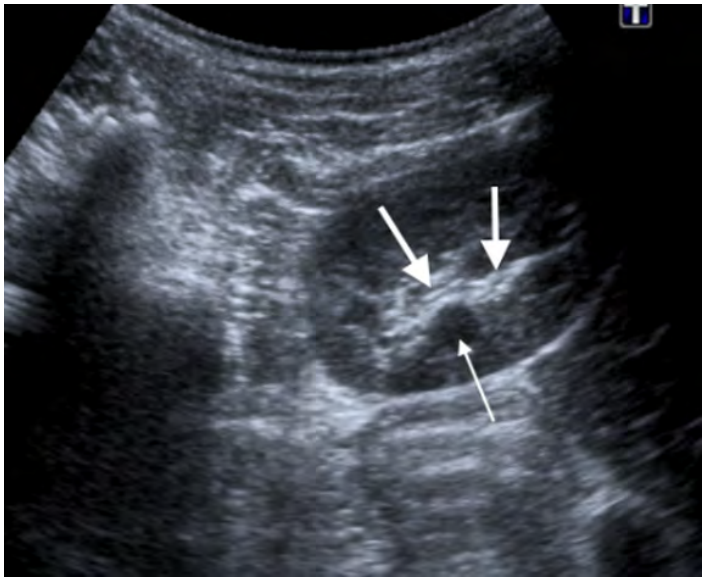

Figure 14: Normal kidney in 13 year old child - prone transverse view
Corticomedullary differentiation is visible (renal pyramid thin arrow) and there is prominent renal sinus fat with bright echoes centrally (thick arrows). There is no collecting system dilatation.

25.3.2 Kidney size

Kidney length can be compared to standards for age, weight, height etc. and to the contralateral kidney. Growth can be assessed on serial examinations.

Large kidneys

Causes of unilateral kidney enlargement include: pyelonephritis, renal vein thrombosis, acute ischaemia (e.g. trauma), mass or infiltration (e.g. leukaemia, lymphoma, nephroblastomatosis).
Causes of bilateral kidney enlargement include: acute glomerulonephritis, nephritis, mass or infiltration (e.g. leukaemia, lymphoma, nephroblastomatosis), sickle cell disease (acutely).

Small (atrophic) kidneys

Small kidneys may be congenital (hypoplasia) or be secondary to trauma, vascular insults, infection or obstruction (Figure 15).

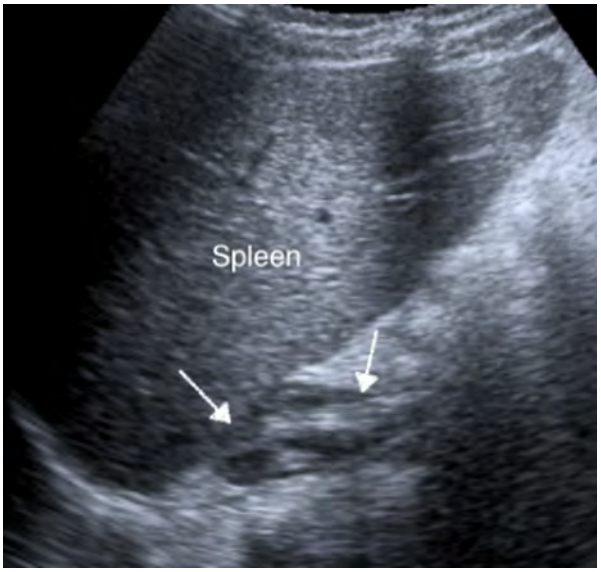

Figure 15: Small kidney (atrophy) secondary to previous obstruction
There is a small but otherwise normal appearing kidney (arrows) adjacent to the spleen. Parenchymal thickness is globally reduced.

25.3.3 Congenital anomalies: duplex, ectopic, horseshoe Kidney

A kidney with a duplex collecting system is not uncommon. It may be uncomplicated with no dilatation of the pelvis or calyces of its moieties. It may be recognised by identifying a gap between the renal sinus echoes of the upper pole pelvis and those of the lower pole. This is more obvious in older children who have more renal sinus fat. Often the upper pole is dilated and the overlying renal parenchyma is thinned or dysplastic (Figure 16). The upper pole moiety of a duplex renal collecting system is associated with an ectopic insertion of its ureter – more medial and distal to the normal ureteric insertion on the affected side. The ectopic ureter is often associated with an ureterocoele, or its insertion into urethra and seminal vesicles (boys) or vagina in girls.

If only one kidney is found the other may be absent, hypoplastic, dysplastic, ectopic or correctly located and possibly obscured by bowel gas. If only one kidney is suspected it's important to search for an ectopic kidney in the lower abdomen, pelvis, ideally with a full bladder, (Figure 17) and on the contralateral side where it may be in contact with or fused to the other kidney. Check that the kidney has not been surgically removed.

A horseshoe kidney is caused by the fusion of the inferior poles of the left and right kidneys during development. The isthmus across the midline may contain functioning renal tissue or there may be a fibrous connection. The presence of the fusion prevents the kidneys from rotating and ascending normally. As such their inferior poles are more anteriorly and medially positioned. Whilst many children with horseshoe kidneys are asymptomatic, because the renal pelvis are also more anterior, they have a greater risk of becoming obstructed. In addition a horseshoe kidney may make operating on the kidney or surrounding structures more hazardous if it is not recognised in advance. It is also more susceptible to trauma given its anterior location.

A clue to the presence of a horseshoe kidney is a slightly unusual longitudinal axis of the kidneys and difficulty in clearly identifying the lower poles. In this situation scan transversely in the anterior abdomen to look for a connecting isthmus (Figure 18). Horseshoe kidneys are very easy to overlook unless a conscious search is made for it. This includes looking carefully at the lower poles of the kidneys and checking that they are separate. Overlying bowel gas may obscure the isthmus of a horseshoe kidney leading to it being missed.

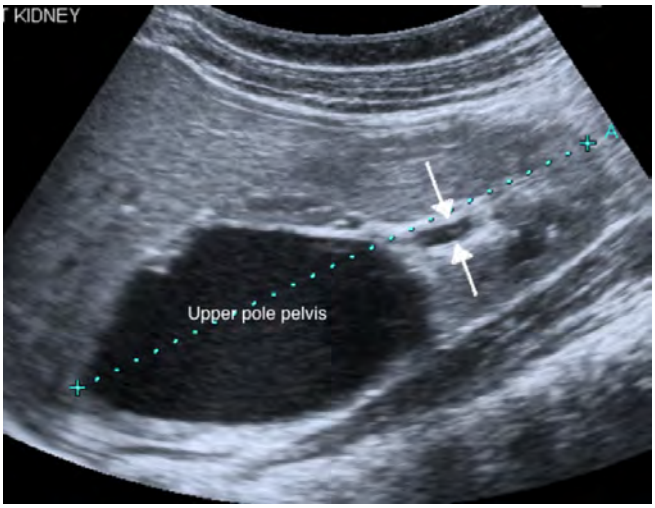

Figure 16: Duplex kidney with dilatation of upper moiety collecting system - longitudinal view
There is marked dilatation of the upper pole moiety collecting system in this kidney. The parenchyma over the upper pole is markedly reduced in thickness. The lower pole moiety collecting system is minimally prominent seen between the renal sinus echoes (arrows). Differential diagnosis is a large cyst, so the diagnosis of duplex requires a search for a dilated associated upper pole moiety ureter, ureterocoele and / or a ureter extending below the bladder base.

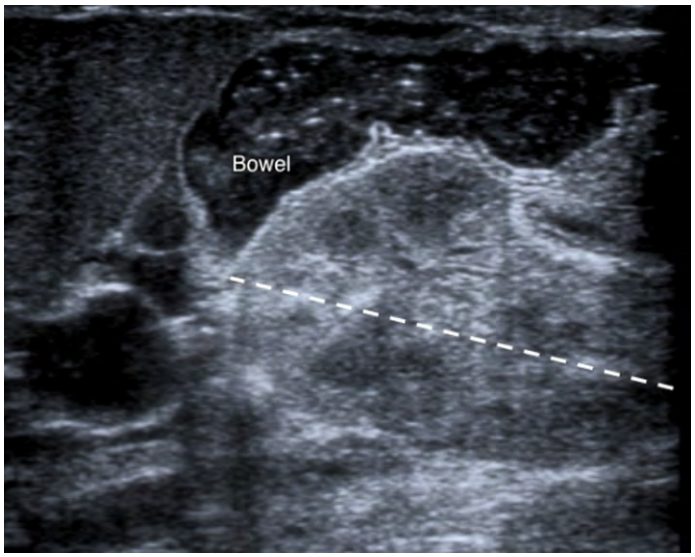

Figure 17: Pelvic kidney - transverse view
There is a kidney visible deep to loops of bowel in the pelvis in this child (dashed line). The kidney is structurally normal with no collecting system dilatation and corticomedullary differentiation. Renal ectopia should be considered if a kidney cannot be identified in its normal position and a thorough search of the rest of the abdomen should be undertaken.

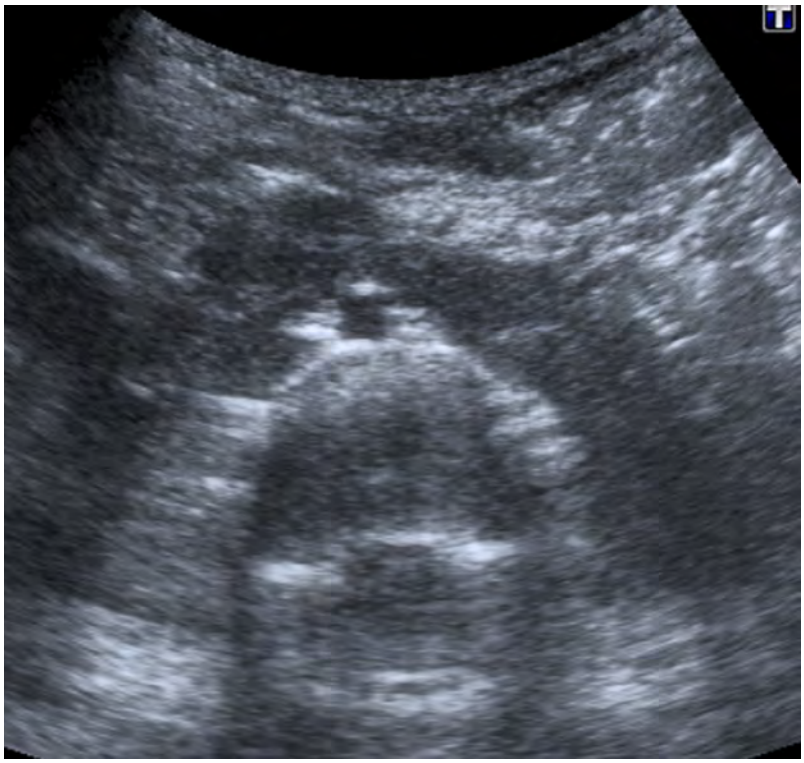

Figure 18: Horshoe kidney
Transverse anterior image of the mid abdomen showing the fused inferior poles (isthmus) of an horseshoe kidney (short thick arrows). This lies anterior to the aorta (arrow heads) and the vertebral body (thin arrows).

