KARNATAKA RADIOLOGY EDUCATION PROGRAM

ULTRASOUND

Sound is a mechanical, longitudinal wave that travels in a straight line
Sound requires a medium through which to travel
Ultrasound is a mechanical, longitudinal wave with a frequency exceeding the upper limit of human hearing, which is 20,000 Hz or 20 kHz.
Medical Ultrasound 2MHz to 16MHz

Basic Ultrasound Physics

Amplitude - oscillations/sec = frequency - expressed in Hertz (Hz)

ULTRASOUND – How is it produced?

Produced by passing an electrical current through a piezoelectrical (material that expands and contracts with current) crystal.

Ultrasound Production

Transducer produces ultrasound pulses (transmit 1% of the time)
These elements convert electrical energy into a mechanical ultrasound wave
Reflected echoes return to the scan-head which converts the ultrasound wave into an electrical signal .

Frequency vs. Resolution

The frequency also affects the QUALITY of the ultrasound image
The HIGHER the frequency, the BETTER the resolution
The LOWER the frequency, the LESS the resolution

A 12 MHz transducer has very good resolution, but cannot penetrate very deep into the body
A 3 MHz transducer can penetrate deep into the body, but the resolution is not as good as the 12 MHz
Low Frequency 3 MHz , High Frequency 12 MHz

Image Formation Electrical signal produces ‘dots’ on the screen
Brightness of the dots is proportional to the strength of the returning echoes
Location of the dots is determined by travel time. The velocity in tissue is assumed constant at 1540m/sec
Distance = Velocity Time

Interactions of Ultrasound with

Tissue

Acoustic impedance (AI) is dependent on the density of the material in which sound is propagated - the greater the impedance the denser the material.

Reflections comes from the interface of different AI’sgreater of the AI = more signal reflected works both ways (send and receive directions)

Interaction of Ultrasound with Tissue

Greater the AI, greater the returned signal largest difference is solid-gas interface

we don’t like gas or air.
we don’t like bone for the same reason
GEL!!
Sound is attenuated as it goes deeper into the body

Interactions of Ultrasound with Tissue

1. **Reflection**
2. **Refraction**
3. **Transmission**
4. **Attenuation**

Reflection
The ultrasound reflects off tissue and returns to the transducer, the amount of reflection depends on differences in acoustic impedance
The ultrasound image is formed from reflected echoes –transducer

Angle of incidence = angle of reflection
Refraction
reflective
refraction
Scattered
echoes
Incident

Angle of incidence = angle of reflection

Transmission
Some of the ultrasound waves continue deeper into the body
These waves will reflect from deeper tissue structures
transducer

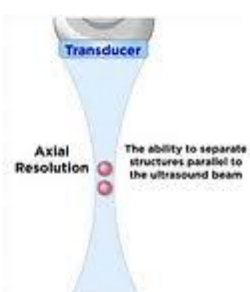
Attenuation
Defined - the deeper the wave travels in the body, the weaker it becomes -3 processes: reflection, absorption, refraction
Air (lung)> bone > muscle > soft tissue >blood > water.

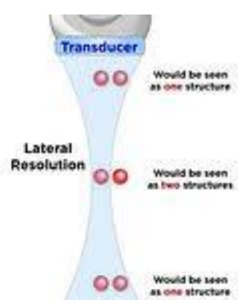
Reflected Echo's Strong Reflections = White dots
Diaphragm, tendons, bone
'Hyperechoic'

Reflected Echo's Weaker Reflections = Grey dots Most solid organs, thick fluid – 'isoechoic'

Reflected Echo's No Reflections = Black dots
Fluid within a cyst, urine, blood
'Hypoechoic' or echofree

What determines how far ultrasound waves can travel?
The FREQUENCY of the transducer
The HIGHER the frequency, the LESS it can penetrate
The LOWER the frequency, the DEEPER it can penetrate
Attenuation is directly related to frequency





Accomplishing this goal depends upon...

Resolving capability of the system

axial/lateral resolution

spatial resolution

contrast resolution

temporal resolution

Lateral resolution in ultrasound refers to the ability to discern two separate objects that are adjacent to each other. The ultrasound beam should be narrower than the gap between the two objects in order to resolve them .
At the focal region of the beam, lateral resolution is roughly three times worse than axial resolution in ultrasound, meanwhile, the axial resolution is about one wavelength in size.

Axial resolution in ultrasound refers to the ability to discern two separate objects that are longitudinally adjacent to each other in the ultrasound image. Axial resolution is generally around four times better than lateral resolution.
Axial resolution is defined by the equation: axial resolution = ½ $\times$ spatial pulse length. The spatial pulse length is determined by the wavelength of the beam and the number of cycles (periods) within a pulse

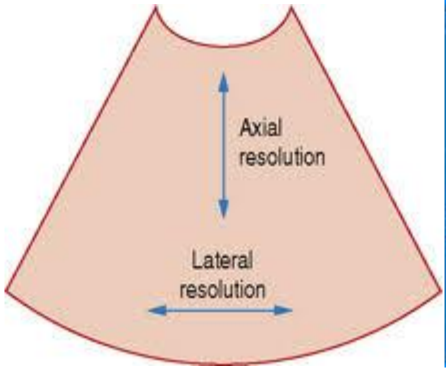
Elevational resolution represents the extent to which an ultrasound system is able to resolve objects within an axis perpendicular to the plane formed by the axial and lateral dimensions. As one component of overall spatial resolution, the elevational axis represents the height or "thickness" of the beam itself (or slice thickness).

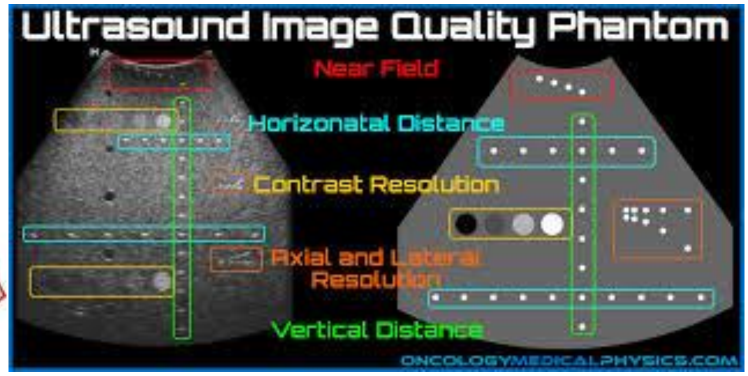
Temporal resolution in ultrasound represents the extent to which an ultrasound system is able to distinguish changes between successive image frames over time (i.e. movement). Temporal resolution is chiefly determined by the image frame rate of the system (measured in Hertz), which may vary depending on a number of factors. Overall, an increased frame rate equates to an increased likelihood of discerning rapid movements (e.g. valve leaflets in echocardiography), and thus improved temporal resolution.

Factors which improve temporal resolution
Factors which increase frame rate, and hence improve temporal resolution include

- **increased propagation speed of sound waves through the tissue**
- **reduced depth of field (as it shortens pulse travel distance)**
- **reduced number of beamlines per field**
- **reduced width of field**

In many instruments, a narrowed field equates to fewer beamlines per field
reduced number of focal points limits beamline duplication. Some new systems can utilize a broad array of focal points for a single field, without significantly restricting temporal resolution





Compiled by: Dr Pravin G U Principal,Prof.RadioDiagnosis .
Sri Chamundeshwari Medical college Hospital & Research Institute,Channapatna,Karnataka.
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