IMAGE ARTIFACTS

Artifacts are image appearances that do not represent the true anatomy being scanned. Artifacts occur due to a variety of reasons in particular:

- Acoustic artifacts due to ultrasound machine assumptions (attenuation, depth, beam dimension, and beam path artifacts)
- Inappropriate equipment settings (i.e. Gain, TGC, depth, focus, and dynamic range)
- Equipment function or electrical interference

Artifacts are an important part of clinical ultrasound; it is important to be able to recognise these and interpret the relevance:

- Artifacts can lead to inappropriate interpretation or hinder imaging.

- Some artifacts are useful diagnostic clues in clinical ultrasound and can help interpretation (e.g. Reverberation artifact B lines in lung imaging).

<u>IMAGING ASSUMPTIONS</u>

Ultrasound machines must make assumptions in order to facilitate the conversion of received echoes into ultrasound images. These assumptions contribute in particular to the formation of acoustic artifacts. The basic assumptions include:

- A constant speed of sound in the body (assumed 1540m/s).

- All echoes detected by the transducer originate from the central axis of each beam formed, (i.e. The line of sight).

- The ultrasound beam travels in straight lines

- The time taken for an echo from a given interfaces to return to the transducer is directly related to its distance from the transducer (Pulse Echo Principle).

- The rate of attenuation of the beam is constant with depth and the same in all tissues being imaged.

- Each echo received by the transducer is from the most recent transmit pulse.

ATTENUATION ARTIFACTS

The assumed attenuation by the ultrasound machine is based on that of a soft tissue average of 0.5 (dB/cm/MHz). There are marked differences in attenuation depending on the tissue being imaged:

Blood 0.15

Liver 0.5

Muscle 1.5-3.5

Bone 10

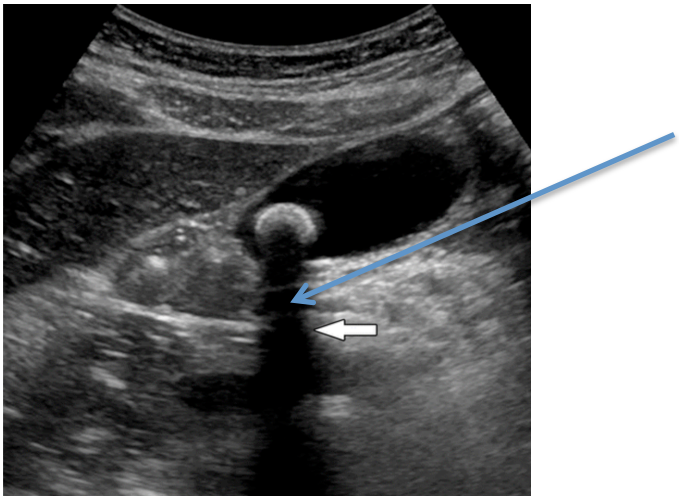
Lung 40

Attenuation also occurs via reflection at tissue interfaces. Tissues that have markedly different acoustic impedance to soft tissue, such as bone or lung, will have the majority of ultrasound energy reflected at the interface.

SHADOWING

Shadowing is a common form of attenuation artifact that leads to a reduction in the detected amplitude of echoes deep to an attenuating surface or object, producing an acoustic shadow.

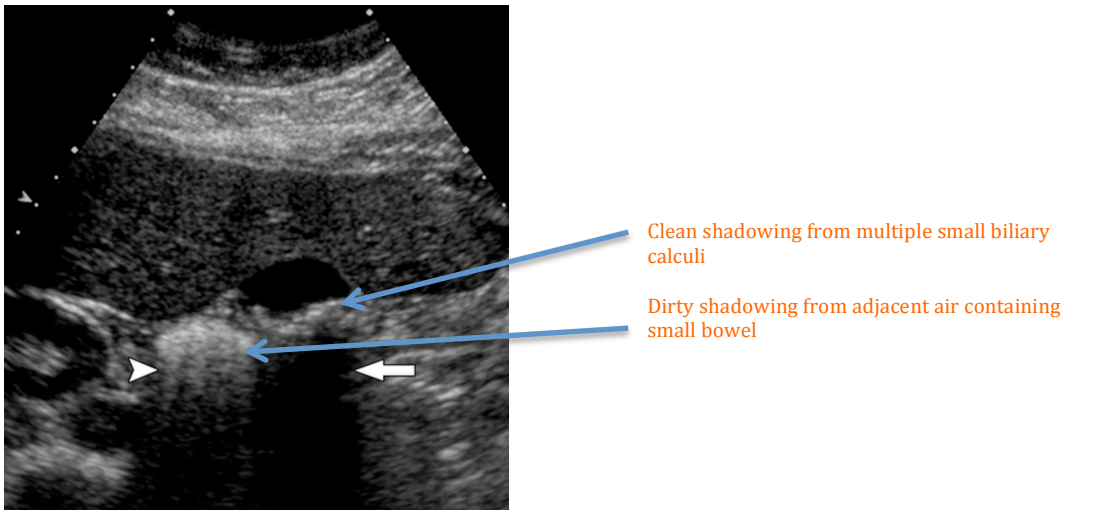
- The acoustic shadowing may be clean (black- e.g. tissue/bone) or dirty (contain artifactual echoes e.g. soft tissue with lung or bowel) depending on the nature of the tissue interface and reflectivity, the degree of attenuation of that tissue, any reverberation artifact (common in gas containing tissues lung/bowel), and the size and location of the object relative to the focal zone/beamwidth.



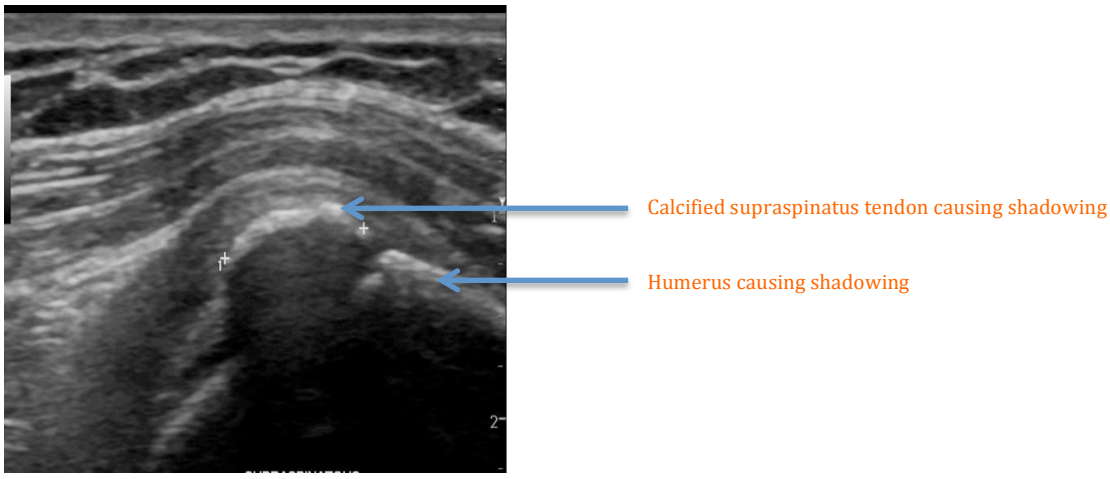
Clean acoustic shadowing from a highly reflective calcium-containing gallstone.

