Ultrasound Physics – Cardiovascular Credentialing International (CCI) Registry Review
The CCI adult echocardiography board examination consists of 175 multiple choice questions (150 are graded – 25 questions are test questions for future examinations) – 13% are ultrasound physics questions (approximately 22 questions).

Below is the CCI outline for the ultrasound physics portion of the CCI adult echocardiography board examination. Test information including the complete adult echocardiography test outline is available at the CCI website - https://cci-online.org

E. Applying the Physics of Ultrasound	13%

1. Identify properties of ultrasound waveforms
2. Recognize artifacts
3. Optimize resolution
4. Optimize frame rate
5. Optimize Doppler waveforms
6. Optimize color Doppler
7. Optimize 2D image
8. Optimize 3D image
9. Optimize contrast image

The following is the **MINIMUM MUST KNOW** for the ultrasound physics portion of the CCI examination.

Nature of Ultrasound
Sound is a mechanical, longitudinal (particles of the medium move parallel to the direction of sound travel) wave.
As it travels through the medium, sound creates regions of high pressure, high density called compression and low pressure, low density called rarefaction.
Sound as it travels alters (but does not permanently change) the medium. The four acoustic variables are:
- Pressure – force per unit of area (lbs/in^2, Pascals)
- Density – mass per unit of volume (g/m^3)
- Temperature (F, K, C)
- Particle motion (mm, cm)

Sound cannot travel in a vacuum. It requires a medium.
Sound travels in a straight line.

Nature of Ultrasound – Multiple Choice Questions

1. Sound is a mechanical, ___ wave.
    A. Transverse
    B. Longitudinal
    C. Shear
    D. Oscillating
2. The particles of a medium move parallel to the direction of sound travel. This is a ___ wave.
    A. Longitudinal
    B. Transverse
    C. Shear
    D. Oscillating

3. The region of high pressure, high density of a longitudinal sound wave is called:
    A. Compression
    B. Rarefaction
    C. Refraction
    D. Reverberation
4. The region of low pressure, low density of a longitudinal sound wave is called:
    A. Refraction
    B. Reverberation
    C. Range ambiguity
    D. Rarefaction
5. The units for the acoustic variable pressure are:
    A. Pascals (Pa)
    B. mm
    C. m/sec
    D. sec

Answers: 1.B; 2.A; 3.A; 4.D; 5.A

Frequency (f)

Definition: The number of cycles per second

Units: Hertz (Hz), kilohertz (kHz), MegaHertz (MHz)

Ranges:

Infrasound: < 20 Hz

Audible sound: 20 Hz to 20 kHz

Ultrasound: > 20 kHz

Medical ultrasound 2 MHz to 15 MHz

As f increases – attenuation increases -depth of penetration decreases – spatial (axial, lateral) resolution improves

As f decreases – attenuation decreases - depth of penetration increases – spatial (axial, lateral) resolution degrades

Frequency (f) – Multiple Choice Questions

1. The number of cycles per second is:
    A. f
    B. T
    C. Lambda
    D. c
2. The units for f are:
    A. Hz
    B. mm
    C. cm
    D. m/sec
3. The range for audible sound is:
    A. < 20 Hz Infrasound
    B. 20 to 20000 Hz
    C. > 20 kHz >20,000Hz
    D. 2 MHz to 15 MHz the range we use imaging

4. As f increases, attenuation:
    A. Increases
    B. Decreases
    C. Remains unchanged
    D. Cannot be predicted
5. As f decreases, attenuation:
    A. Increases
    B. Decreases
    C. Remains unchanged
    D. Cannot be predicted
6. As f increases, depth of penetration:
    A. Increases
    B. Decreases
    C. Remains the same
    D. Dependent on the medium
7. As f decreases, depth of penetration:
    A. Increases
    B. Decreases
    C. Remains the same
    D. Dependent on the medium
8. As f increases, spatial (axial, lateral) resolution:
    A. Improves
    B. Degrades
    C. Remains the same
    D. Dependent on the medium
9. As f decreases, spatial (axial, lateral) resolution:
    A. Improves
    B. Degrades
    C. Remains the same
    D. Dependent on the medium

Answers: 1.A; 2.A; 3.B; 4.A; 5.B; 6.A; 7.A; 8.A; 9.B

Tissue Harmonic Imaging (THI)