25.3.4 Renal contour and parenchymal echogenicity

It is normal for the renal cortex in neonates and infants to be as bright as or brighter than the liver or spleen. There is very little echogenic renal sinus fat in infants compared to older children and adults. The renal pyramids, i.e. medulla, can look very hypoechoic in neonates and some infants and may initially be confused with dilated calyces. If not sure remember that calyces should communicate with the renal pelvis.

In the first few days of life the renal pyramids may be paradoxically bright and mimic nephrocalcinosis, also known as Tamm-Horsfall proteinuria (Figure 19). This quickly resolves once urine flow is established.

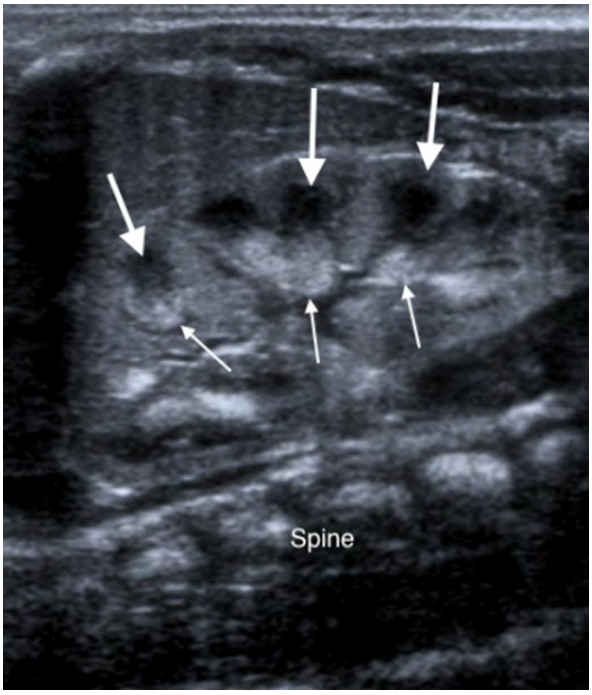

Figure 19: Neonatal kidney with tamm-horsfall proteinuria - longitudinal view
There is increased echogenicity of the tips (central parts) of the medullary pyramids due to intratubular protein deposition (thin arrows). This resolves with no sequela as postnatal urine flow becomes established. The more peripheral parts of the renal pyramids remain of low echogenicity (thick arrows).

The contour of the kidney should be smooth, though in infancy foetal lobulation of the renal contour is normal and can be prominent - and make one think of scarring. If present, foetal lobulation it should be bilateral. The lobular bulges overlie the calyces and medullary pyramids, unlike scarring where the parenchymal loss overlies the calyces and medullary pyramids. A focal contour defect overlying a calyx, particularly if the calyx is mildly dilated, is suspicious for a parenchymal defect or scar.

Causes of general increased parenchymal echogenicity include: glomerulonephritis, nephritis, pyelonephritis, haemolytic uraemic syndrome and Henoch-Schonlein purpura.

Increased echogenicity of the renal pyramids, i.e. nephrocalcinosis include: renal tubular disorders, medullary sponge kidney, metabolic conditions such as hyperparathyroidism, sickle cell disease, certain drugs, e.g. diuretics in patients with cardiac disease (Figure 20).

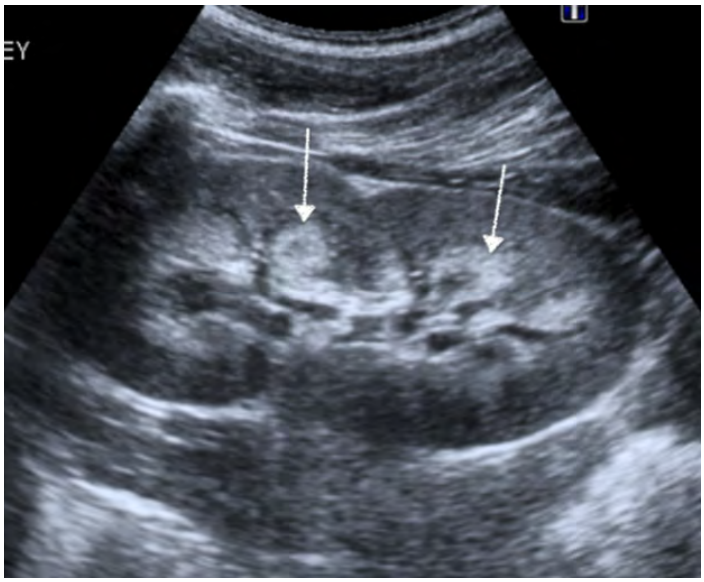

Figure 20: Echogenic renal pyramids (nephrocalcinosis)
The renal pyramids (normally hypoechoic with respect to the cortex) are much brighter than the renal cortex - nephrocalcinosis (arrows). There are many causes of this including renal tubular acidosis, drugs (particularly long term diuretics), hyperparathyroidism / hypercalciuria and medullary sponge kidney. There is a spectrum of appearances from mild to severe. Initial involvement begins in the tips of the medullary pyramids and it extends peripherally as severity worsens.

25.3.5 Collecting system, renal pelvis dilatation, hydronephrosis

In children a dilated renal collecting system does not automatically equate to 'obstruction'. Whilst obstruction must be considered, vesicoureteric reflux is a cause, and some neonates and infants will have dilatation with no evidence of obstruction or reflux.

A dilated collecting system should contain anechoic, i.e. black, fluid: urine. Normal images earlier (Figure 10, Figure 11 and Figure 12) can be compared to moderate hydropnephrosis (Figure 21 and Figure 22) and marked hydronephrosis (Figure 23 and Figure 24).

It is important to try to identify the extent and level of the dilatation: does it involve only the intrarenal collecting system, is there a dilated extrarenal pelvis and is there any evidence of associated ureteric dilatation. One should also look for any lesion that might be causing dilatation such as an ureterocoele, calculus or tumour.

If the collecting system contains echogenic debris then a complication such as an infection, e.g. pyonephrosis, should be considered (Figure 25).

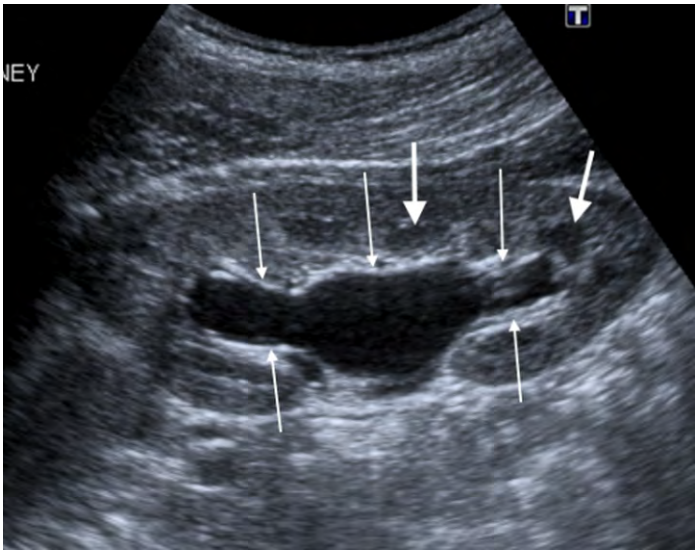

Figure 21: Hydronephrosis - longitudinal view
There is modest dilatation of the renal pelvis centrally separating the normal renal sinus echoes (thin arrows). There is no calyceal dilatation. Corticomedullary differentiation is visible with hypoechoic medullary pyramids (thick arrows). Whilst renal length should be measured on longitudinal images, the degree of renal pelvic dilatation should only be measured on transverse images.

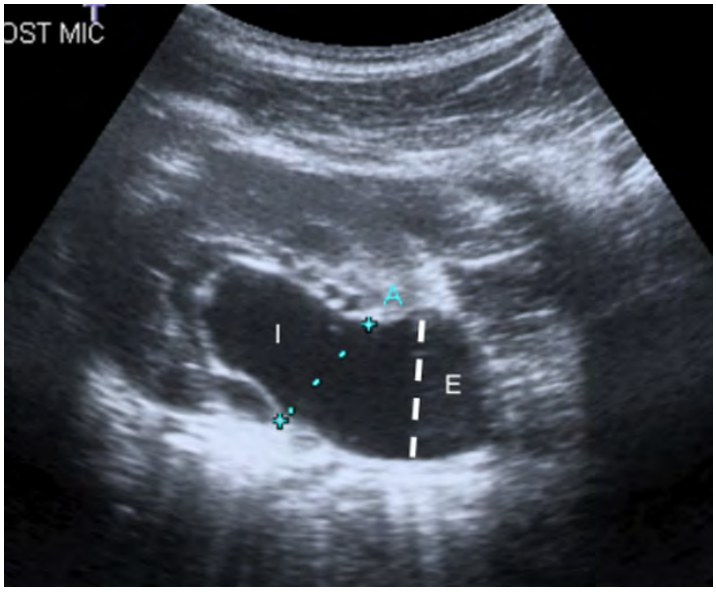

Figure 22: Hydronephrosis - transverse view
There is dilatation of the intrarenal pelvis within the kidney (I) and also of the extrarenal component of the pelvis (E). There is no calyceal dilatation. Measurement of intrarenal pelvic dilatation should be made in the AP plane at the renal hilum as shown. When there is a distended / ballooned extrarenal pelvis a separate diameter can be measured on the transverse view (dashed line).

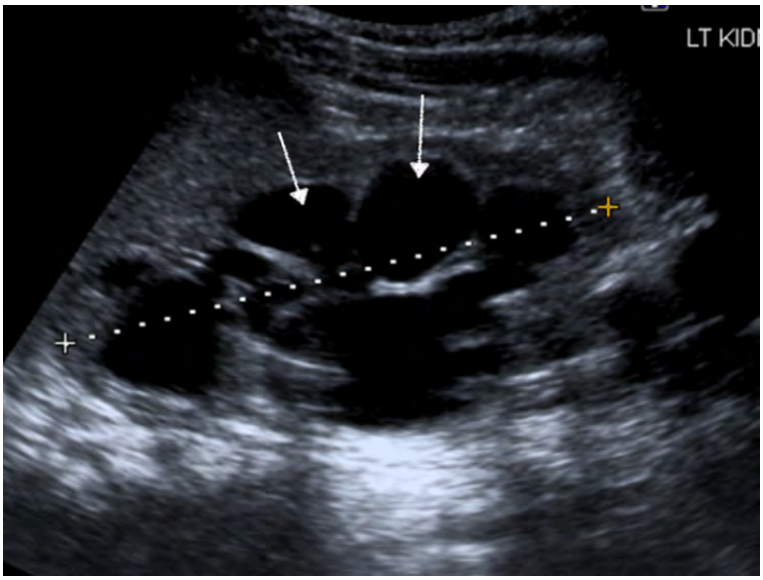

Figure 23: Hydronephrosis - longitudinal view
There is marked dilation of the intrarenal collecting system involving the renal pelvis centrally and many calyces (arrows) peripherally. Calyces are seen to communicate with the renal pelvis, differentiating them from hypoechoic pyramids.