For small objects (e.g. small calculi) or areas of tissue, shadowing may not occur unless the focal zone is set at the expected depth of the area of interest. This ensures the area is at the focal point; the narrowest beamwidth helps amplify any useful diagnostic shadowing

Long Gallbladder



Transverse Gallbladder



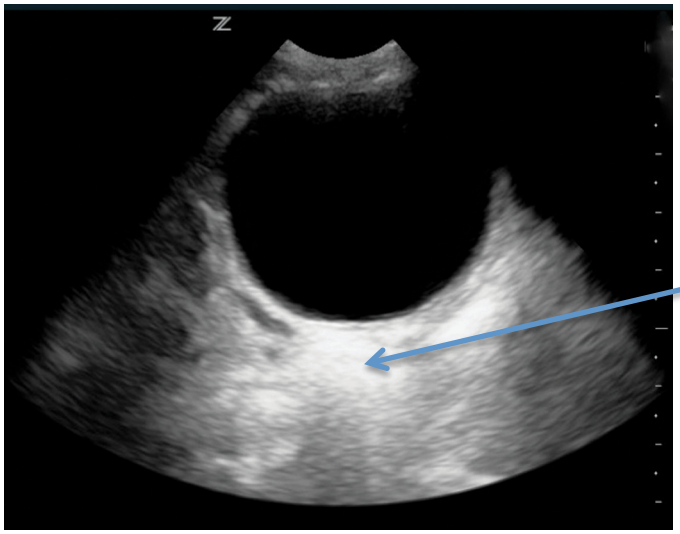
Transverse view Supraspinatus tendon

ACOUSTIC ENHANCEMENT

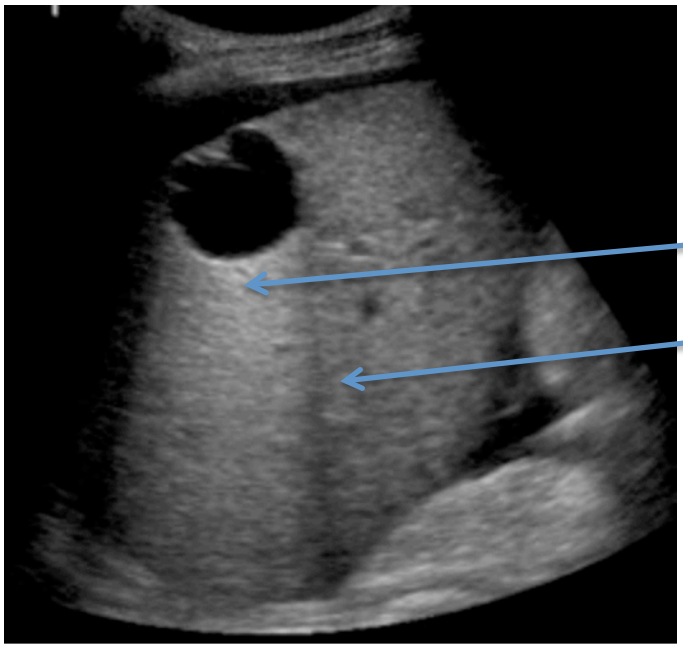
Acoustic enhancement occurs due to reduced attenuation through an area being scanned relative to surrounding tissue. This results in an area of increased brightness deep to this area or structure. As echoes received are of greater amplitude due to undergoing less attenuation on the round path travel.

This occurs with fluid filled structures (e.g. cysts, gall bladder), which attenuate ultrasound energy to a much lesser degree than other soft tissues.

- Acoustic enhancement is part of the characterization of a simple cyst (others being an echo free interior and having a defined thin smooth wall)
- Excessive posterior acoustic enhancement can reduce interpretation of the area imagined deep to the offending structure (e.g. deep to the bladder). This can be somewhat mitigated by adjusting the gain and TGC.



Posterior acoustic enhancement from the reduced attenuation of the urine filled bladder.



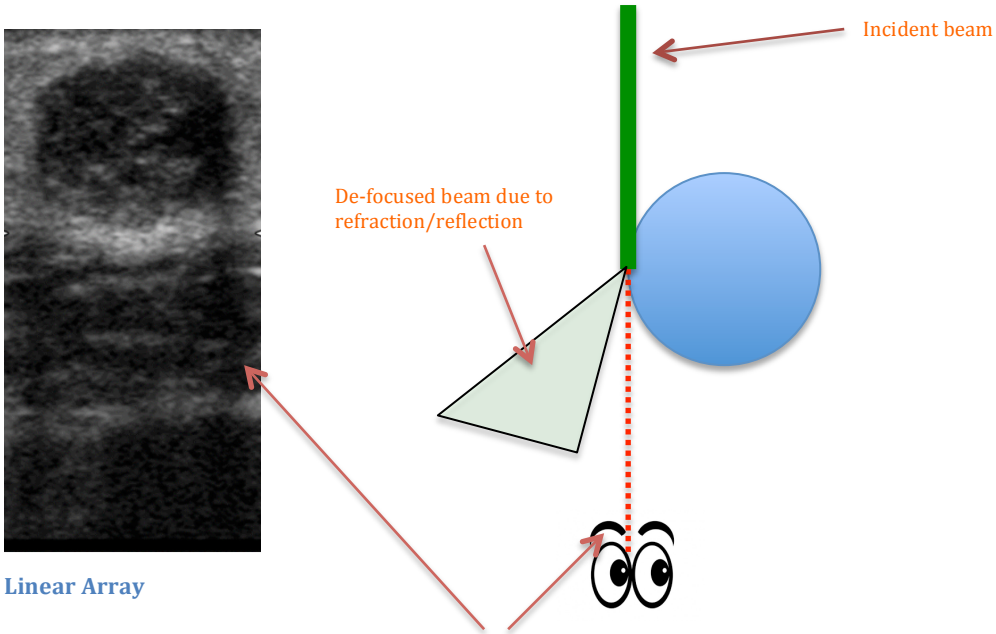
Posterior acoustic enhancement Liver cyst

Edge artifact

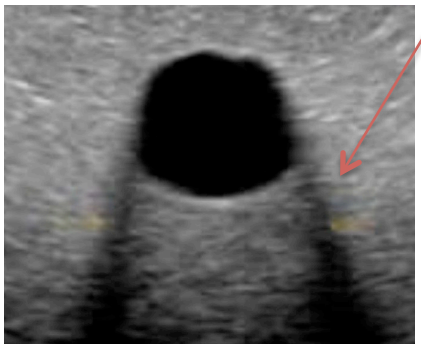
EDGE ARTIFACT

This occurs at the edge of rounded/circular objects where the ultrasound beam strikes the edge undergoing reflection and refraction defocussing and broadening the beam.

Broadening of the beam reduces intensity and therefore reduces received echo amplitude. The result is shadowing at the edge of the structure displayed in a line of sight fashion



Linear Array



Curvilinear Array

DEPTH ARTIFACTS

These result in incorrect display of depth of tissue in the image, the cause being:

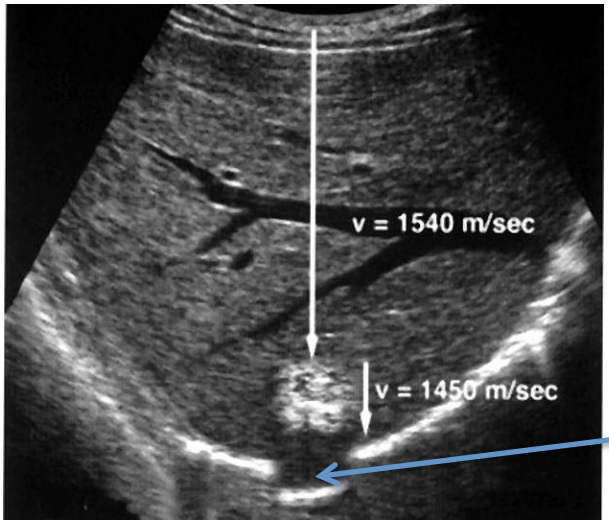
- Differences in propagation speed
- Reverberation artifacts (Ring down, comet tail)
- Range ambiguity

PROPAGATION SPEED ARTIFACT

Different tissues have variable propagation speeds for sound. Remembering the Pulse Echo Principle where time for echo reception is directly proportional to the distance travelled. If an area being scanned has a different propagation speed to surrounding tissue it will variably affect transmission and reception of echoes through that area.

- A low propagation speed will delay returning echoes meaning those echoes will be displayed at a relatively greater depth in the image

- A higher propagation speed will mean echoes return earlier, and the area will be displayed at a relatively more superficial depth



Lower propagation speed through fatty lesion (c= 1450 m/s) in the liver (c= 1540 m/s) resulting in image displacement deeper of the related portion of the diaphragm

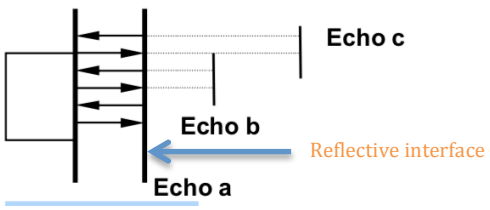
REVERBERATION ARTIFACTS

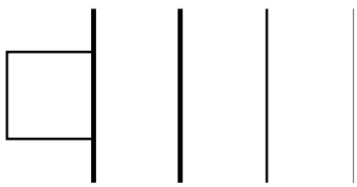
Reverberations are multiple representations in the image of the same interface.