Definition: Transmits at a low fundamental frequency (e.g.; 1.8 MHz) – receives and displays twice the fundamental frequency (e.g.; 3.6 MHz)

Based on the non-linear sound travel through the medium

Improves depth of penetration, lateral resolution, reduces near field reverberations, reduces side and grating lobes

Tissue Harmonic Imaging (THI) – Multiple Choice Questions

1. Tissue harmonic imaging (THI) is based on:
    A. Doppler principle
    B. Conservation of energy
    C. Conservation of mass
    D. Non-linear sound travel

2. For tissue harmonic imaging, the fundamental frequency is 2 MHz. The received and displayed frequency will be: ___ MHz
    A. 1
    B. 2
    C. 4
    D. 8
3. Which of the following is **NOT** an advantage of tissue harmonic imaging?
    A. Improves frame rate
    B. Improves lateral resolution
    C. Reduces near field reverberations, grating lobes, side lobes
    D. Improves depth of penetration

Answers: 1.D; 2.C; 3.A

Period (T)

Definition: The time it takes for one cycle to occur
Units: Units of time: sec, milliseconds (msec), microseconds (us)
Formula: T (μs) = 1/f

Period (T) Multiple Choice Questions

1. The time it takes for one cycle to occur is
    A. f
    B. T
    C. Lambda
    D. c
2. The sonographer increases the transmit f, T will: ___ and spatial (axial, lateral) resolution will: __.
    A. Increase; Improve
    B. Increases; Degrade
    C. Decrease; Improve
    D. Decrease; Degrade
3. Frequency decreases, T will: _____, spatial resolution (axial, lateral) will: _____.
    A. Increase; Degrade
    B. Decrease; Improve
    C. Remain the same
    D. Dependent on the medium
4. The shorter the pulse, the better the: ___ resolution.
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational
5. Yes or No: Increasing the frequency, increases attenuation, decreases depth of penetration, decreases period, shortens the pulse duration (PD = T x number of cycles in a pulse), improves spatial resolution (axial, lateral).

Answers: 1. B; 2.C; 3.A; .A; 5.Yes

Wavelength (lambda)

Definition: The distance or length covered by one cycle
Units: Units of distance (e.g.; mm)
Formula: Propagation speed (mm/μsec) / f (MHz)

Wavelength – Multiple Choice Questions

1. The distance or length covered by one cycle is:
    A. f
    B. T
    C. Wavelength
    D. c
2. The propagation speed of sound in of soft tissue is 1.54 mm/us. The transmit frequency is 3 MHz. The wavelength is:
    A. 5
    B. .5
    C. .5 mm
    D. .5 mm/sec
3. The propagation speed of sound in soft tissue is 1.54 mm/sec. The transmit frequency is 5 MHz. The wavelength is:
    A. 3
    B. .3
    C. .3 mm
    D. 3 mm/sec
4. For a given medium, as frequency increases, wavelength will:
    A. Decrease
    B. Increase
    C. Remain unchanged
    D. Cannot be predicted
5. For a given medium, as frequency decreases, wavelength will:
    A. Decrease
    B. Increase
    C. Remain unchanged
    D. Cannot be predicted
6. The shorter the pulse, the better the: ___ resolution.
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational
7. Yes or No: Increasing the frequency, increases attenuation, decreases depth of penetration, decreases period, decreases wavelength, decreases spatial pulse length (SPL = wavelength x number of cycles in a pulse), improves spatial (axial, lateral) resolution.

Answers: 1.C.; 2.C.; 3.C; 4.A; 5.B; 6.A; 7. Yes

Propagation Speed (c) (Speed of Sound)

Definition: The rate at which sound travels through a medium

Units: Units of distance/time (e.g.; mm/µsec; mm/sec)

Propagation speed is determined by the medium's density and stiffness

Stiffness (bulk modulus) has a greater effect on propagation speed than density

Propagation speed for:

- Air: 330 m/sec
- Fat: 1450 m/sec
- Water: 1480 m/sec
- Soft tissue: 1540 m/sec
- Blood: 1570 m/sec
- Muscle: 1580 m/sec
- Bone: 3500 m/sec