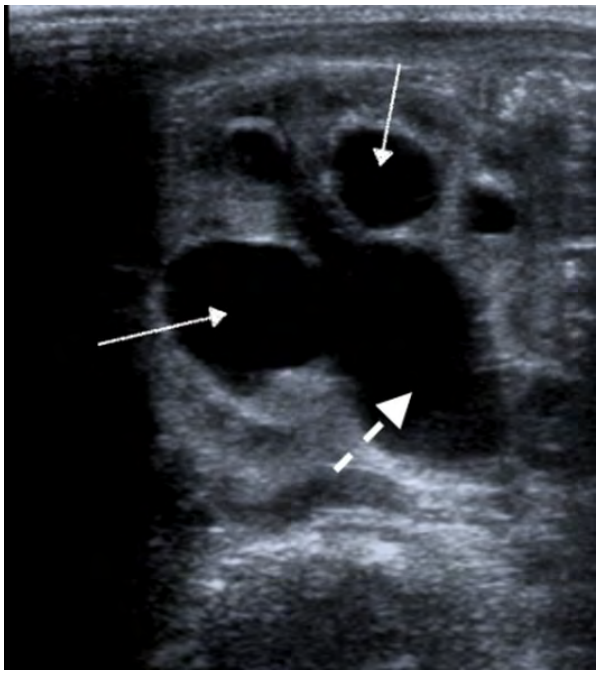

Figure 24: Hydronephrosis - transverse view
There is dilatation of the renal pelvis (broken thick arrow) which communicates with dilated calyces peripherally (thin arrows).

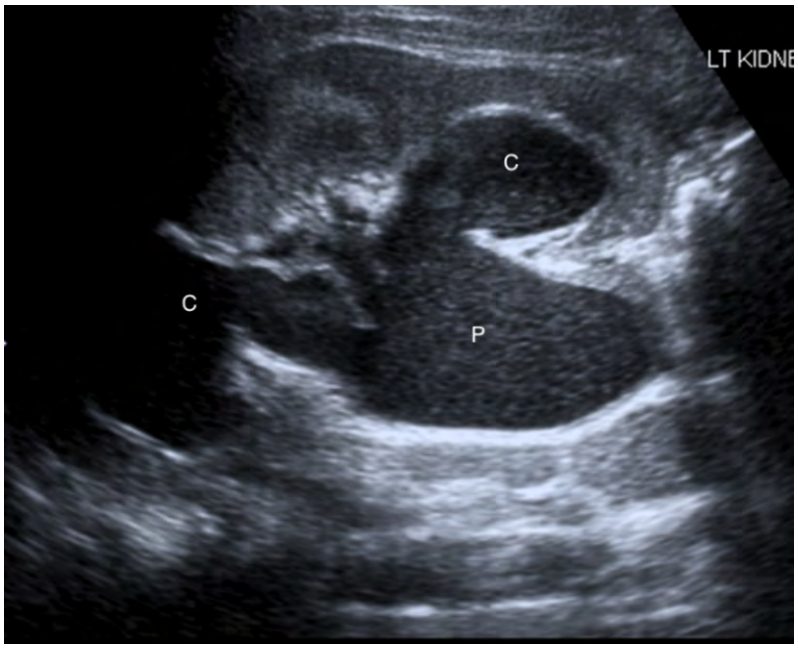

Figure 25: Pyonephrosis - longitudinal view
There is dilatation of the renal collecting system - pelvis (P) and calyces (C).
The contained fluid contains fine mobile echogenic debris in keeping with pus.
This child had an obstructed infected renal collecting system which required drainage with a percutaneous nephrostomy.

25.3.6 Kidney stones / renal calculi

Renal calculi are 'stones' that develop or crystallise from minerals within the urine in the renal collecting systems. They range in size from less than a millimetre to a large 'staghorn' calculus that completely fills a dilated renal pelvis and calyces. They can be associated with pain and infection. The passage of small stones or fragments in the ureters may lead to intense spasmodic loin or flank pain called (ureteric) colic. This may be associated with blood in the urine. Passage of a small calculus in the urine may be noted.

Renal calculi may be caused by underlying metabolic conditions, certain drugs and dehydration. In addition to colic they may cause ureteric obstruction which may be complicated by infection in the obstructed kidney.

Calculi are seen as brightly echogenic foci with posterior acoustic shadowing. They may lie within the renal calyces or within the renal pelvis. Those in the pelvis may cause obstruction and collecting system dilatation (Figure 26). They should be documented and if possible their size should be measured. Ureteric calculi are more difficult to identify, particularly if there is no ureteric dilatation.

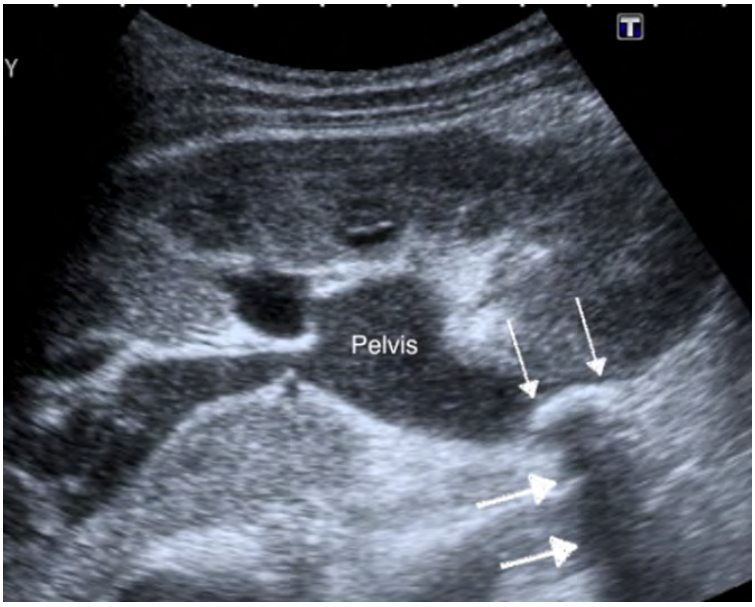

Figure 26: Renal calculus causing obstruction
There is a well-defined convex echogenic entity within the lower part of the renal pelvis at the junction between pelvis and ureter (thin arrows). It cases dense acoustic shadowing (thick arrows) in keeping with calcification. The appearances are consistent with a calculus. There is some dilatation of the intrarenal collecting system dilatation due to obstruction. There is also debris within the renal collecting system - this was an obstructed infected kidney due to the calculus impacted at the pelviureteric junction.

25.3.7 Renal cysts

Renal cysts in children are uncommon. They are occasionally seen as an incidental finding. They should be well defined, thin walled and contain anechoic (black) fluid. There should be no communication with the collecting system. If there is more than one cyst then an underlying condition should be suspected such as autosomal dominant polycystic kidney disease (Figure 26), tuberous sclerosis, von-Hippel Lindau disease. There may be features in the family history or clinical features that help make a diagnosis.

Other lesions in the kidney that might appear cystic include renal abscess, haematoma (post-trauma), an arteriovenous malformation if there has been a previous trauma or renal biopsy (consider Doppler). Renal tumours may contain cystic elements but are usually obvious. A thick wall, internal echoes / debris and vascularity are features that suggest a ‘complicated’ cyst that might require further evaluation,

Cysts in autosomal-recessive polycystic kidney disease are very small. They can be better demonstrated with a high frequency transducer such as the HFL38x, but the multiplicity of interfaces means that the overall echogenicity of the kidney is increased (Figure 27-Figure 29).

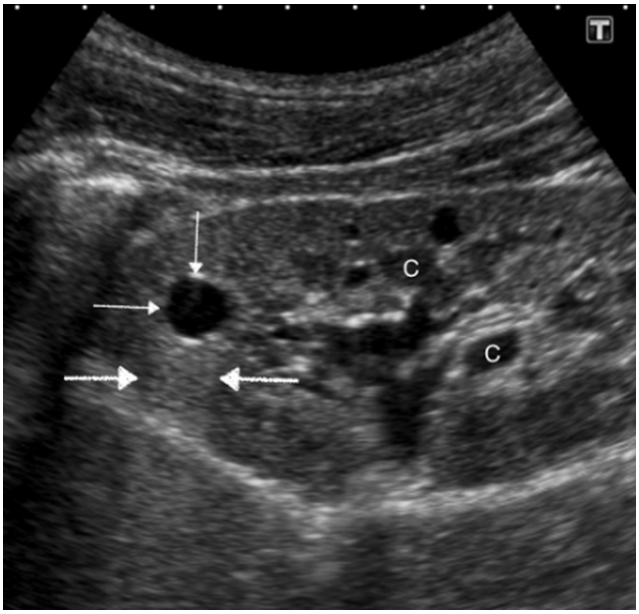

Figure 27: Autosomal dominant polycystic kidney disease
There is a well-defined spherical anechoic cyst in the upper pole of this kidney (thin arrows). It casts posterior acoustic shadowing (thick arrows). A solitary simple cyst would look identical to the upper pole cyst. There are several smaller cysts visible in the mid-pole of the kidney (C) in this patient with autosomal dominant polycystic kidney disease.
Other general conditions in which renal cysts may develop include tuberous sclerosis and von Hippel-Lindau disease.

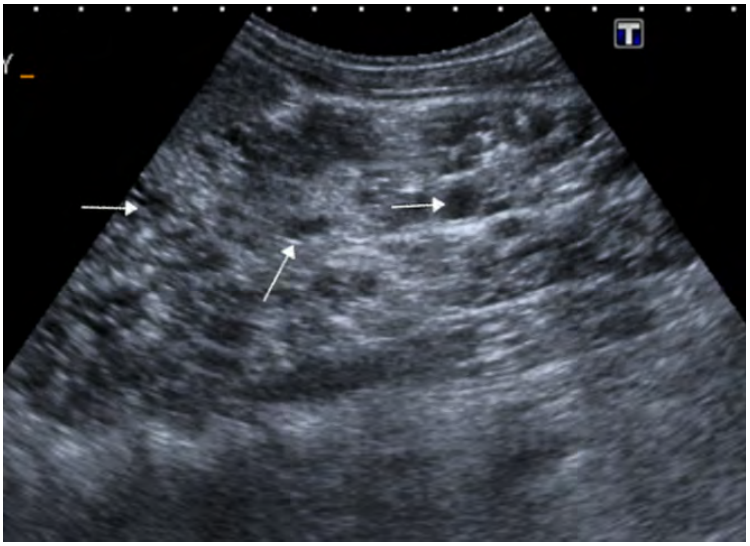

Figure 28: Autosomal recessive polycystic kidney disease
The kidney is enlarged and of generalised increased echogenicity.
Multiple tiny cysts are visible within its parenchyma (arrows).
The kidney is echogenic because of all of the multiple interfaces between the many cysts.

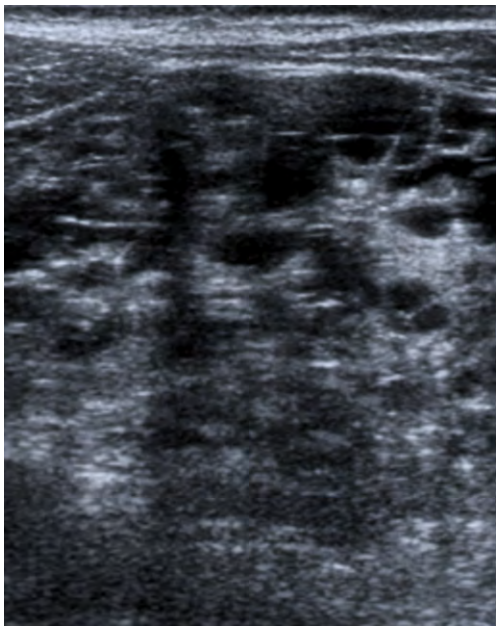

Figure 29: Autosomal recessive polycystic kidney disease in the same patient
Scanning with a high frequency linear array transducer shows more clearly
the multiple tiny cysts and interfaces.