- They occur because of repeated reflections of the ultrasound waves between two interfaces
- They are generated by high-level acoustic impedance mismatch/high reflection coefficient interface:

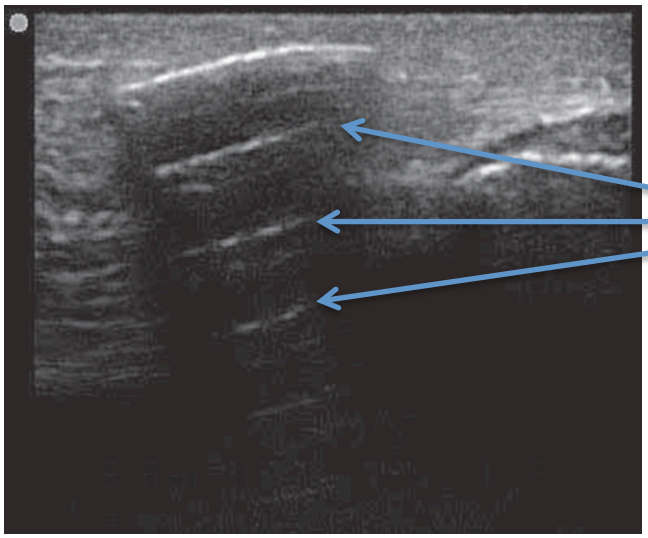
- Tissue/bone
- Tissue/lung
- Calcified structures
- Foreign bodies

- Echoes are placed in the display according to the time taken for their return to the transducer after the transmission.
- If an echo repeatedly reflects (reverberates) between two interfaces each successive returning echo will be perceived as coming from twice the distance as the reflection before, and will be placed at twice the distance on the display.

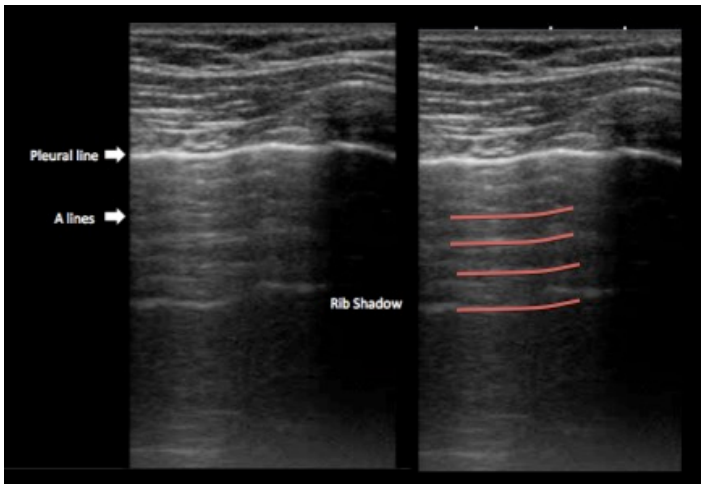




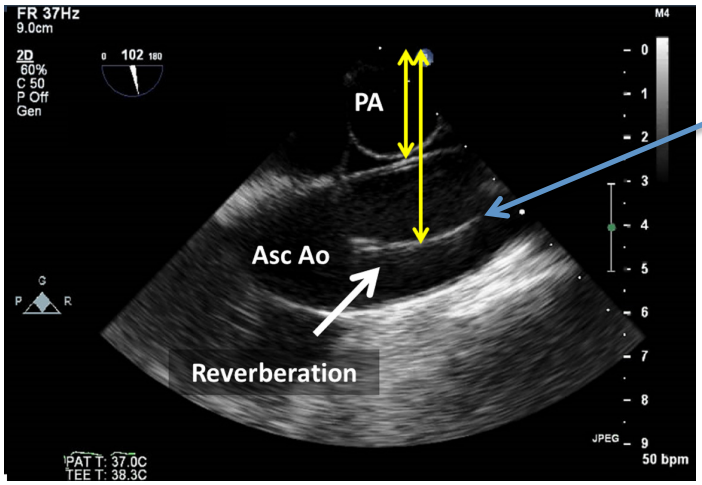
Reverberations at repeating depths



Reverberations of a metallic foreign body



A-line reverberations of the pleural line



Reverberation artifact anterior wall of the proximal ascending aorta giving the impression of an artifactual dissection flap

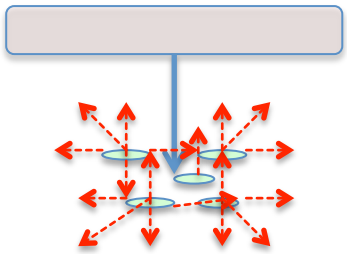
RING-DOWN REVERBERATION ARTIFACT

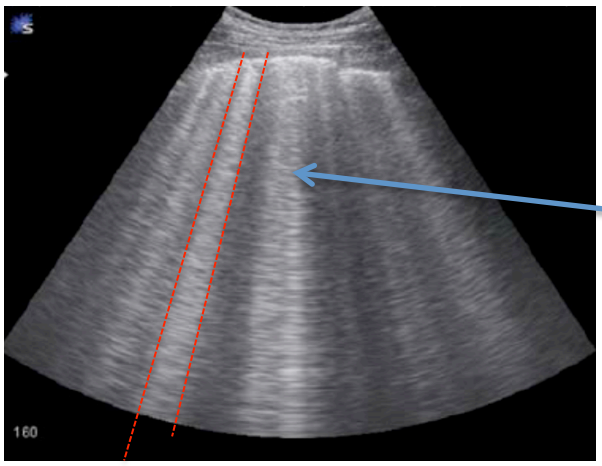
This is reverberation that occurs between multiple small gas bubbles usually suspended in fluid, if in fluid there is little attenuation. Examples of this are B-lines in wet lungs, and ring-down from gas bubbles in fluid filled bowel.

- The echoes reverberate between multiple small bubbles with echoes returning not being from a discrete point

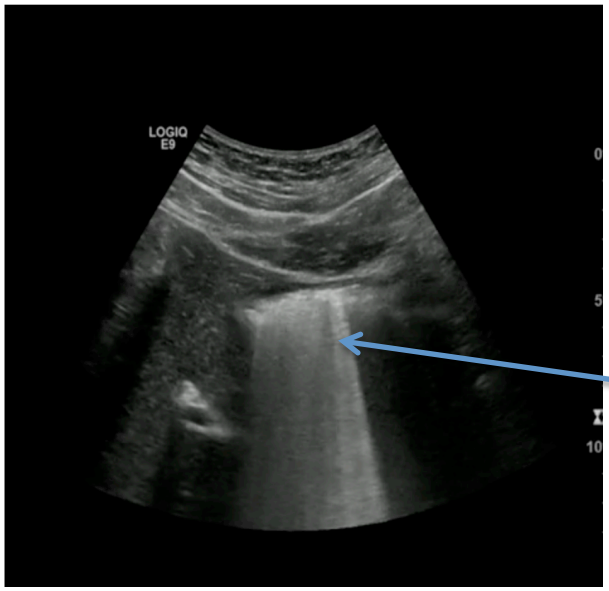
- Some theories include resonant ringing of air bubbles as the origin of ring-down

- The reflection coefficient of the bubbles is high, so high intensity echoes are produced through the whole depth of the image





Multiple B-line ring-down artifacts from sub-pleural fluid that may occur in pulmonary edema and also seen in pleural thickening. (Less than 3 B-lines per field of view is likely normal)



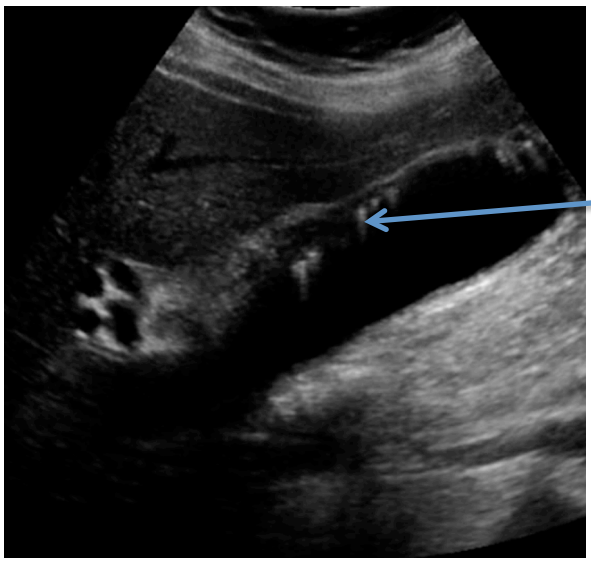
Ring down artifact due to gas filled bowel

COMET TAIL REVERBERATION ARTIFACT

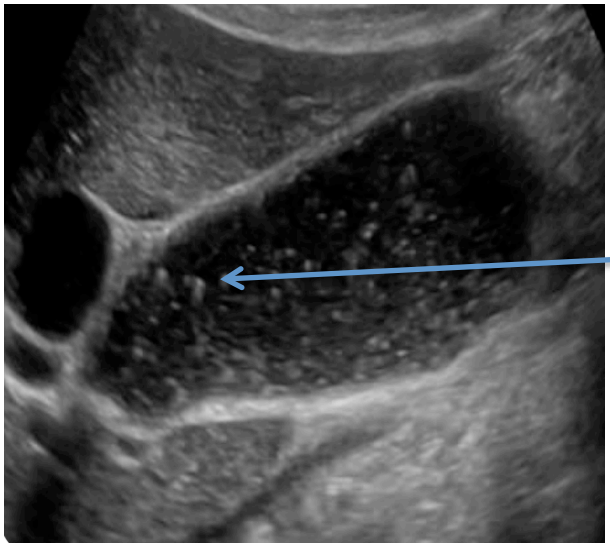
This is a type of reverberation artifact caused by reverberation between very closely spaced interfaces, which are not discernable on the ultrasound image.