The **AVERAGE** speed of sound in soft tissue: 1.54 mm/µsec, 1540 m/sec, 1.54 km/sec, 154000 cm/se

Propagation Speed (c) – Multiple Choice Questions

1. Propagation speed is determined by the:
   A. f
   B. T
   C. Wavelength
   D. Medium
2. The **AVERAGE** propagation speed of sound in soft tissue is:
   A. 1.54 mm/µsec
   B. 15.4 msec
   C. 1.54 mm
   D. 1540 cm/sec
3. As bulk modulus increases, propagation speed:
   A. Increases
   B. Decreases
   C. Remains unchanged
   D. Cannot be predicted
4. Which medium will have the highest propagation speed?
   A. Air
   B. Soft tissue
   C. Bone
   D. All three will be equal
5. Which is **CORRECT** from lowest to highest?
   A. Air, Bone, Soft tissue
   B. Soft tissue, Bone, Air
   C. Air, Soft tissue, Bone
   D. All travel at 1540 m/sec
6. Which is **CORRECT** from highest to lowest?
   A. Air, Bone, Soft tissue
   B. Soft tissue, Bone, Air
   C. Bone, Soft tissue, Air
   D. All travel at 1540 m/sec

Answers: 1.D; 2.A; 3.A; 4.C; 5.C; 6.C

Amplitude (A)
Definition: How "loud" sound is
Units: Unit of the acoustic variable (e.g.; pressure, density, temperature, particle motion) being measured or decibels (dB)
Determined by transmit gain (Increase transmit gain = Increased risk of bioeffects)
The greater the returning amplitude of the reflection, the brighter the reflection on the display

Amplitude (A) Multiple Choice Questions

1. Amplitude is determined by:
    A. f
    B. T
    C. Medium
    D. Transmit gain
2. An increase in amplitude will **NOT** result in:
    A. Greater depth of penetration
    B. Brighter reflection will be displayed
    C. Improved temporal resolution
    D. Increase risk of bioeffects
3. The units for A are:
    A. Hz
    B. W
    C. dB
    D. Rayls

Answers: D; 2.C; 3.C

Power (P)
Definition: The rate at which sound energy is transferred
Units: Watts (W), milliWatts (mW)
Formula: Power $=A^2$
Determined by transmit gain (Increase transmit gain-Increase P-Increased risk of bioeffects)

Power (P) Multiple Choice Questions

1. The rate at which sound energy is transferred is called:
    A. f
    B. T
    C. A
    D. P
2. Power is determined by:
    A. Gain
    B. Receiver gain
    C. Transmit gain
    D. Overall gain
3. The amplitude is doubled. The new power will be:
    A. Half
    B. Equal to
    C. Double
    D. Quadrupled

4. The amplitude is halved. The new power will be:
    A. Halved
    B. Equal to
    C. Double
    D. Quartered

Answers: 1.D; 2.C.; 3.D; 4.D

Intensity (I)

Definition: Rate of energy transfer/ area; (Power/area)
Units: W/cm^2; mW/cm^2
Determined by transmit gain (Increase transmit gain-Increase I-Increased risk of bioeffects)
Several ways to measure intensity including SPTA (Spatial Peak Temporal Average)
SATA (Spatial Average Temporal Average) is the lowest intensity measured; SPTP (Spatial Peak Temporal Peak) is the highest measured intensity
There have been no proven biological effects for **UNFOCUSED** sound beams below 100 mW/cm^2 SPTA
There have been no proven biological effects for **FOCUSED** sound beams below 1 W/cm^2 SPTA

Intensity (I) – Multiple Choice Questions

1. The rate at which sound energy is transferred divided by area (Power÷Area) is:
    A. f
    B. A
    C. P
    D. I
2. Intensity is determined by:
    A. Transmit gain
    B. Gain
    C. Overall gain
    D. Receiver gain
3. The lowest intensity value is:
    A. SPTP
    B. SATP
    C. SPTA
    D. SATA
4. The highest intensity value is:
    A. SPTP
    B. SATP
    C. SPTA
    D. SATA
5. There have been no proven bioeffects for unfocused sound beams below:__ mW/cm^2 SPTA.
    A. 1
    B. 10
    C. 100
    D. 1000
6. There have been no proven bioeffects for focused sound beams below___ W/cm^2 SPTA.
    A. 1
    B. 10
    C. 100
    D. 1000