25.3.8 Renal abscess

An intrarenal abscess is uncommon but should be considered if a 'complicated' cyst is demonstrated. The clinical context and laboratory findings are helpful pointers to the diagnosis.

A subcapsular collection or abscess will also look complicated and may contain internal echoes and septate. It will indent the underlying renal parenchyma (Figure 30). A perirenal abscess may spread around the kidney in the perirenal space.

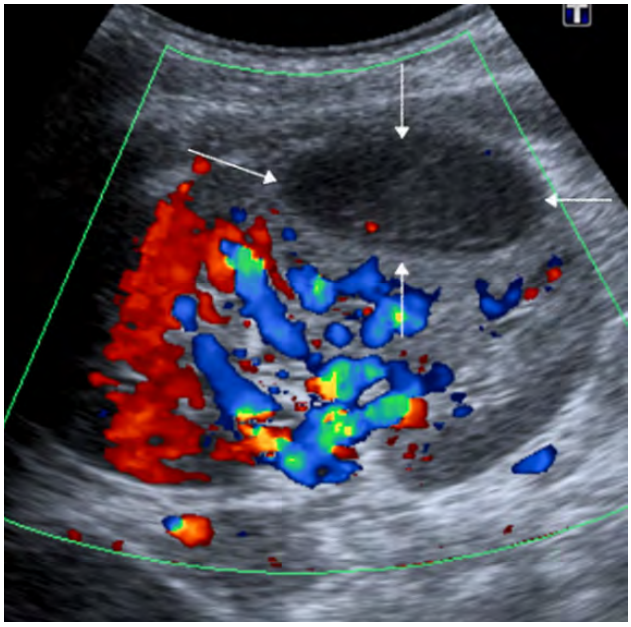

Figure 30: Subcapsular renal abscess - longitudinal view
There is an ovoid hypoechoic entity related to the lateral aspect of the lower pole
of the kidney (arrows). It indents the underlying renal parenchyma and is bounded peripherally
by the renal capsule - it does not extend into the surrounding perirenal soft tissues.
It contains some internal echoes. There is no internal blood flow.
This represented a subcapsular renal abscess which was successfully drained percutaneously.

25.3.9 Renal tumours

Renal tumours are relatively uncommon in children. The most frequent is nephroblastoma (Wilms tumour) with a mean age of presentation of 3 years. Renal tumours under the age of 6 months are very rare, with mesoblastic nephroma the most likely diagnosis. Over the age of 8 years a renal cell carcinoma becomes more likely as a cause for a renal tumour but is also very rare. Other causes of an intrarenal mass or masses include leukaemia and lymphoma.

Nephroblastomatosis is a developmental abnormality of kidneys. Though not malignant itself, it is a recognised risk factor for the development of a nephroblastoma and so is considered a pre-malignant condition. It can present as bilateral renal masses or as diffuse enlargement of the kidneys (Figure 31-Figure 34).

A renal pseudo-masses appear as a tumour, but are actually a benign condition simulating a tumour. Examples include focal pyelonephritis (acute lobar nephronia) (Figure 35) and rarely hypertrophy of 'columns of Bertin', i.e. infolding of renal cortex that can occasionally look very prominent and 'mass-like'. The real diagnosis is often suggested by the clinical presentation and sometimes early repeat ultrasound is useful to ensure resolution.

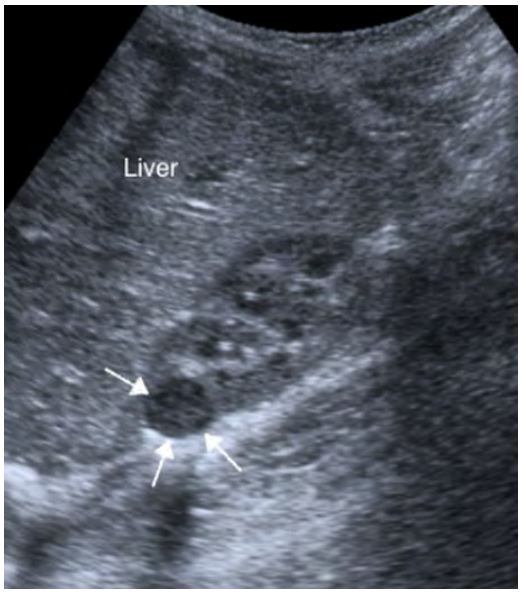

Figure 31: Small renal tumour (nephroblastoma) - longitudinal view
There is a small well-defined hypoechoic mass near the upper pole of the kidney, causing a slight contour bulge (arrows). It is not anechoic like a cyst and there is no posterior acoustic enhancement. It represents a small tumour which turned out to be a nephroblastoma.

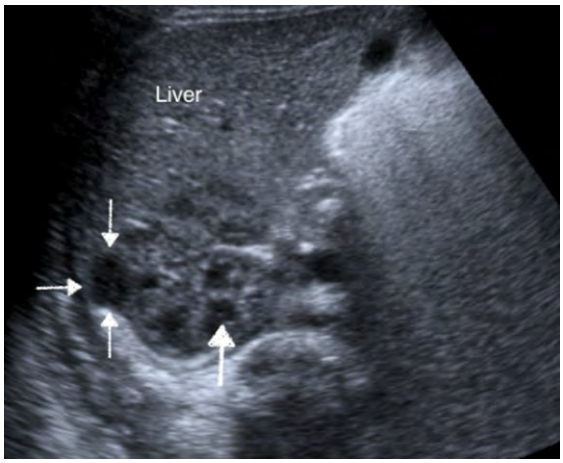

Figure 32: Small renal tumour (nephroblastoma) - transverse view
Transverse image of the same kidney as in Figure 31 showing clearly the contour bulge caused by the peripheral tumour (thin arrows). Corticomedullary differentiation is prominent in this infant with hypoechoic medullary pyramids (thick arrow).

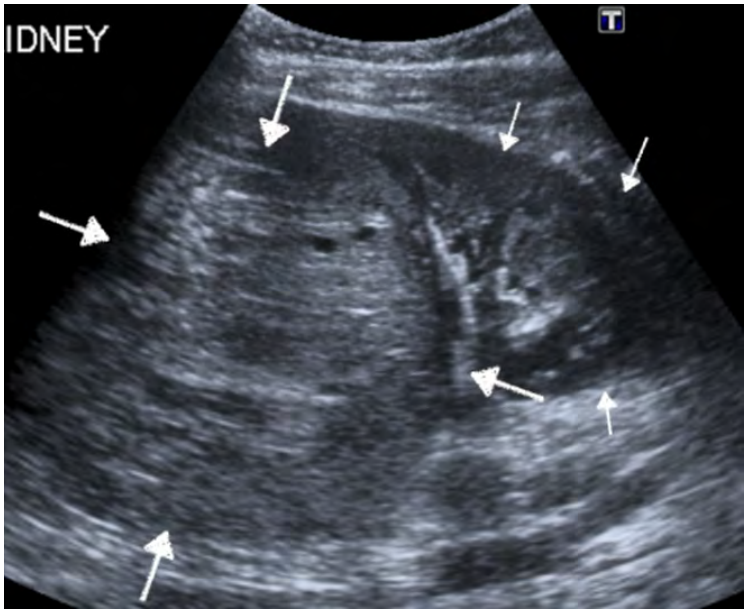

Figure 33: Nephroblastoma - longitudinal view
There is a large mass arising from the upper pole of the kidney (thick arrows). The mass is of intermediate and heterogeneous echogenicity, clearly different from the remaining normal lower pole seen to the right of the image (thin arrows). Several small cystic components are visible within the tumour representing haemorrhage or necrosis.

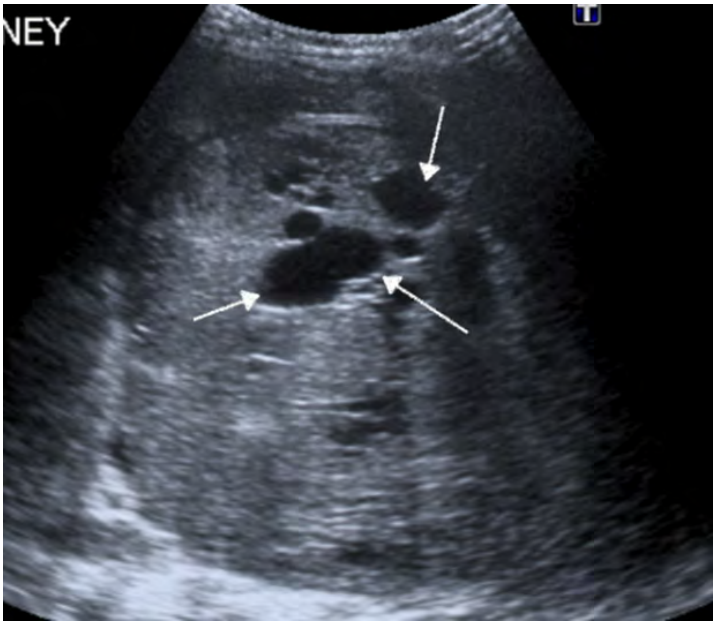

Figure 34: Nephroblastoma - transverse view
A transverse view through the tumour shows some internal 'cystic' components which are frequently seen in nephroblastoma (arrows). These are likely to represent focal necrosis or intratumoural haemorrhage. No recognisable normal kidney is seen on this image.

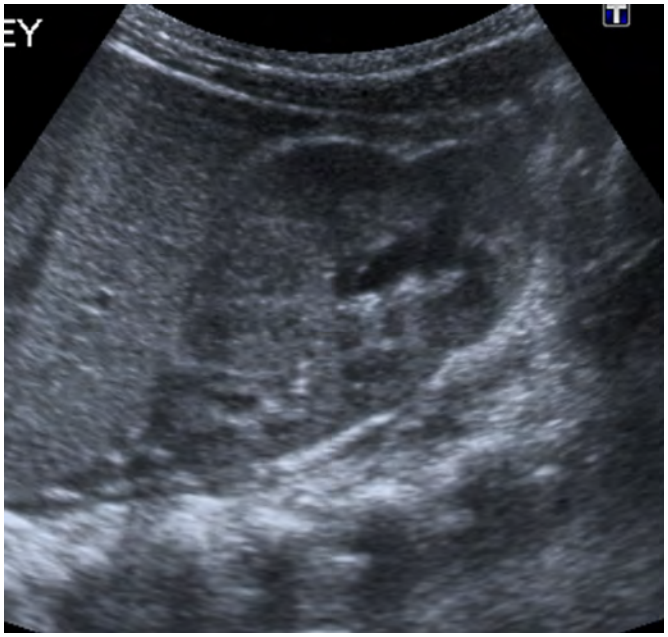

Figure 35: Acute lobar nephronia
Coronal image of the right kidney. The upper pole (arrows) is diffusely swollen compared to the lower pole. There is increased parenchymal echogenicity and absent corticomedullary differentiation. The patient had a severe urinary tract infection and the appearances are compatible with acute lobar nephronia.

25.3.10 Renal trauma

Injury to the urinary tract is not uncommon after abdominal trauma, though liver and splenic injuries are more frequent. Blunt abdominal trauma in children is generally managed conservatively if the patient is stable. Very few children require emergent surgery. The goal of imaging is to identify any abnormalities so that if the patient then deteriorates the surgeon knows the likely source of bleeding and can promptly plan the surgery accordingly.