- Usually this occurs between groups of small calcifications, which have less efficient reflection compared to gas bubbles in ring-down reverberation.

- The result is short tapering artifact resembling a comet tail.



Comet-tail reverberation artifact seen in adenomyomatosis of the gallbladder



Gallbladder microlithiasis causing multiple comet-tail artifacts

BEAM DIMENSION ARTIFACTS

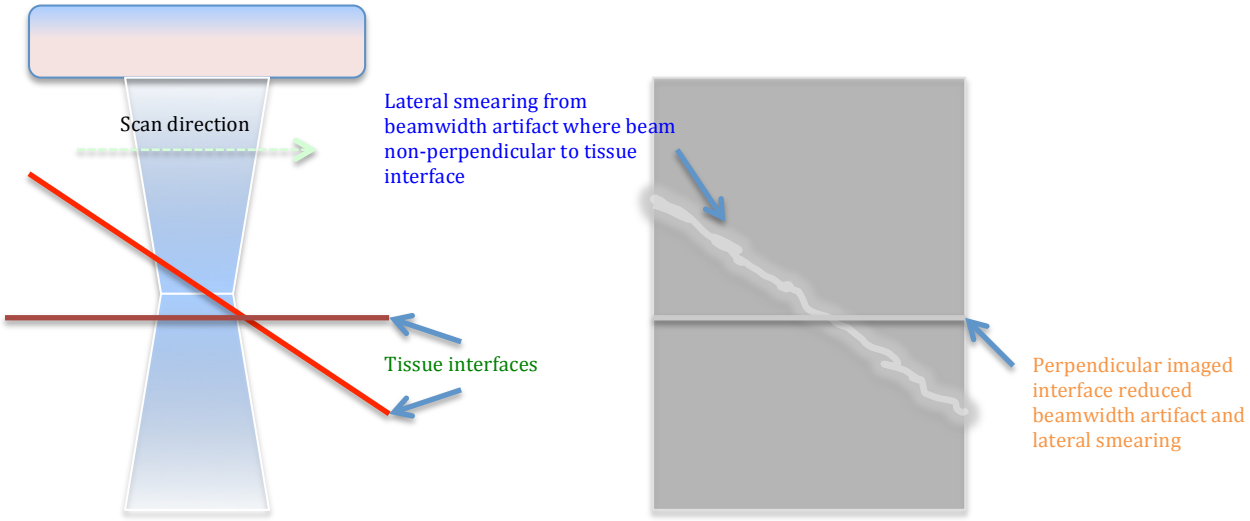
Artifacts associated with the physical construct of the beam dimensions and intensity:

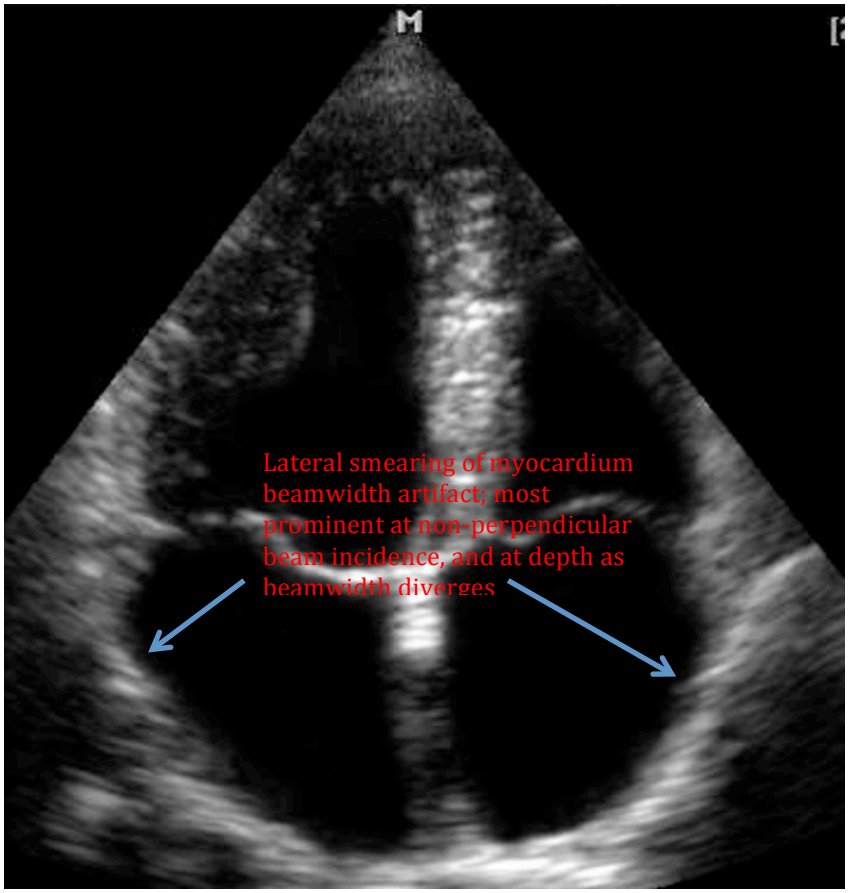
- Beamwidth or scan plane dimension
- Slice thickness or elevation plane dimension
- Sidelobe and Grating artifacts

BEAMWIDTH ARTIFACT

The beamwidth cause degradation of the lateral resolution by the dimension of the beam at the point of interrogation of a tissue interface, the result being lateral smearing. This

- Lateral smearing is least where the beamwidth is at its narrowest i.e. the focal point/zone.
- When the beam is at perpendicular incidence to an interface lateral smearing is largely eliminated





- Lateral smearing can have important clinical consequences, such as appearance of valvular thickening, and affecting clinical measurements e.g. Gallbladder wall thickness.

- When measuring an object, such as the Gallbladder wall thickness, it is important to minimize lateral smearing in order to get an accurate measurement. This is achieved by ensuring a narrow beamwidth:

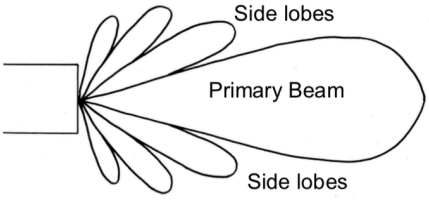
- Ensure transducer face is at near perpendicular incidence to the Gallbladder wall

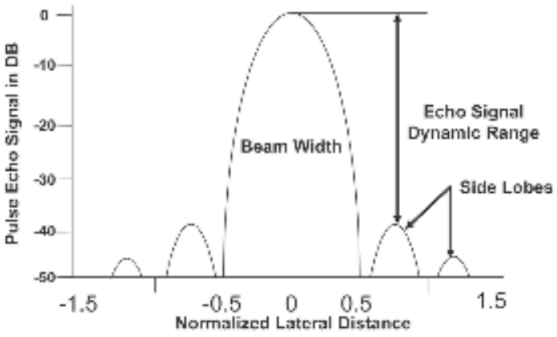
- Place the focal zone at the level of the wall being measured

- Also helpful to use pre-write dynamic zoom function to enlarge area to be measured

SIDELOBE ARTIFACT

Transducers produce side lobes, which consist of multiple low-intensity beams (at least 20dB less than the main beam, or a 100 fold reduced intensity) symmetrically located outside of the central ultrasound beam axis.