Answers: 1.D; 2.A; 3.D; 4.A; 5.C; 6.A

Acoustic Impedance (Z)

Definition: Opposition to sound as it travels through a medium

Formula: Density (kg/m^3) x Propagation speed (m/sec)

Units: Rayls

A reflection will occur at the boundary of two media if the media impedances are different

The greater the difference between the two media impedances, the greater the reflection and with less sound energy being transmitted

Acoustic Impedance (Z)

1. The acoustic impedance value for soft tissue is 2 MRayls. The acoustic impedance value for air is .0004 Rayls. How much reflected sound energy will occur at a soft tissue – air interface? ___%
    A. 1
    B. 10
    C. 50
    D. 99
2. Predict the amount of sound energy transmitted at a fat – muscle interface. __%
    A. 1
    B. 50
    C. 75
    D. 99
3. Predict the amount of sound energy reflected at a fat-muscle interface. __%
    A. 1
    B. 50
    C. 75
    D. 90

Answers: 1.D; 2.D; 3.A

Specular Reflectors

Definition: Large, smooth surfaced reflectors that are mirror-like; create strong amplitude reflections

Highly incident angle dependent

Specular Reflectors – Multiple Choice Questions

1. Which of the following is **NOT** considered a specular reflector?
    A. Diaphragm
    B. Red blood cell
    C. Interatrial septum (IAS)
    D. Common carotid artery
2. The preferred incident angle when imaging a specular reflector is___ degrees.
    A. 0
    B. 1
    C. 60
    D. 90

Answers: 1.B; 2. D

Scatter Reflectors (Diffuse Reflectors)

Definition: Small and/or rough surfaced reflectors which are not angle dependent but are frequency dependent (Increase frequency – Increase backscatter); create weak amplitude reflections

Rayleigh scatterers are a special type of scatter reflector (scatters sound energy equally in all directions)

The best example of a Rayleigh scatterer is the red blood cell

Scatter Reflectors

1. Which of the following is **NOT** considered a scatter reflector?
    A. Abdominal aorta
    B. Tissue parenchyma
    C. Myocardial cells
    D. Endocardial cells
2. Which of the following is considered a Rayleigh scatterer?
    A. Septal tricuspid valve leaflet
    B. Red blood cell
    C. Interatrial septum
    D. Superficial femoral artery
3. Which of the following has the greatest effect on scatter reflectors: Increase____.
    A. Frequency
    B. Image depth
    C. Transmit Gain
    D. TGC

Answers: 1.B; 2.B; 3.A

Perpendicular Incidence

Definition: The ultrasound beam strikes the boundary of two media at a 90-degree incident angle

Formula: Intensity reflection coefficient (IRC) =$(Z_2 – Z_1) / (Z_2 + Z_1)^2$

For perpendicular incidence, a reflection will occur at the boundary of two media if the media impedances are different

For perpendicular incidence, Intensity Transmission Coefficient (IRC) = $Z_2 – Z_1/Z_2 + Z_1)^2$

Intensity Transmission Coefficient (ITC) = 1 – IRC

The IRC for Soft Tissue-Air: 99%; ITC: 1%

The IRC for Fat-Muscle: 1%; ITC: 99%

The IRC for Soft Tissue-Bone: 60%; ITC: 40%

Perpendicular Incidence – Multiple Choice Questions

1. The ultrasound beam strikes the boundary at an incident angle of 90 degrees. A reflection will occur if the
    A. Propagation speeds are equal
    B. Propagation speeds are unequal
    C. Acoustic impedances are equal
    D. Acoustic impedances are unequal
2. The IRC for Soft Tissue-Air is___%.
    A. 1
    B. 20
    C. 60
    D. 99

3. The ITC for Soft Tissue-Air is:___%
    A. 1
    B. 20
    C. 60
    D. 90
4. The IRC for fat-muscle is: ___%
    A. 1
    B. 20
    C. 60
    D. 99
5. The ITC for fat-muscle is: ___%
    A. 1
    B. 20
    C. 60
    D. 99

Answers: 1.D; 2.D; 3.A; 4.A; 5.D

Oblique Incidence

Definition: The incident angle is **NOT** 90 degrees

The incident angle = the reflected angle

Refraction will occur at the boundary of two media if there is oblique incidence and the propagation speeds of the two media are different

Refraction will **NOT** occur if 1: There is perpendicular incidence or 2: There is oblique incidence and the propagation speeds are equal

Refraction may result in the duplication of images (e.g.; two left ventricles in the subcostal short axis view of the left ventricle) and/or the artifact called edge shadowing.