The kidneys may be contused, lacerated or fractured (Figure 36). Shearing or penetrating injury may dissect or avulse the renal artery and render the kidney avascular. The renal collecting system may rupture allowing urine to enter the perirenal soft tissues and blood to enter the renal collecting system and ureter.

Haemodynamically unstable patients require resuscitation and surgery. Imaging is of value in the haemodynamically stable patient. In many centres contrast enhanced computed tomography of the abdomen is the technique of choice, However, if this is not available ultrasound can be very useful.

The whole abdomen should be examined when trauma is the indication. The kidneys should be specifically evaluated for contour, echogenicity, vascularity. A search should also be made for sub-capsular and perirenal fluid. Colour Doppler should be used to assess for parenchymal vascularity and evidence of damage to the renal arteries.

The urinary bladder may be very difficult to examine. It may be empty due to urethral catheterization, hypovolaemia with decreased urine output etc. If full its contour should be checked for obvious defects. Intraluminal debris or clot may be seen within the bladder, arising from either direct bladder injury or injury to the kidneys.

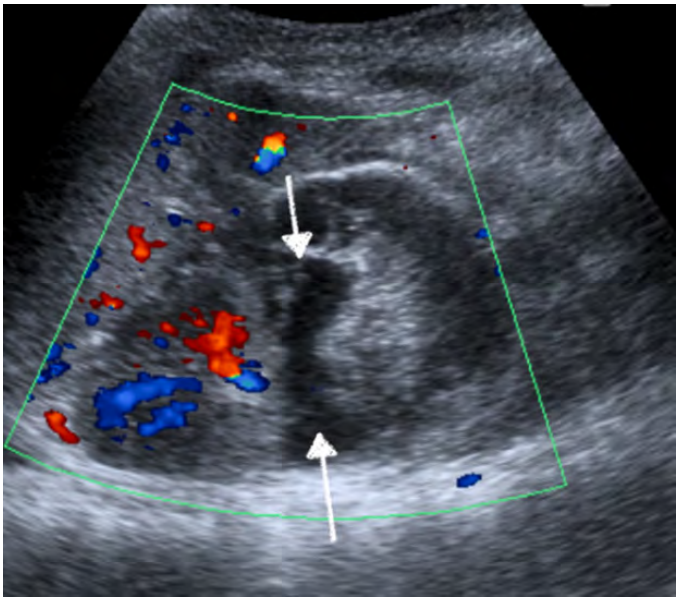

Figure 36: Renal trauma, fractured kidney
There is an almost completely anechoic 'fracture' through the kidney in the middle between the upper pole and the lower pole (thick arrows). The fracture contains a mixture of urine and blood. Colour Doppler shows that the upper pole (left part of the image) is contains vascularity and is viable and the lower pole (right part of the image) is avascular. There was a history of acute blunt abdominal trauma on the day of the scan. The patient was managed conservatively. The lower pole atrophied on subsequent imaging.

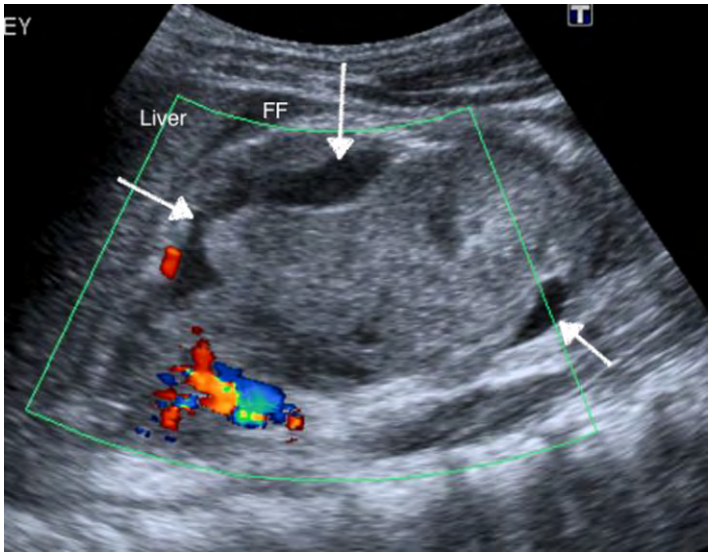

Figure 37: Renal trauma with perirenal haematoma
Most of the kidney is echogenic and featureless. Its contour is distorted by hypoechoic subcapsular fluid representing haematoma and probably urine (thick arrows).
Colour Doppler shows vascularity in part of the upper pole of the kidney but no flow can be identified in the mid and lower poles indicating that they are avascular.
There is a small amount of free intraperitoneal fluid between the liver and kidney (FF).
The patient was managed conservatively; the mid and lower poles of the kidney atrophied on serial ultrasound scans and the subcapsular fluid resolved.

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Riccabona M. Obstructive diseases of the urinary tract in children: lessons from the last 15 years. Pediatr Radiol. 2010 Jun;40(6):947-55. doi: 10.1007/s00247-010-1590-1. Epub 2010 Apr 30.

Wood BP, Donaldson JS, Johnson N, Kaminsky C, Parisi MT, Schlesinger A, Slovis TL. Pediatric radiology. Radiology. 1994 Feb;190(2):618-20.

Suggested reading

Konus O, Ozdemir A, Akkaya A, Erbas G, Celik H, Isik S. Normal Liver, Spleen, and Kidney Dimensions in Neonates, Infants, and Children: Evaluation with Sonography. AJR Am J Roentgenol. 1998 Dec;171(6):1693-8.

26. Paediatric hips

Prepared by:
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The hip joint consists of the articulation of the acetabulum with the femoral head. In younger children, the femoral head is made predominantly of cartilage, which can be quickly destroyed by infection. Femoral head necrosis and cartilage destruction can lead to long-term sequelae to the joint, with major lifelong impact. In order to avoid these complications, early diagnosis and prompt treatment (antibiotics and surgery) of hip infections is very important.

Infection of the hip should be considered in a child of any age who presents with fever, constitutional symptoms, swelling and tenderness in the region of the thigh or buttock, and pain with active or passive movement of the hip.

26.1 Scanning technique – paediatric hips

Transducer

A 13-6 MHz linear array vascular transducer such as the HFL38x which is compatible with the MSF standard M-Turbo is preferred for paediatric hips.

Apply gel to the transducer face and / or patient. If no gel is available, use water. Never use oil based products as this may damage the transducer.

Hand washing and cleaning of the transducer between patients is important to avoid spread of infection.

Patient position

Position the patient supine on the examination table or bedside, with the legs extended in neutral position. It is important that both feet are also on neutral position, that is, with the toes pointing up. Expose the hip to be scanned.

Scanning steps and technique – paediatric hips

1. Start by positioning the transducer on a sagittal plane along the anterior surface of the upper thigh, marker pointing to the patient's head (Figure 1).
2. Identify the femoral neck deep to the iliopsoas muscle and inferior to the femoral head. The hip joint is accessible to ultrasound imaging where it extends as a potential space between the femoral neck and the iliopsoas muscle, circumscribed by the hip capsule. The hip capsule can be seen at times as a band-like structure, echogenic, i.e. bright, or of medium echoes i.e. medium grey.
3. Look for a joint effusion between the femoral neck and the iliopsoas muscle. Measure the thickness of the effusion using the calipers function.
4. Scan the contra lateral, i.e. opposite, side for comparison, also with the transducer's marker pointing to the patient's head.
5. Measure on both hips the maximum distance between the anterior surface of the femoral neck and the anterior limit of the hip capsule.

Scanning notes for paediatric hips

– A common mistake in hip sonography for effusions is to scan too superiorly, at the interface between the femoral head and the acetabulum. It is much easier to evaluate for effusion along the femoral neck (as described in the paragraphs above).

– Hip effusions are usually unilateral. As such, always compare the appearances with the contralateral, unaffected side, as the normal joint capsule can be at times confused with a small effusion, especially when using portable machines.

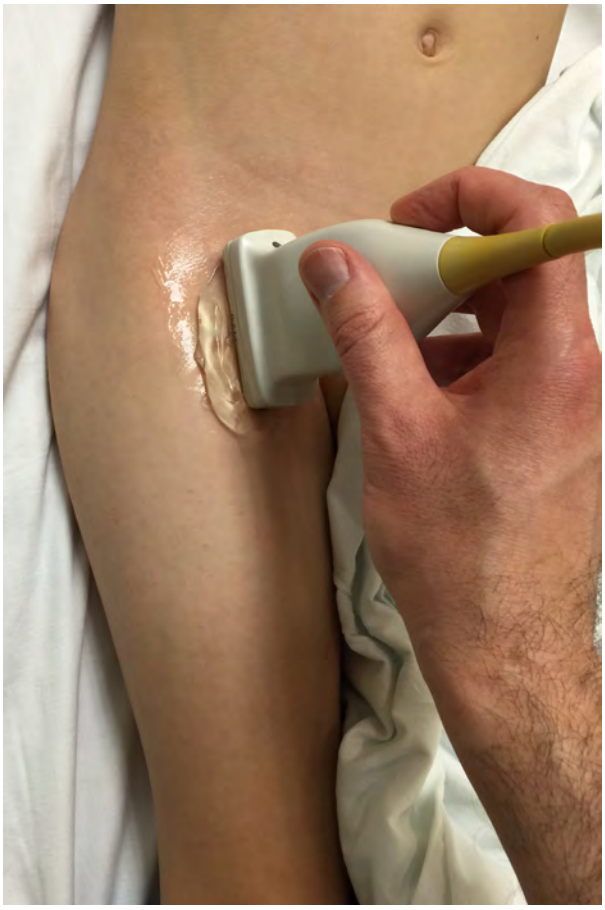

Figure 1: Positioning for scanning of a paediatric hip
The transducer is placed on a sagittal plane along the anterior surface of the upper thigh, marker pointing to the patient's head.

If uncertainty occurs with any findings during an ultrasound scan, or if a second opinion is beneficial, short clips (preferably) or sets of images can be saved and be sent to the MSF Telemedicine platform for consultation.

- Use the 'clip' function to record a short clip / movie.
- To save a static image, click the 'freeze' button to pause scanning. Use the touch pad to scroll through the last 30-60 seconds of scanning and then click the 'save' button on representative images.

Saved clips and images can be exported for expert consultation via the MSF Telemedicine platform.

Note: clips are preferred over static images for telemedicine consultation.

For more information on teleradiology and creating cine clips, please see Chapter 4, for detailed instructions on how to export images / clips, please see Annex 3, Annex 4 and Annex 5.

26.2 Normal paediatric hips

The femoral neck is located deep to the iliopsoas muscle and inferior to the femoral head. The hip joint extends as a potential space between the femoral neck and the iliopsoas muscle, circumscribed by the hip capsule. The hip capsule can be seen at times as a band-like structure, echogenic, i.e. bright or of medium echoes, i.e. medium grey (Figure 2).