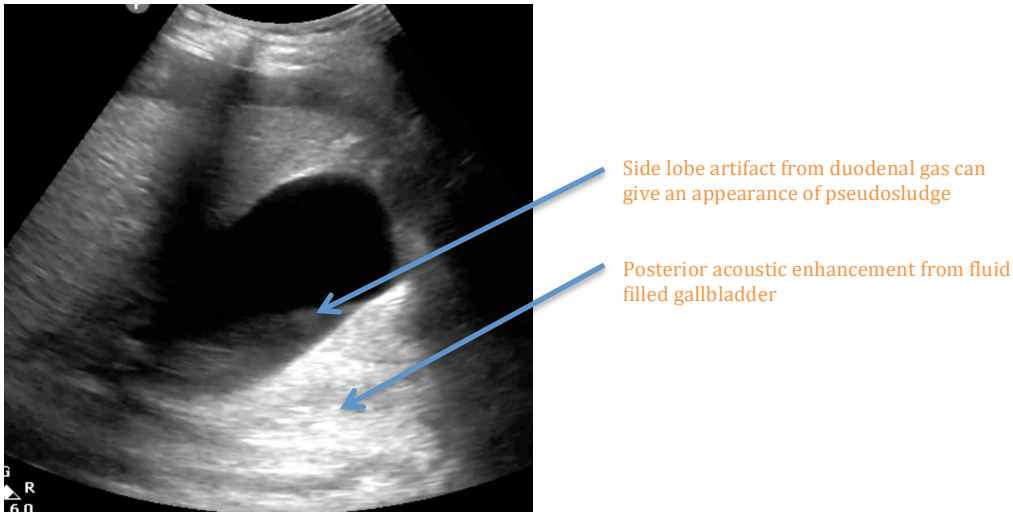


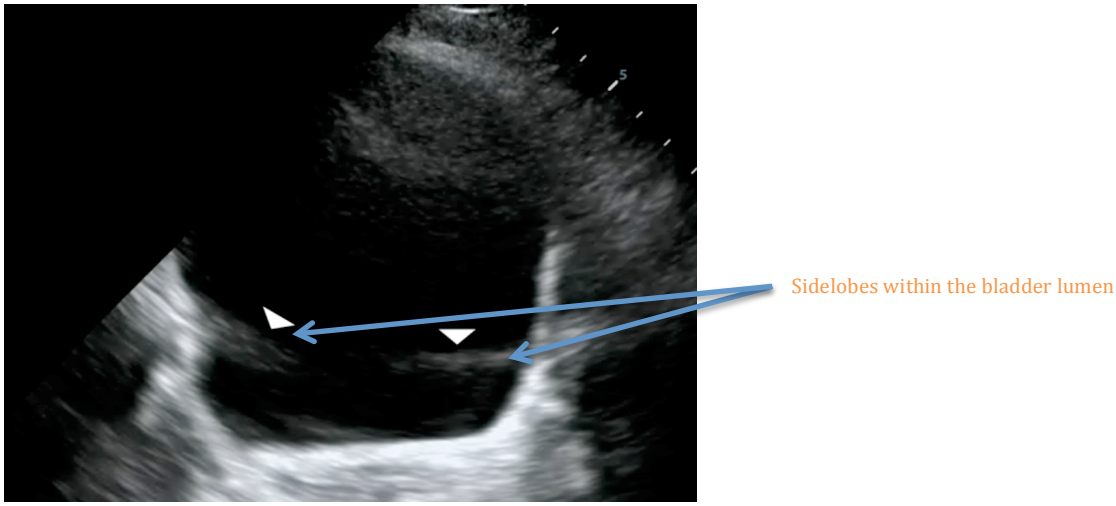


Although the echoes generated by side lobes originate outside of the main beam central axis; if they encounter a strong reflector the echoes appear as specular or diffuse reduced intensity artifactual echoes in the image, either side of reflector location, as if originating from the central beam axis.

- Strong reflectors will be scanned by the central beam along with the sidelobes as the transducer acquires an image

- Can be seen in a variety of imaging situations, such as in the gallbladder from duodenal gas, from reflective boundary between foetus and amniotic fluid, from cardiac valves, cysts, and within bladder from surrounding bowel gas.





- Side lobes are reduced by the ultrasound machine via apodisation, which de-emphasises the outer aperture of the transducer by reducing the amplitude of transmit and receive pulses from these portions of the transducer

- Apodisation does cause slight increase in beamwidth (narrow beamwidth dependent on large aperture transducer and high frequency ultrasound)

- **Grating lobes** are another type of side lobe but if they occur they are of greater intensity, similar to that of the central beam.

- They occur via constructive superposition of transmit pulses of adjacent elements, and are transmitted at an angle away from the central axis.

- Any echoes from grating lobes are of high intensity and would be displayed as if from the central axis in the image.

- Transducer elements are constructed in certain geometry in order to largely eliminate the potential for grating lobes to occur.

SLICE THICKNESS ARTIFACTS

Slice thickness artifacts arise from the beam dimension of the transducer in the elevation plane/slice thickness. This is considerably larger than that of the beamwidth dimension in the scan plane.

- It is essentially relates to the ability to discriminate two points as distinct in a direction perpendicular to the imaging plane.

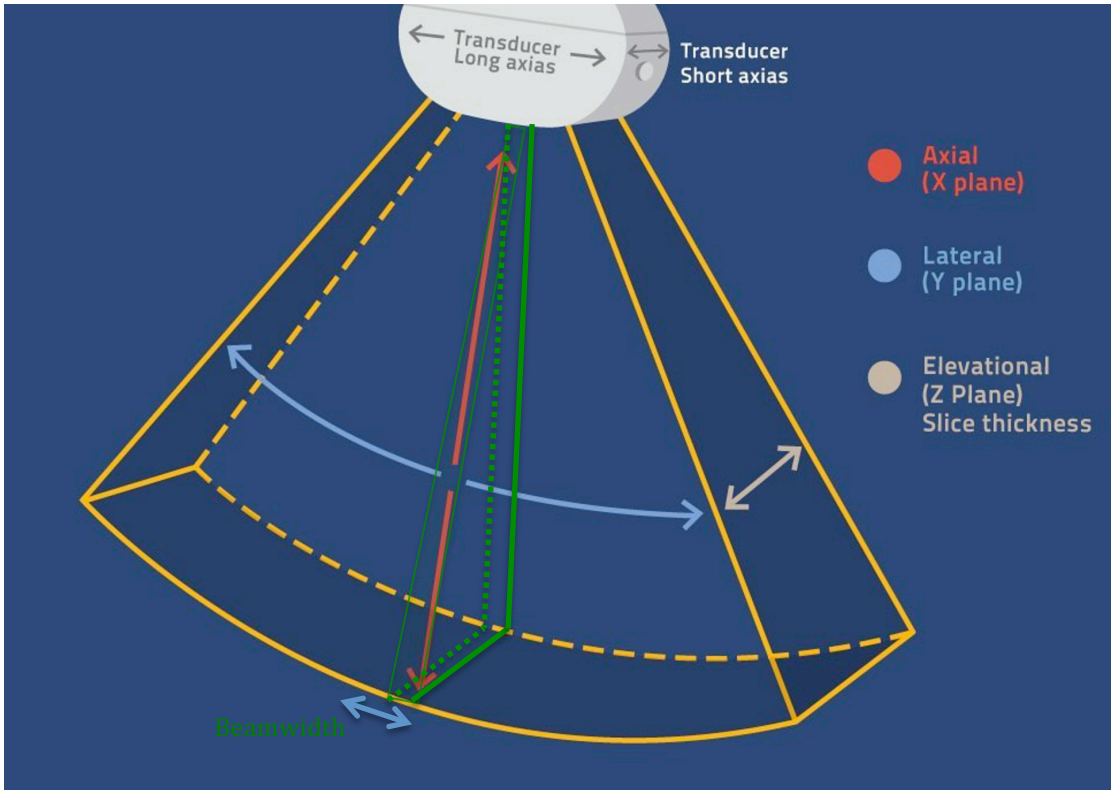
- Elevation resolution is usually the most limited component of spatial resolution and is less in the near and far fields, similar to scan plane resolution.