Oblique Incidence – Multiple Choice Questions

1. The incident angle for the sound beam is 89.9 degrees. This is___ incidence.
    A. Perpendicular
    B. Normal
    C. Oblique
    D. Direct
2. The incident angle is 56 degrees. The reflected angle is: ____ degrees.
    A. Less than 56
    B. Equal to 56
    C. Greater than 56 degrees
    D. Dependent upon propagation speeds of the two media
3. The change in the direction of sound travel as it crosses the boundary of two media is called:
    A. Refraction
    B. Reflection
    C. Reverberation
    D. Range ambiguity
4. Refraction will **NOT** occur if there is perpendicular incidence or there is oblique incidence and:
    A. The propagation speeds of the two media are different
    B. The acoustic impedances are different
    C. The propagation speeds are equal
    D. The acoustic impedances are equal

5. Refraction may result in the artifacts of:
    A. Propagation speed error; Enhancement
    B. Duplication of images; Edge shadowing
    C. Shadowing; Enhancement
    D. Comet tail; Reverberation

Answers: 1.C; 2.B; 3.A; 4.C; 5.B

Attenuation

Definition: The loss of sound energy amplitude and intensity as sound travels through the medium
Units: Decibels (dB)
Primary causes: Absorption, Reflection, Scatter
Absorption (conversion of sound energy unto heat) is the primary cause of attenuation in soft tissue
The instrument control which compensates for attenuation is time gain compensation (TGC).

Attenuation – Multiple Choice Questions

1. The primary cause of attenuation in soft tissue is:
    A. Absorption
    B. Reflection
    C. Scatter
    D. Perpendicular incidence
2. The conversion of sound energy into heat is:
    A. Absorption
    B. Reflection
    C. Scatter
    D. Refraction
3. The instrument control which compensates directly for attenuation is:
    A. Transmit gain
    B. Gain
    C. Time gain compensation (TGC)
    D. Lateral gain compensation (LGC)

Answers: 1.A; 2.A. 3.C

Attenuation Coefficient

Definition: The rate of attenuation
Units: dB/cm
Formula for soft tissue: 0.5 x frequency
The attenuation for soft tissue is: 0.5 dB/cm/MHz
For soft tissue; every 3 dB represents a 50% loss in sound energy
As frequency increases, attenuation increases, depth of penetration decreases
Total attenuation dB) = Attenuation coefficient x path length

Attenuation Coefficient

1. The units for attenuation coefficient are:
    A. Hz
    B. Rayls
    C. dB/cm
    D. mm

2. The attenuation coefficient for soft tissue is:
    A. 0.5
    B. 0.5 dB
    C. 0.5 dB/cm
    D. 0.5 dB/cm/MHz
3. For soft tissue, the attenuation coefficient for 2 MHz is: ____ dB/cm.
    A. 1
    B. 2
    C. 3
    D. 4
4. For soft tissue, the attenuation coefficient for 4 MHz is: ___ dB/cm.
    A. 1
    B. 2
    C. 3
    D. 4
5. The beginning intensity is 100 mW/cm^2. 6 dB in attenuation occurs. The amount of remaining sound intensity is: ____ mW/cm^2.
    A. 150
    B. 200
    C. 50
    D. 25
6. Which of the following does **NOT** increase with an increase in frequency?
    A. Attenuation
    B. Attenuation coefficient
    C. Total attenuation
    D. Depth of penetration

Answers: 1.C; 2.C.; 3.A; 4.B; 5.C; 6.D

Piezoelectric Effect

Definition: The piezoelectric effect is the conversion of sound energy into electrical energy and electrical energy into sound energy (piezo means sound)

PZT (lead zirconate titanate) is a common material for ultrasound elements.