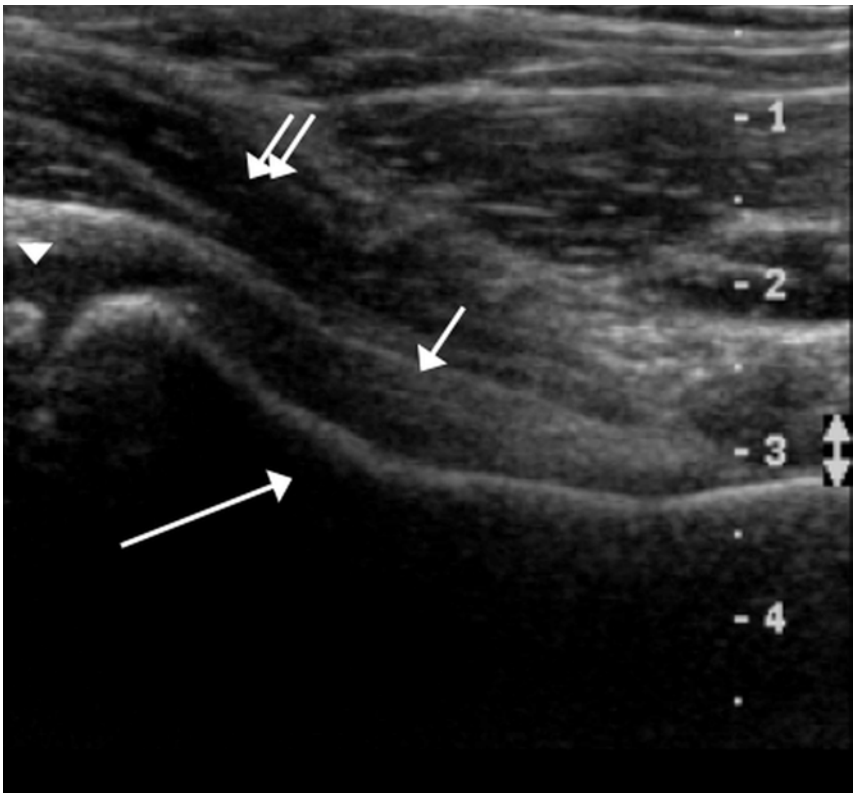

Figure 2: Normal hip joint appearances
The femoral neck (long arrow) is located deep to the ileopsoas muscle (double-arrows) and inferior to the femoral head (arrowhead). The hip joint extends as a potential space between the femoral neck and the ileopsoas muscle, circumscribed by the hip capsule. The hip capsule (short arrow) can be seen at times as a band-like structure, echogenic (bright) or of medium echoes (medium grey).

26.3 Septic arthritis of the hip

Bacterial or fungal infection in the hip joint, i.e. septic arthritis, leads to the accumulation of joint fluid, i.e. joint effusion (Figure 3), which can result in cartilage destruction and femoral head necrosis. Ultrasound aims to detect the joint effusion which, if present, requires further orthopaedic evaluation.

As mentioned, the hip joint is accessible to ultrasound imaging where it extends as a potential space between the femoral neck and the iliopsoas muscle, circumscribed by the hip capsule. The hip capsule can be seen at times as a band-like structure, echogenic, i.e. bright, or of medium echoes i.e. medium grey.

As the normal hip capsule may be confused with an effusion at times, it can be useful to measure the thickness of the capsule. The upper limits of normal are proportional to the child's height. Children <100 cm of height have normal measurements ascending from 3.5 to 6.5 mm. Children ≥100 cm have a constant suggested upper limit of normal of 7.5 mm. It is important to scan the contralateral side for comparison (Figure 4 and Figure 5).

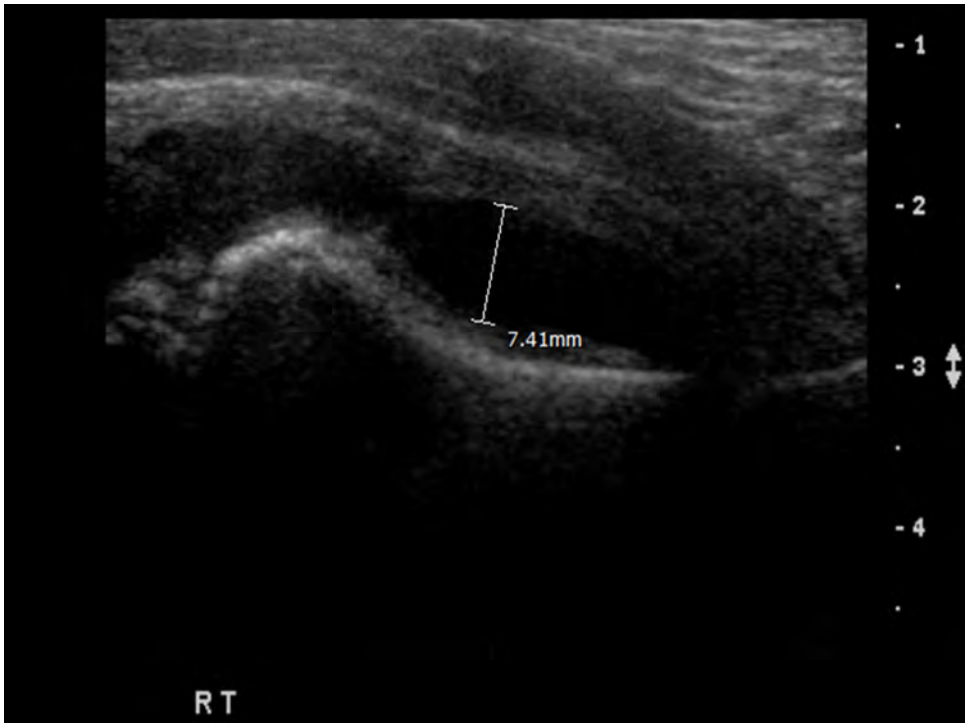

Figure 3: Hip effusion
Anechoic fluid can be seen within the hip joint, measured by calipers.

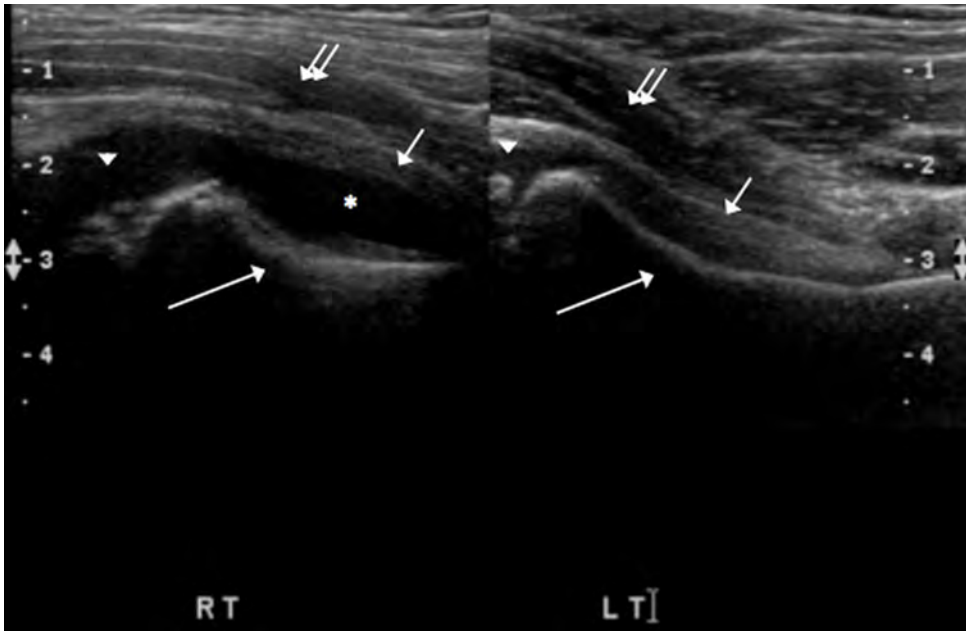

Figure 4: Comparison image of bilateral hips
An effusion (asterisk) is seen within the right hip joint (RT).
No effusion is present in the left hip (LT). Long arrow = femoral neck;
double-arrows = ileopsoas muscle; arrowhead = femoral head; short arrow = hip capsule.

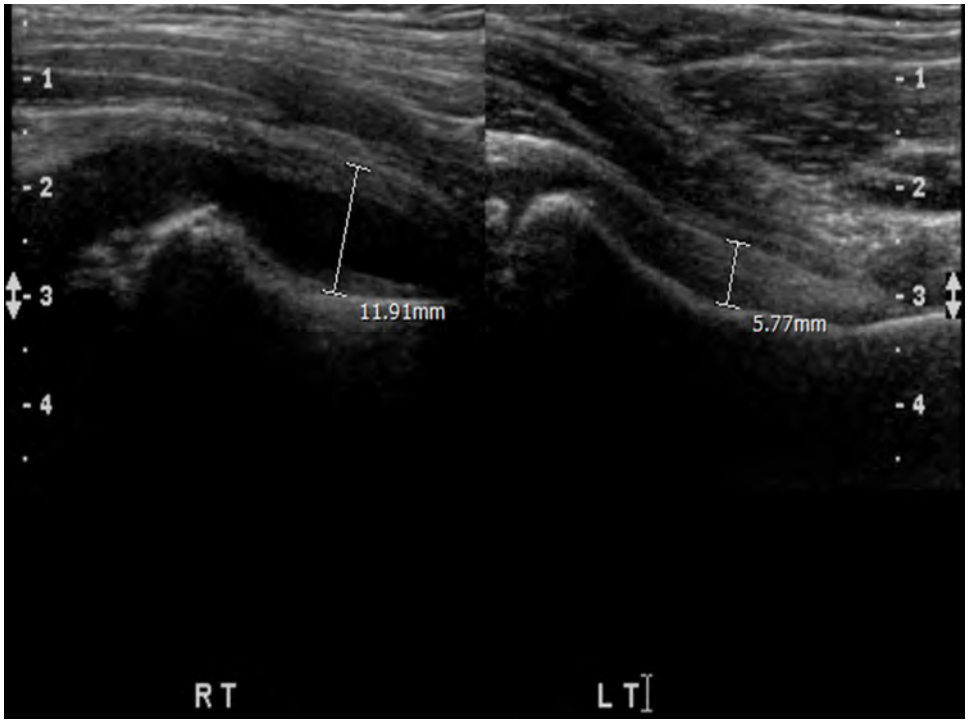

Figure 5: Comparison image of bilateral hips
Comparison image of bilateral hips with measurements on each side of the maximum distance between the anterior surface of the femoral neck and the anterior limit of the hip capsule (between callipers).
Larger measurement on the abnormal hip (right hip = left image).
Note that this measurement is different to what seen on Figure 3. While on Figure 3 only the effusion is being measured, in an attempt to quantify the amount of fluid, on Figure 5 the capsule is also included in the measurements, to illustrate normal (LT) versus abnormal (RT) capsule measurements.
RT = right hip joint; LT = left hip joint.

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Robben SG, Lequin MH, Diepstraten AF, den Hollander JC, Entius CA, Meradji M. Anterior joint capsule of the normal hip and in children with transient synovitis: US study with anatomic and histologic correlation. Radiology. 1999 Feb;210(2):499-507.