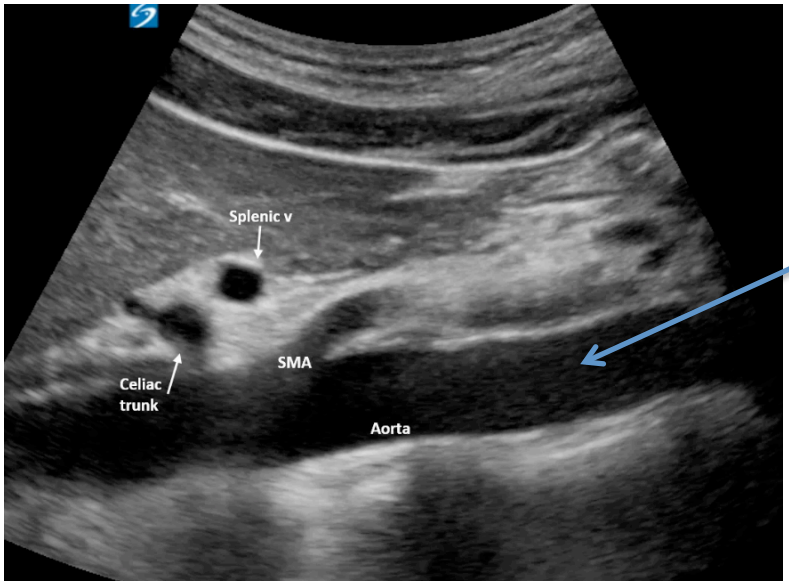
- Transducers use acoustic lenses to focus the elevation plane

- As the beam scans along the length of the transducer it acquires echoes from a volume with a relatively thick slice thickness (Z elevation plane)

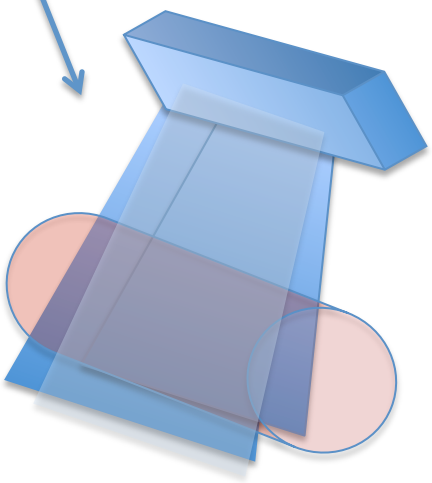
- Slice thickness artifact is caused by echo-signal averaging within the slice thickness

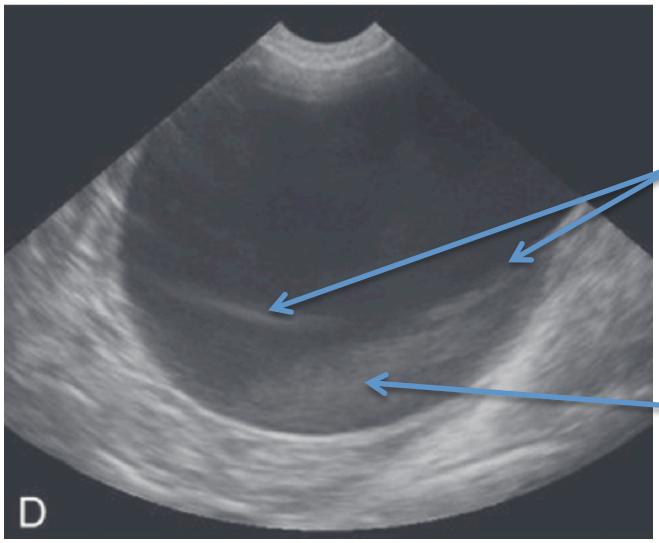
- It is often clinically noticeable as low-level echoes in an anechoic structure such as the bladder, gallbladder, and blood vessels





Long axis view abdominal aorta showing internal echoes relating to volume averaging that occurs in slice thickness artifact





Sidelobe artifact

Pseudosludge in bladder lumen from slice thickness artifact

BEAM PATH ARTIFACTS

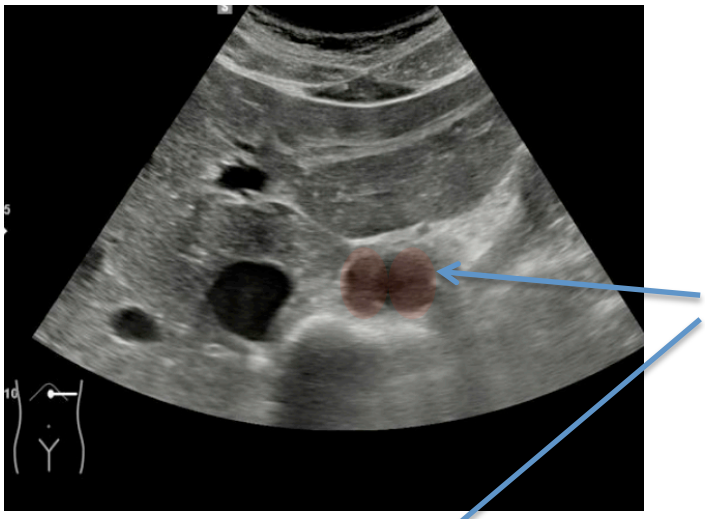
These artifacts are related to refraction and reflection that beams will undergo depending on the interactions with different tissue planes (tissue acoustic impedance, propagations speeds), and the angle of incidence with those planes.

- Ultrasound machines make an important assumption relating to beam path in image production:

- Transmit pulses and echoes travel in a straight line (line of sight)

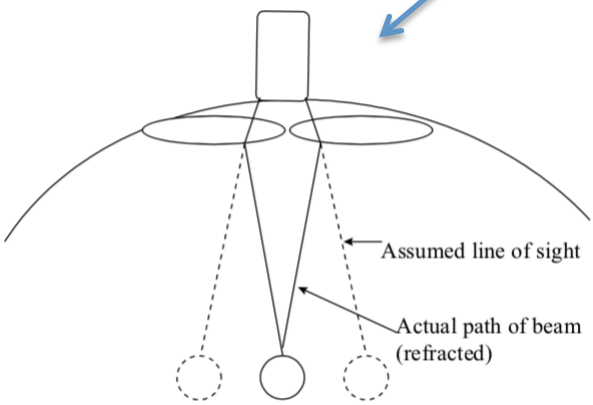
REFRACTION ARTIFACTS

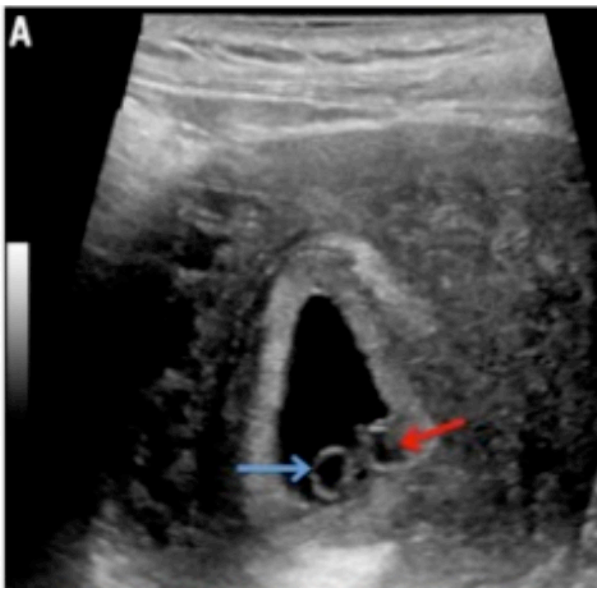
Refraction artifacts are generally not significant in imaging except in some particular situations. In particular the rectus muscles can act as dual biconvex lens, which can produce a double image e.g. abdominal aorta, mesenteric vessels, gestational or yolk sac in early pregnancy.



Artifactual double aorta seen in transverse scans through rectus muscles, which act as biconvex lens as the transducer scans from left to right

If the transducer were moved away from the midline only a single aorta image would be seen.





