CHAPTER FOURTEEN

ULTRASONOGRAPHY BASIC PHYSICS & INSTRUMENTATION

Interaction between Ultrasound and Matter

I. **Acoustic impedance**: The ability of living tissue being imaged to resist or impede the transmission of sound.

This depends on the elasticity and density of the tissue encountered and the differences between adjacent tissues.

Soft tissue impedance varies slightly allowing sound to be reflected and to pass through so a composite image of the reflected echoes can be made of the tissue.

Air and bone have great differences in acoustic impedance and are barriers to sound waves.

II. **Attenuation**: As sound travels through tissue it loses intensity either through scatter or absorption.

Scatters occur when sound reflects in many directions from an irregular tissue interface and never reach the transducer.

Absorption occurs due to molecular friction from the sound passing through the tissues and dissipating as heat.

Attenuation limits the depth of interrogation. It depends on the frequency of the transducer. Some tissue e.g. fat (in hepatic lipidiosis) attenuates more.

III. **Reflection:**

- Sound is reflected at all tissue interface
- Amount of reflection depends on the difference in acoustic impedance of his two tissues.
- The sound reflected to the transducer is what makes up the displayed composite image as white dots.

Sound waves: classifications

Sound wave is classified by (1) wavelength (i) (ii) frequency and (iii) velocity.

Wavelength: sound waves travel through a media and form longitudinal from one band of compression or rarefaction to the next.

Frequency (f): This is the number of complete cycles per unit time it is inversely related to wavelength.

Velocity: This is the speed the sound travels through a media (1540m/s is soft tissue). The computer measures the time each wave takes for the round trip and thus calculates the depth where the sound was bounced from a reflector and displays the echo as a white dot at a corresponding depth.

V= f

V= velocity of sound in medium (m/s)

F= frequency (Hertz)

= wavelength (m)

Transducer

- The transducer converts the voltage from the machine into an ultrasound pulse and then converts the returning echo into voltage.
- It composes of an element with a material called piezoelectric (pressure electricity). This element contracts or expands when voltage is applied on the other hand. It generates voltage when pressure is applied.
- Transducer could either be (i) Sequenced a group of elements moving across the beam (linear and convex). (ii) Phased short delays are placed in the voltages that drive the elements. So that the first element is fired just before the second. This allows focusing, multiple focusing points and beam steering.

(iii). Annual made up of rings. It allows for focusing and not beams Steering.

- The frequency of the transducer ranges between 2-13 MH2 this is determined by the thickness of the element or a specific voltage. A transducer can have multiple frequency.
- The higher the frequency of a transducer, the higher the resolution and the lower the depth of penetration. Thus there is a trade off between depth and resolution.
- Thus the selection of transducer is based on (1) money / availability (2) patients imaged (3) depth needed (4) resolution needed (5) location of practice.
- The followings may damage the transducer

(1) Gas sterilization (2) Ultra-violet sterilization (3) Dry heat sterilization (4) Autoclaving (5) soaking in chlorine beach

(6) iodine / alcohol (7) Biopsying the end of the probe.

ULTRASOUND MACHINE DISPLAY MODES

- A mode (amplitude mode) = this shows sense of peaks on a graph the higher the intensity of the returning signal the higher the peak at the tissue depth it is not used to display anatomy or motion .it often is used for eye measurements back fat, Pregnancy in pigs.
- B mode (brightness mode)= series of dots on the screen corresponding to the depth the echo was generated from a reflector the brightness of the echo corresponds to the intensity of the returning echo The whiter the dot the more intense the echo the generated image is a 2-D anatomic slice that is continually updated (real time). It is used for diagnostic application.

- M mode (motion mode) A continuous display of a thin slice of organ overtime the echoes are displayed over a moving time oriented based-line the main use is in echocardiography to measure size of heart chambers and motions of valves and wall.
- Doppler Mode: There are four Doppler mode namely (1) Continuous wave Doppler, (2) Pulsed wave Doppler, (3) Colour Doppler, (4) Power Doppler.

  Continuous wave Doppler is performed using 2 piezo-electric crystals housed in one transducer. One crystal continuously emits sound waves while the other receives it. It accurately measures Doppler shift and much higher velocities can be recorded.

  Pulsed- wave Doppler has one crystal that both emits and receives sound waves. It is used in combination with B mode imaging. This is referred to as Duplex Doppler. It has the advantage of being able to select blood vessel for interrogation.

  Colour Doppler is a variation of Pulsed- wave Doppler. Blood velocities are color coded depending on manufacturer. One color represents flow towards the transducers while the other color represents flow away from the transducer. Color Doppler only display mean velocity while the maximum velocity that can be displayed is limited.

Power Doppler is a signal- processing method that analyzes the total strength of the Doppler signal while ignoring the direction. It creates a color map of the Doppler shift where the hue and the brightness of the color represent the power of Doppler signal.

Ultrasound Interactions

Mineral- hypertonic surfaces/shadow

Air Hyper Echoic Surface Reverberation

Connective tissue moderately hyperechoic may attenuate sound

Fat – hyper echoic depends on where it is attenuated

Oran/soft tissue surface is parenchyma/granular texture depends on reflector present.

Blood/urine/Bile usually anechoic may have some reflectors present through transmission occurs.

Terminology

Echogenic- relates to brightness of returning echoes

Isoechoic- equal echoes to surrounding echoes

Hyperechoic- brighter or whiter relative to normal or reference tissue stronger reflector

Hypoechoic- less bright relative to normal or reference tissue weaker reflector anechoic no echoes black.

Complex areas of increased echogenicity intermixed with hypo to anechoic areas.

Heterogeneous dissimilar echo pattern.

Homogenous uniform echo pattern.

ULTRASOUND ARTIFACTS

Artifact is a misrepresentation of structures caused by some characteristics of the imaging technique. Although radiographic artifacts are undesirable as it hinders evaluation of image, sonographic artifacts enhances evaluation of structures by providing insight regarding the composition of the structures. Ultrasound artifacts include

1. Acoustic Enhancement: This is a region of increase echogenecity behind structures of low attenuation. Examples are seen distal to urinary bladder and the gall bladder.

2. Acoustic Shadowing: This is a region of decrease echogenecity distal to structures of high reflectivity making the primary beam to be completely attenuated or absorbed. Examples are seen in soft tissue gas interface (lung/bowel), renal calculi, cystic calculi e.t.c

3. Mirror Image: It is a duplication of image on the other side of a strong reflector. It is commonly seen in the liver where the reflection from the ribs causes duplication of gall bladder image.

4. Reverberation: These are multiple hyperechoic foci which occur at regular intervals. It occurs when sound waves encounter an area of high reflectivity resulting in multiple reflection of the image. Example is seen with intestinal gas.

5. Side lobes: These are secondary beam that emanate in a different direction than the primary sound beam. It results in an error in positioning of returning echo.

6. Aliasing: This is a Doppler artifact which occurs when pulse repetition frequency is too low. It is characterized by wrong display of Doppler signal on the opposite direction of the base-line.

7. Range Ambiguity: It occurs when the pulse repetition frequency is high enough that not all the returning echoes are received before the next sound wave pulse is sent. The lagging echoes are misinterpreted as being close to the transducer than they actually are. This creates ghost images between the structures of interest and the skin surface.