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27. Reference resources for ultrasound

Ultrasound resources for ordering via the international catalogue

Lutz H, Gharbi, H. Manual of diagnostic ultrasound in infectious tropical diseases. Springer. Germany. 2006
(MSF code: L012ULTX06E-P)

World Health Organization. Basic physics of ultrasonographic imaging. WHO. Geneva, Switzerland. 2005.
http://apps.who.int/iris/bitstream/10665/43179/1/9241592990_eng.pdf
(MSF code: L012ULTX02E-P)

World Health Organization. Manual of diagnostic ultrasound. Volume 1. Second edition. WHO. Geneva, Switzerland. 2011.
http://apps.who.int/iris/bitstream/10665/43881/1/9789241547451_eng.pdf
(MSF Code: L012ULTX01E-P)

Helpful online resources

The following websites that offer downloadable pdfs, narrated lectures, scanning protocols, case studies, anatomy and pathology images and videos. These hhelpful resources can be found online;

1. **5 min sono**
   Available from: http://5minsono.com/vids/
   The website provides free access to a library of narrated ultrasound tutorials, anatomy and pathology videos. Topics include; EFAST, RUSH, IVC, gallbladder, liver, procedures, pleural effusion, pneumonia, cardiac, genitourinary, gastrointestinal, nerve blocks, ocular and fetal heart rate.

2. Abuhamad A, Chaoui R, Jeanty P, Paladini D. **Ultrasound in Obstetrics and Gynaecology: A Practical Approach**. First edition. 2014.
   Available from: http://www.evms.edu/education/centers_institutes_departments/obstetrics_gynecology/ultrasound_ebook/
   A free downloadable pdf (available with or without imbedded) that covers in detail the practical aspects of OB/GYN ultrasound from the basics of ultrasound physics and how to hold the transducer, to detailed explanations and imaging examples of 1st, 2nd and 3rd trimester ultrasound. It covers the basic topics more familiar to many MSF contexts as well as more advanced topics.

3. **Emergency ultrasound teachings**. Resources and tutorials on emergency ultrasound.
   Available from: http://www.emergencyultrasoundteaching.com/
   This website has free access to; narrated lectures, ultrasound cases, images, videos and a selection of relevant journal articles on ultrasound. Topics include; Aorta, Appendix, gallbladder, Cardiac/IVC, DVT, FAST, OB/GYN.

4. **European Federation of Societies for Ultrasound in Medicine and Biology. Course book.**
   Available from: http://www.efsumb.org/ecb/ecb-01.asp
   This website provides free access to chapters of the EFSUMB course book. Chapters topics include: physics, liver, spleen, pancreas, genitourinary, bladder, chest, interventional, echocardiography, E-FAST and HIV infection.

5. Fujifilm **Sonosite. Clinical images and videos.**
   Available from: https://www.sonosite.com/clinical-media
   The website provides an free access to an extensive library of clinical images, videos, how to and case study videos covering a very wide range of topics including; covered include OB/GYN, EFAST, Cardiac, IVC, liver, spleen, RUQ,LUQ, RLQ, urinary, regional anaesthesia, bones, DVT, procedures, chest, paediatrics, abdominal aorta.

6. Hoffmann B, Nixon MS. **Ultrasound Guide for Emergency Physicians. An introduction.**
   Available from: http://www.sonoguide.com/
   The website was created by the member of the American Colleague of Emergency Medicine (ACEM). It provides step by step scanning instructions, clinical images and videos. Topics covered include the following; Physics, FAST, aortic aneurysm, Cardiac, gallbladder, renal, early pregnancy, DVT, soft tissue, procedures.

7. **International Society of Ultrasound in Obstetrics and Gynaecology (ISUOG)**
   Available from: http://www.isuog.org/OnlineLearning/Learning+Modules/
   The ISOUG website has an online learning section, ISOUG requires membership to access all the site content, but some sections are free to access. Learning modules and recorded lectures or presentations are available without membership. Topics include; Generic learning, gynaecological, early pregnancy and first trimester, second and third trimester ultrasound and basic ultrasound training.

8. **Mount Sinai. Emergency Medicine Ultrasound.**
   Available from: http://sinaiem.us/tutorials/
   The Sinai EM ultrasound website offers free access to narrated tutorials and scanning guides including; how use the m-turbo ultrasound machine, FAST, RUSH (Rapid Ultrasound for Shock and Hypotension), cardiac, obstetrics, pelvis, pneumothorax, gallbladder, aorta, renal, DVT and IVC access.

9. Partners in Health. **Manual of Ultrasound for Resource-Limited Settings**. First edition. Partners in Health. 2011.
   Available from: http://www.pih.org/library/manual-of-ultrasound-for-resource-limited-settings
   A free downloadable pdf scanning guide with anatomy and pathological examples of ultrasound scanning relevant to resource constrained settings. Topics include; fundamentals, trauma, echocardiography, OB/GYN, liver, gallbladder, spleen, kidney, DVT volume status, AAA, bladder skin procedures and vascular access. Available in English and French.

10. **Phillips: education and training**.
    Available from: http://www.usa.philips.com/healthcare/education-resources/education-training
    Free downloadable quick scanning guides and narrated lectures on the following topics; FAST, lung ultrasound , transthoracic echo, ultrasound assisted thoracentesis, soft tissue, AAA, airway management, assessment of LV function, ocular, DVT and CVC and ulnar nerve block ultrasound.

11. **PoCUS4Peds**. Point of care ultrasound for paediatrics.
    Available from: https://www.youtube.com/user/LungUltrasound4Peds
    This YouTube channel has a large selection of Paediatric POCUS videos for anatomy and pathology cases and a video journal club. Topics include; lung, bowel, biliary, renal colic, skin and soft tissue, musculoskeletal (including hip effusions).

12. **Radiopaedia**

    Available from: https://radiopaedia.org/

    The ultrasoundapaedia website provides a large detailed library of radiology cases including ultrasound images, pathology and case studies. It is possible to search specific pathology, or filter by ultrasound cases. Topics include; Cardiac, chest, GI, hepatobiliary, OB/GYN, trauma and paediatrics.

13. **Society of Ultrasound in Medical Education**. Learning modules.

    Available from: http://www.susme.org/learning-modules/learning-modules/

    The SUSME website offers a good selection of free narrated learning modules. Topics include; physics, transducers, image orientations and resolution, artefacts, bio-effects of ultrasound, liver, gallbladder, spleen, renal, urinary, AAA, IVC, cardiac and neck ultrasound.

14. **Ultrasound cases info**.

    Available from: http://www.ultrasoundcases.info/Default.aspx

    The ultrasoundcases website provides access to a large number of general ultrasound cases, videos, and slideshows. There are detailed anatomy and pathology on topics including; abdomen and retroperitoneum, including, liver, gallbladder, pancreas, spleen, appendix, GI tract, urinary tract and male reproductive system, gynaecology, thorax. Also paediatric; abdomen, urinary tract, hip, neonatal brain.

15. **Ultrasoundpaedia**.

    Available from: http://www.ultrasoundpaedia.com/

    The ultrasoundapaedia website provide access to some content free, however some requires paid membership. Free anatomy, pathology topics and scanning guidelines include the following topics; upper abdomen, liver, spleen, biliary, urinary, appendix, bowel, gynaecology and obstetrics, neonatal head.

16. **World Health Organization. Manual of diagnostic ultrasound**. Volume 1. Second edition. WHO. Geneva, Switzerland. 2011.

    http://apps.who.int/iris/bitstream/10665/43881/1/9789241547451_eng.pdf

    A free downloadable pdf from the WHO with detailed chapters, scanning guides, anatomy and pathology including the following topics; physics, ultrasound techniques, artefacts, chest, liver, gallbladder, pancreas, spleen, kidneys ureters and bladder.

Annexes

Annex 1: Standard configuration and accessories for SonoSite M-Turbo

ITEM	ICT CODE
M-Turbo Ultrasound • Standard application software • Colour Doppler and velocity colour • Pulse wave Doppler and continuous wave Doppler • Advanced obstetrics and gynaecology calculations • Clips storage • C-60 (abdominal) transducer • Carry case • Mini-doc • Power supply • Power cord • User guide in English and French • Service manual • English control panel	EDIMULSE4--

ACCESSORY ITEMS	ICT CODE
Battery	EDIMULSS401
Abdominal transducer C60x	EDIMULSA406
Vaginal transducer ICTx	EDIMULSA407
Transducer superficial structures HFL38x	EDIMULSA408
Cardiac transducer P21x	EDIMULSA409
Coupling agent (Ultrasound gel)	EDIMULSC1CA
Condom, lubricated + reservoir	SMSUCOND1--
Detergent / Disinfectant for med. equip. Hexanios, 5 L tin + pump	SDISMHEX5B-

Annex 2: Ultrasound transducer selection for SonoSite US machines

C60

This is the general abdominal transducer that comes as the standard transducer with each ultrasound machine. It is a low frequency transducer which is best used for visualising deep structures in the abdomen.

ICTx

This is a vaginal transducer for dedicated obstetric or gynaecological transvaginal examinations.

HFL38x

This transducer visualizes superficial structures with higher resolution. It is a good choice for assessment of vessels, nerves, soft tissue/abscesses, pneumothorax, venous pressure, pleural effusions etc.

P21/P17

This transducer is best for trans-thoracic or subxiphoid cardiac assessment and for paediatric examinations.

C11X

This transducer is best used for neonatal and paediatric examinations.

M Turbo

SonoSite Code MSF code	**Application**	**Bandwidth**	**Scan Depth**	
C60x EDIMULSA406	Abdominal Gynaecology Musculoskeletal Nerve Obstetrics	5-2 MHz Curved array	30 cm	
ICTx EDIMULSA407	Gynaecology Obstetrics	8-5 MHz Tightly curved array	13 cm	

M Turbo

SonoSite Code MSF code	Application	Bandwidth	Scan Depth	
HFL38x EDIMULSA408	Vascular Nerve Small Parts Venous	13-6 MHz Linear array (High frequency)	6 cm	
P21x EDIMULSA409	Abdominal Cardiology Obstetrics Transcranial Doppler	5-1 MHz Phased array	35 cm	
C11xE DIMULSA410	Abdominal Neonatal Nerve Vascular	8-5 MHz Curved array	10 cm	

MicroMaxx

SonoSite Code MSF code	Application	Bandwidth	Scan Depth	
C60e EDIMULSA203	Abdominal Gynecology Obstetrics	5-2 MHz Curved array	30 cm	
ICTe EDIMULSA201	Gynecology Obstetrics	8-5 MHz Tightly curved array	10 cm	
L38e EDIMULSA204	Vascular Nerve Small Parts	10-5 MHz Linear array	6 cm	
P17 EDIMULT2A05	Abdominal Cardiology Obstetrics Transcranial foppler	5-1 MHz Phased array	35 cm	

NanoMaxx

SonoSite Code MSF code	**Application**	**Bandwidth**	**Scan Depth**	
C60n EDIMULTA303	Abdominal Gynecology Nerve Obstetrics	5-2 MHz Curved array	30 cm	
ICTn EDIMULTA301	Gynecology Obstetrics	8-5 MHz Tightly curved array	10 cm	
L38n EDIMULTA304	Vascular Nerve Small Parts Venous Musculoskeletal	10-5 MHz Linear array	9 cm	
P21n EDIMULTA305	Abdominal Cardiology Gynecology Obstetrics	5-1 MHz Phased array	35 cm	

– All ultrasound machine images sourced from: https://www.sonosite.com/products

– All ultrasound transducer images Image sourced from: https://www.sonosite.com/transducers

Annex 3: Exporting ultrasound clips or images on SonoSite M-Turbo

Saving clips or images

Images and clips are saved onto the internal memory of the M-Turbo.
– Images are saved using the “save” button on the keyboard.
– Short clips / movies can be recorded using the “Clips” button on the keyboard, then by using the “save”.

Before clips or images are exported from the M-Turbo, it is important that the images are reviewed and saved correctly.