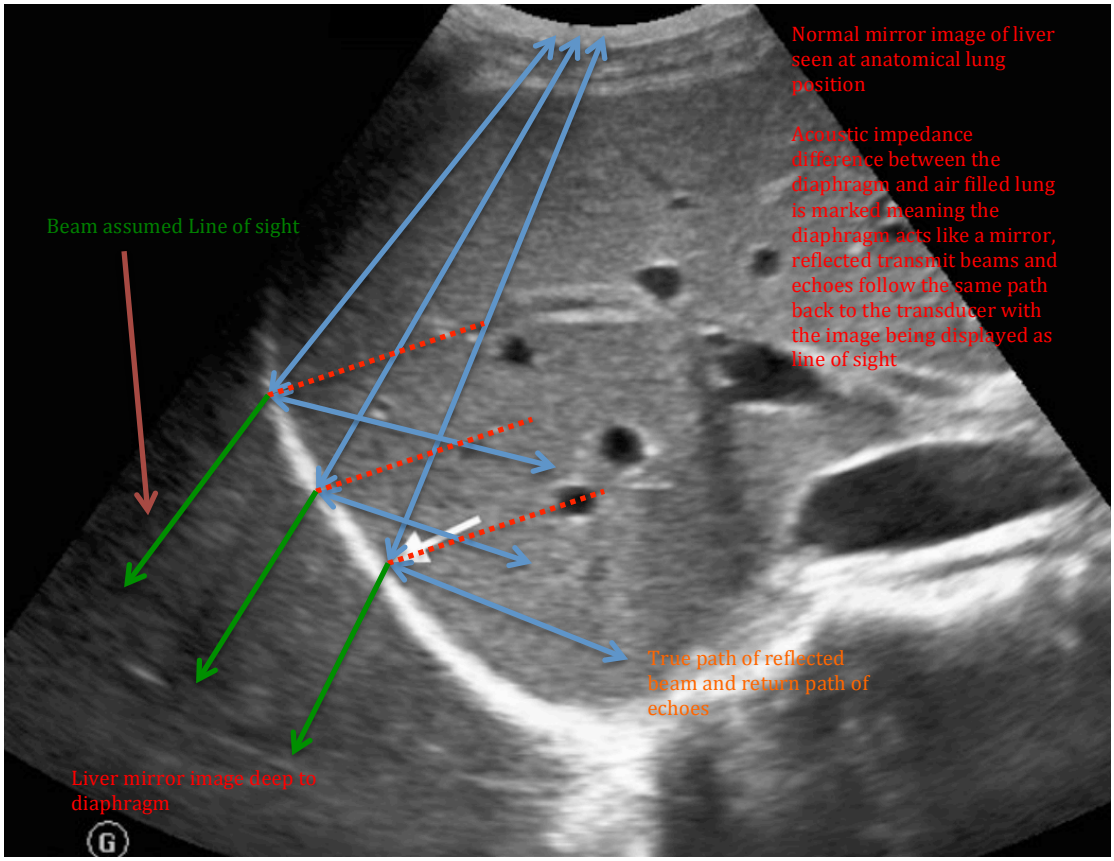
Midline trans abdominal scan through rectus muscles in early gestation showing a double artifactual yolk sac (Blue arrow true yolk sac)

REFLECTION ARTIFACTS

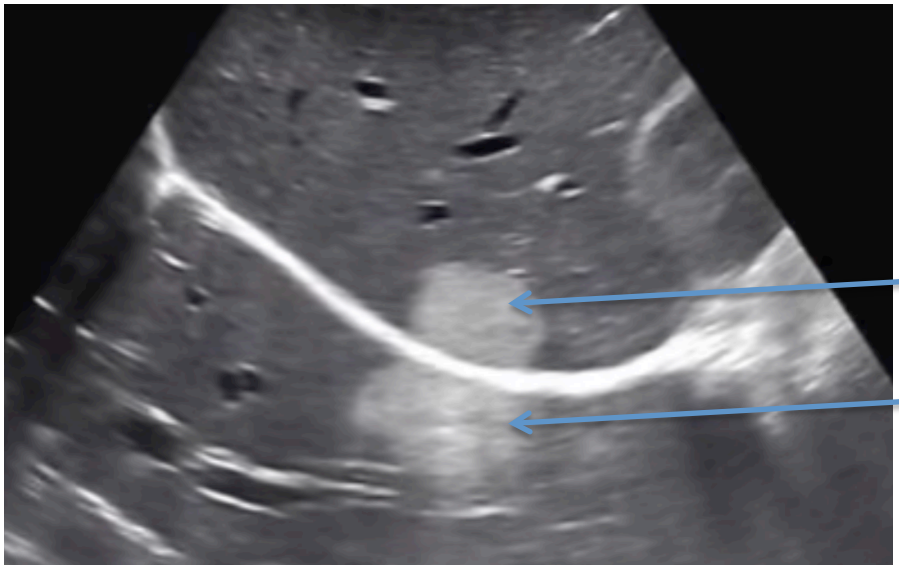
- **Mirror Image** artifacts, these occur at specular (mirror like) type tissue interfaces (Marked differing acoustic impedances).

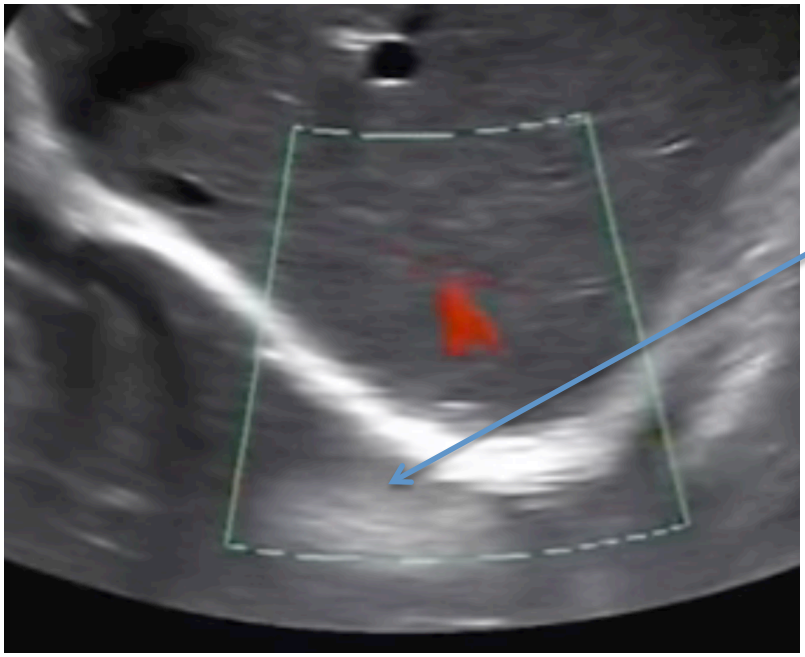
- The angle of incidence at the interface will equal the angle of reflection

- If incident angle is perpendicular to the interface no reflection will occur



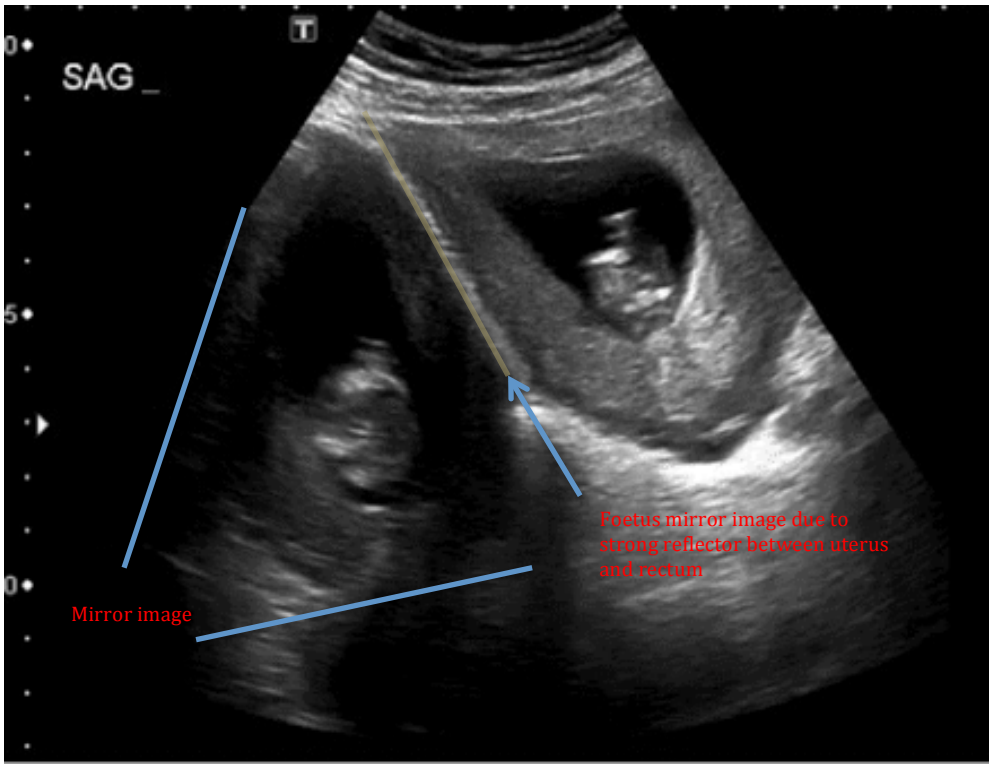
Normal Lung Appearance





Mirror image of the haemangioma is displayed but true haemangioma is not in the scan plan so not seen in the image

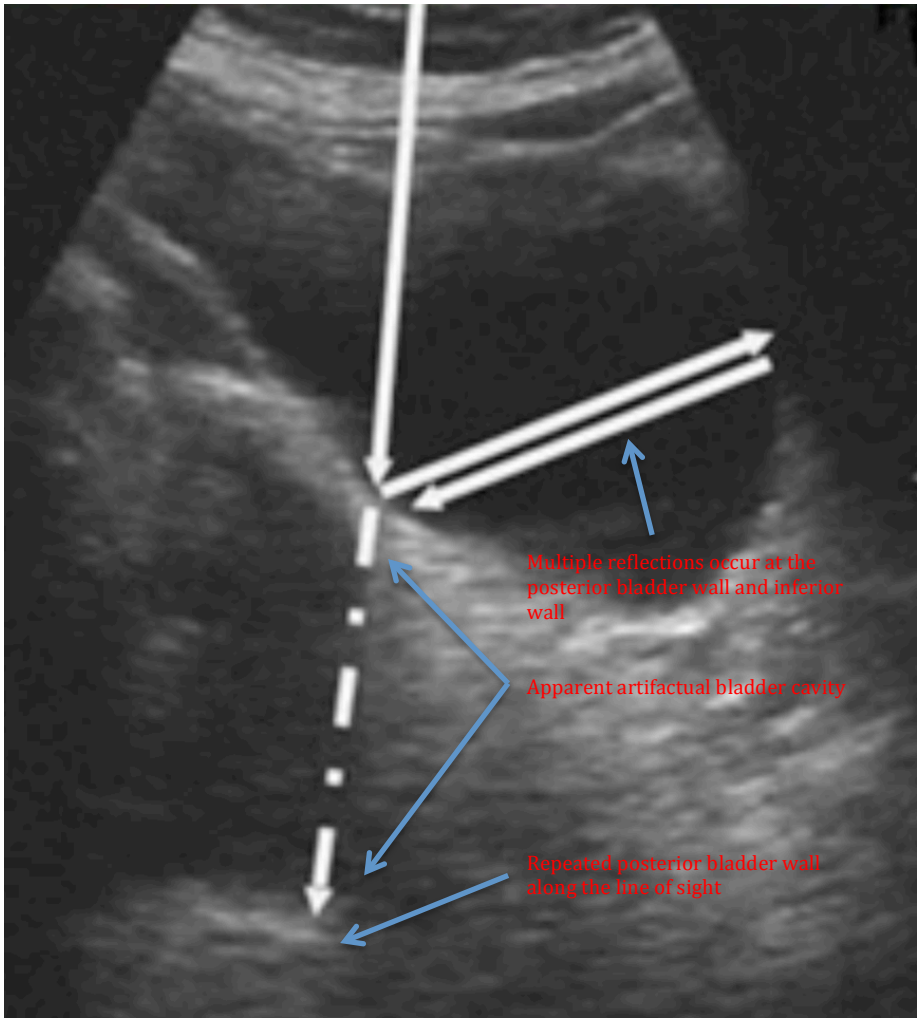
The beams strike the diaphragm and reflect out of the scan plan interrogating the liver haemangioma



- **Multipath artifact** is when reflectors occur at incorrect depths in the image, when reflections take shorter or longer paths to the incident beam back to the transducer.

- Occurs when the beam reflects off more than one reflective interface causing echoes returning variable intervals, usually delayed

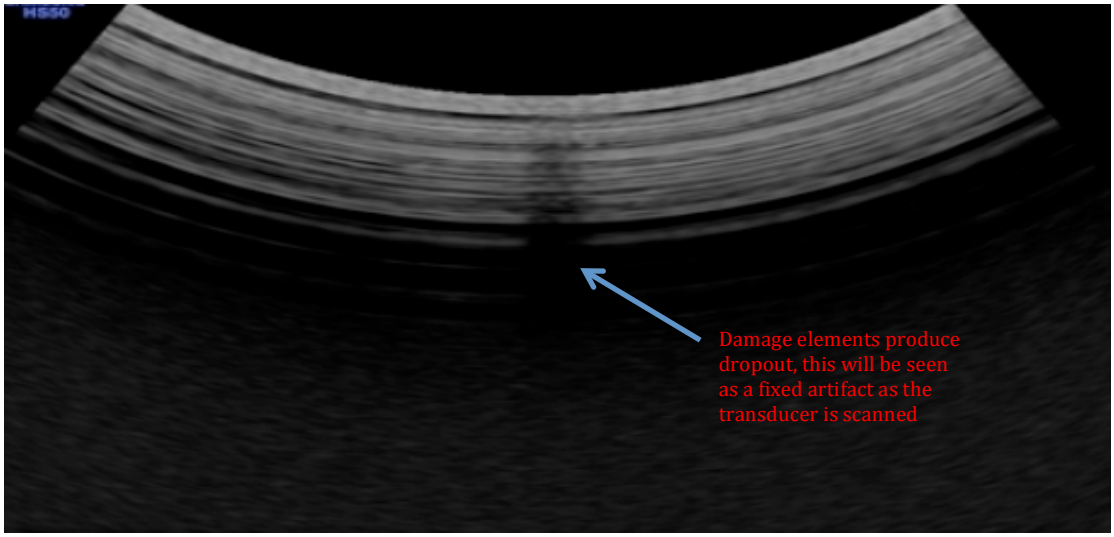
- This means the reflective interface is perceived again along the central axis at a greater depth in the image displayed.



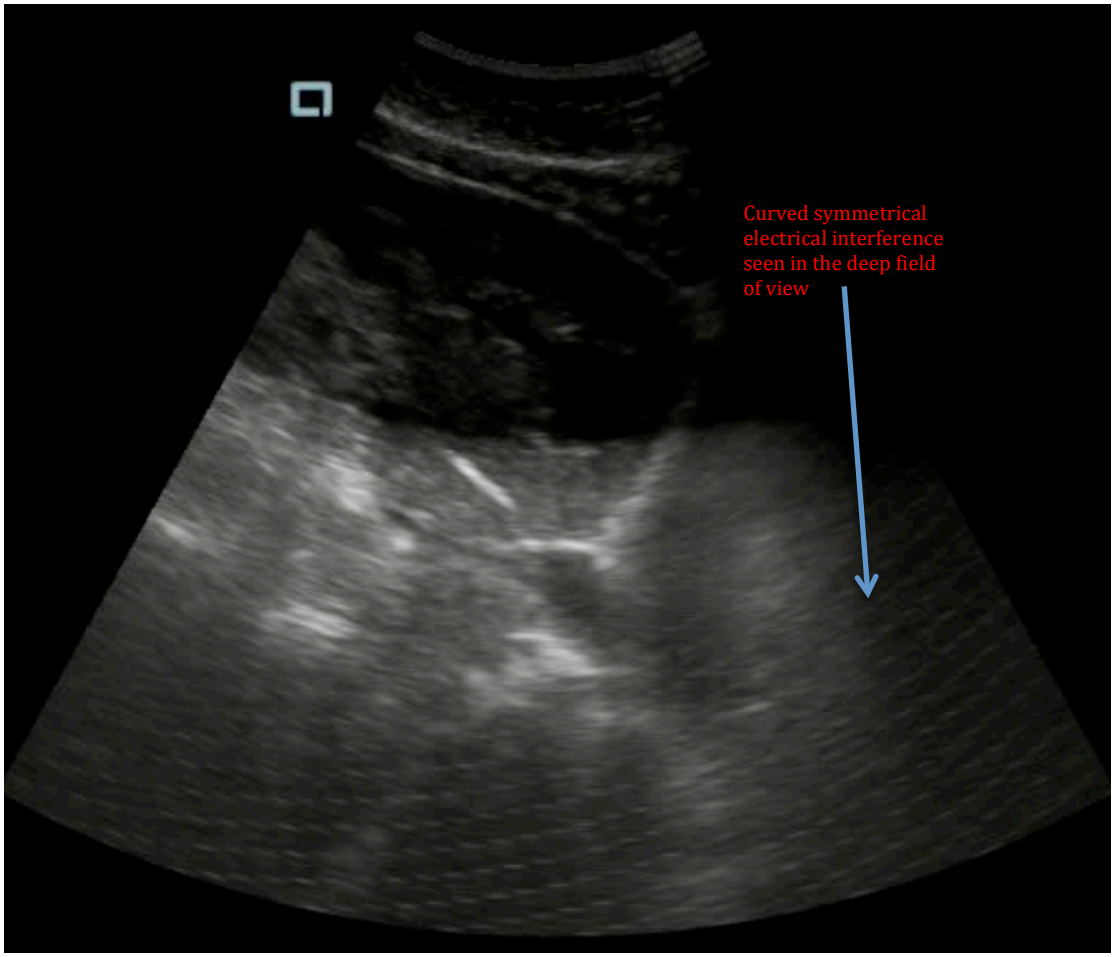
EQUIPMENT AND ELECTRICAL ARTIFACTS

PROBE DROPOUT

This occurs from transducer element damage resulting in fixed areas of drop out artifact.



ELECTRICAL INTERFERENCE



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