NOTE: the image must be saved with the button on the keypad before saving the measurement. If you do a measurement on an image that is not saved but then save the measurement with the button on the screen, the measurement result will be included in the patient report but the image will not be automatically saved.

Exporting saved clips or images

Clips or images with the M-Turbo are exported in JPEG or MPEG format via a USB.

1. Select ‘Review’ button on the keypad.
2. Select the patient to be exported.
3. Insert USB stick and select Exp. USB.
4. Select the USB storage device.
5. Check the ☐ box to export with patient details. Un-check the ☐ box to export the clip / images anonymously.
6. Select ‘Export’.
7. NOTE: Ensure that the USB is free of viruses; it is recommended to have a separate USB stick only for this purpose.

Memory and image size

– Memory
  The M-Turbo has an internal memory of 8 GB. The disc symbol with percentage (%) on the right side of the screen indicates the amount of memory left. Once the memory is full, images will need to be deleted to create more space.
– File size
  The size of one ultrasound image in a folder with report file is approximately 100 KB. The size of a clip varies depending on the length of the recording.

Annex 4: Exporting ultrasound clips and images on SonoSite MicroMaxx

Saving images

Before clips or images are exported from the MicroMaxx, it is important that the user can be identified and that the images are saved correctly.

When entering patient details in 'New Patient', select 'More', and at 'User' field, enter the name of the user.

To close the current patient exam, press the 'Patient' key and select 'End Exam' from the on-screen menu.

NOTE: Selecting End Exam, selecting New Patient, or modifying patient name or ID will erase any previously entered information, including the calculations and report page. To save this information, save the screen for each time. For example, to save a report, select 'Save' at the report screen to ensure that it is included inside the patient file.

Always save the required image with the button on the keypad; save the measurement results with the button on the screen.

Installing SiteLink software

The images produced on the MicroMaxx are in a unique format (SonoExport) and must be converted to a JPEG file using the program supplied with the machine: SiteLink Image Manager 3.4.5.

The CD required to install this program is supplied with every MicroMaxx. If for any reason you do not have this CD, please contact diagnostic-network@msf.org.

A copy of this program is also available on the OCA ftp server and can be accessed by following this link: ftp://msf_int:dr4g$Dr0p-@files.amsterdam.msf.org. Copy this link into a Windows Explorer window (i.e. in My Computer, not in an internet Explorer browser) and copy all three files to a location on your computer. Open the setup.exe file and follow the installation prompts.

NOTE: installing the software on an MSF computer will require administrative access.

While installing the software, the computer must be connected to the MicroMaxx at the same time in order to configure the driver of the computer to recognise the MicroMaxx as removable media. Insert the CD into the computer and follow the prompts for installation.

Once the program is installed, ensure that the 'Configure' option is set to 'JPEG'. Images will then be in the JPEG file format. The report is generated in both HTML and PDF format.

The MicroMaxx itself must also be configured for image type.
1. Press the 'Setup' key, and then select 'Connectivity'.
2. In the 'Transfer Mode' list, ensure that it is set to 'SiteLink' and not DICOM.

Exporting clips or images

In order to export from the MicroMaxx, the machine must be connected to the computer directly via the USB cable provided. It is not possible to export the directly to a USB key and then transfer to a computer.

Once the MicroMaxx is connected to the computer
1. Select 'Options'.
2. Select 'Review list' and 'Export to USB'.

Within 'Patient Review', a ✔ will appear next to the patient name once it has been transferred. When the MicroMaxx is next connected to the computer, only the patients that have not been previously transferred will be sent to the computer.

To resend a patient file for any reason, select the 'Review' button on the MicroMaxx keypad and the select 'Archive'.

Note: There is no option to export the file anonymously; i.e. without patient details.

Memory and image size

– Memory
  The MicroMaxx has a 4 GB Compact Flash card installed for memory. The CF symbol on the side of the screen indicates the amount of memory left on the Compact Flash card. Once this card is full, no more images will be able to be saved and old cases that have been archived onto a DVD or computer hard drive should be deleted to create more space.

– File size
  The size of one ultrasound image is approximately 100 KB. A patient folder of several images and one report can be compressed using a zip file application (as required). The size of a clip varies depending on the length of the recording and type of scan. A 15 second clip will be approximately 5 - 10 MB.

Annex 5: Exporting ultrasound images on SonoSite NanoMaxx

Exporting clips or images

Images with the NanoMaxx are in JPEG format and no software is needed for conversion.

Insert USB into back of the NanoMaxx. Ensure that the USB is free of viruses; it is a good idea to have one USB only for this purpose.

To export images via a USB:
1. In the menu, select ‘Patient’ and then ‘Review’.
2. Select the patient to be exported.
3. Insert USB and select ‘Export to USB’.
4. Check the ☐ box to export to export the images anonymously, i.e. without patient details.

Memory and image size

– Memory
  The NanoMaxx has a 4 GB Compact Flash card installed for memory. The CF symbol on the side of the screen indicates the amount of memory left on the Compact Flash card. Once this card is full, no more images will be able to be saved and old cases that have been archived onto a DVD or computer hard drive should be deleted to create more space.

– File size
  The size of one ultrasound image is approximately 100 KB. A patient folder of several images and one report can be compressed using a zip file application (as required). The size of a clip varies depending on the length of the recording and type of scan. A 15 second clip will be approximately 5 - 10 MB.

Annex 6: Diagnosis and management of placenta previa using the Translabial method

Introduction

The use of the Translabial technique for diagnosis and management of placenta previa is intended as an option in those contexts where transvaginal scanning is not possible for medical or cultural reasons.

Definition

Placenta previa is defined as a placenta implanted in the lower uterine segment, presenting ahead of the leading pole of the fetus in close proximity to or covering the internal os of the cervix. Placenta previa occurs in 2.8/1000 singleton pregnancies and in 3.9/1000 twin pregnancies. Placenta previa is commonly observed in early pregnancy with the placental edge reaching or overlapping the internal os in 43 % of patients between 11 and 14 weeks gestational age. Growth of the pregnancy moves the placenta away from the internal os by elongating the lower uterine segment. Diagnosis of placenta previa becomes clinically important in the third trimester and in patients presenting in labor.

Risk factors

Placenta previa places the patient at risk for premature delivery and carries a significant risk for major hemorrhage during labor and delivery. Perinatal mortality is increased 3 - 4 times over normal pregnancies. Risk factors for development of placenta previa include maternal age over 35 years, multiparity, previous Caesarean section, and previous placenta previa.

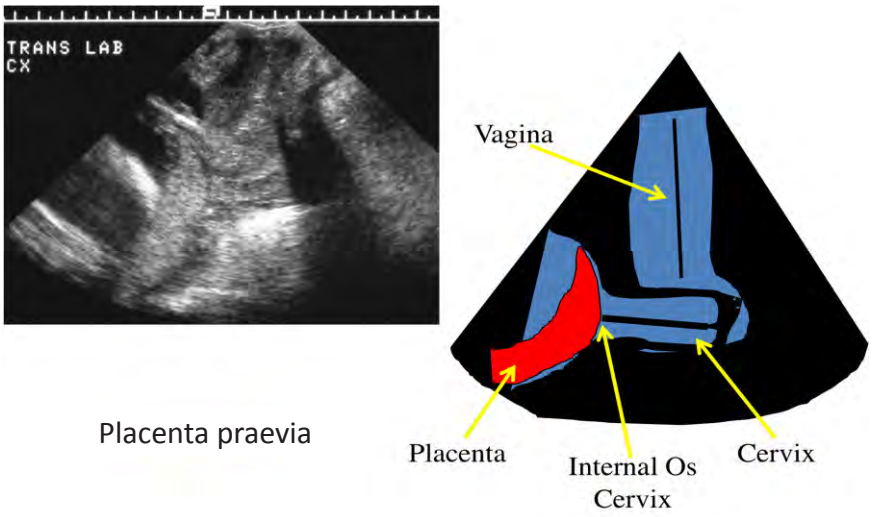
Diagnosis

Diagnosis of placenta previa by transabdominal sonography in the third trimester is limited by the low position of the fetal head or fetal presenting part, which usually obscures visualization of the internal cervical os. The fetus itself obscures visualization of the placenta when it is posterior. Transvaginal sonography is proven effective in the diagnosis of placenta previa but requires availability of an endovaginal ultrasound transducer. The translabial approach to diagnosis is equally effective to transvaginal sonography, but is performed with routinely available abdominal transducers and does not require placement of the transducer in the vagina. Translabial ultrasound examination is safe, easy to perform, and is highly accurate in the diagnosis of placenta previa.

Technique

1. The patient is asked to empty her bladder to avoid a false positive diagnosis of placenta previa caused by the full bladder compressing the lower uterine segment.
2. Use a 3.5 MHz sector or curved array transducer.
3. Cover the transducer face with ultrasound gel (K-Y jelly or equivalent patient examination gel may be used).
4. Cover the transducer with a transducer cover or condom (an examination glove may be used).
5. Place a generous amount of gel on the patient’s labia.
6. Place the transducer on the labia and perform examination of the cervix and placenta in sagittal plane.

7. Measure and report the distance from the edge of the placenta to the internal os of the cervix. If the edge of the placenta just touches the cervical os report a measurement of 0 mm. If the placenta overlaps the cervical os measure and report the amount of overlap from the internal os to the edge of the placenta.



Translabial ultrasound diagnosis of placenta previa

Management guidelines

1. Any degree of overlap (>0 mm) after 35 weeks gestational age is usually considered an indication for Caesarean section.
2. If the placenta edge is >20 mm from the internal os, trial labor and vaginal delivery will usually be successful.
3. When the placental edge lies between 0 and 20 mm from the internal os, Caesarean section will often need to be performed based on clinical circumstances.

Annex 7: Obstetrics and gynaecology ultrasound worksheet

Obstetrics and Gynaecology Ultrasound worksheet				
Patient name		Date		
D.O.B / Age		Time		
Patient ID		Hospital No.		
Gravida /Para / Abort	LMP / /	Scan	GYN / 1st T / 2nd T / 3rd T	

Gynaecology						
Uterus	Length	mm	Height	mm	Width	mm
Endometrium	Thickness	mm	**Fibroids**	Yes / No	**Multiple fibroids**	Yes / No
Largest fibroid	Length	mm	Height	mm	Width	mm
Left ovary	Length	mm	Height	mm	Width	mm
Right ovary	Length	mm	Height	mm	Width	
Cul-de-sac						

Obstetrics						
Intrauterine pregnancy	Yes / No	**Ectopic pregnancy**	Yes / No	**Live foetus**	Yes / No	
Multiple gestation	Yes / No	**Number of foetus(es)**		**Heart rate**	bpm	
Placental location	Anterior	Posterior	Right lateral	Left lateral	Previa	
Presentation	Cephalic		Breech		Transverse	
Cervical length	mm					
Foetal biometry	CRL	mm	HC	mm	FL	mm
	BPD	mm	AC	mm	AFL	mm
GA by foetal biometry	W		D		EFW	
Ultrasound EDD			**Final EDD**			

Abnormality detected			
Diagnosis / comments			
Follow up / management			
Name		**Signature**	

Annex 8: Ultrasound register

Ultrasound Register										
Exam Number	Date (dd/mm/yy)	Pt ID No. / Hospital No.	Patient last name	Patient first name	Patient DOB/Age	Ward / Service	Name requesting physician	Type of exam	Name of US examiner	Comments