All ultrasound transducers operate on the piezoelectric effect by converting electrical energy into sound energy and sound energy into electrical energy

Ultrasound transducers should never be autoclaved

Piezoelectric Effect – Multiple Choice Questions

1. The conversion of sound energy into electrical energy and electrical energy into sound energy is the: ___ effect.
    A. Bernoulli
    B. Doppler
    C. Piezoelectric
    D. Continuity
2. All ultrasound transducers operate on the ____ effect.
    A. Piezoelectric
    B. Doppler
    C. Bernoulli
    D. Continuity
    E.

3. When should an ultrasound transducer be sterilized by autoclaving?
    A. Daily
    B. Weekly
    C. Monthly
    D. Never

Answers: 1.C; 2.A; 3.D

Transducer Construction

The center frequency of an ultrasound transducer is determined by the thickness of the piezoelectric element (primary determinant) and the propagation speed of the piezoelectric material.

The thickness is the primary determinant of the center frequency – thinner the element the higher the center frequency; the thicker the piezoelectric element-the lower the center frequency

For CW (e.g.; Pedof; Therapeutic), the center frequency is determined by the frequency of the driving voltage

The matching layer is placed on the front of the transducer, is one-quarter wavelength thick and reduces the acoustic impedance difference between the piezoelectric element and the skin surface; improves transmission and reception

The damping material is placed behind the piezoelectric element to reduce the ringing of the element allowing short pulses to be produced; improves axial resolution because it shortens the spatial pulse length

Transducer Construction

1. Which transducer will have the thickest piezoelectric element?
    A. 2 MHz
    B. 4 MHz
    C. 10 MHz
    D. 12 MHz
2. Which of the following is **INCORRECT** concerning the matching layer?
    A. Placed behind the piezoelectric element
    B. Reduces the acoustic impedance difference between the piezoelectric element and the soft tissue
    C. Is ¼ wavelength in thickness
    D. Improves transmission and reception
3. Which of the following is **CORRECT** concerning the damping material?
    A. Placed on the front of the transducer face
    B. Is ¼ wavelength thick
    C. Allows short pulses to be produced
    D. Improves transmission and reception

Answers: 1.A; 2.A; 3.A

Bandwidth (BW) (Broadband)

Definition: The range of frequencies produced by a damped piezoelectric element

Imaging transducers are wide bandwidth transducers because they are damped

CW transducers are narrow bandwidth transducers because they are not damped

Bandwidth – Multiple Choice Questions

1. The range of frequencies produced by a damped piezoelectric element is:
    A. Wavelength
    B. Bandwidth
    C. Quality factor
    D. Period
2. Which is **CORRECT**?
    A. Imaging transducers are wide bandwidth transducers
    B. Imaging transducers are narrow bandwidth transducers
    C. CW transducers are wide bandwidth transducers
    D. All ultrasound transducers are narrow bandwidth transducers

Answers: 1.B. 2.A

Quality Factor (Q Factor)

Definition/Formula: Q factor = Operating frequency/Bandwidth

Imaging transducers are wide bandwidth (wide broadband), low Q factor transducers

CW/Therapeutic transducers are narrow bandwidth (narrow broadband), high Q factors

Quality Factor (Q Factor) – Multiple Choice Questions

1. Imaging transducers are:_____, _____ transducers.
    A. Narrow bandwidth, High Q factor
    B. Narrow bandwidth, Low Q factor
    C. Wide bandwidth, High Q factor
    D. Wide bandwidth, Low Q Factor

Answers: 1.D

Capacitive Micromachined Ultrasonic Transducer (CMUT)

CMUT (Capacitive Micromachined Ultrasonic Transducer) is a silicon-based MEMS (micro-electro-mechanical system) technology that converts electrical energy into acoustic waves. Replacing traditional piezoelectric (PZT) crystals, it acts like a microscopic drumhead that expands the capabilities of ultrasound probes by offering wider bandwidth, easier 3D/2D array creation, and direct semiconductor integration

A CMUT consists of thousands of tiny, individual capacitor cells fabricated on a silicon wafer. Each cell has a thin, flexible membrane suspended over a small cavity or vacuum gap

The top of the membrane is coated in metal and the underlying substrate serves as the bottom electrode

A DC bias voltage pulls the membrane towards the substrate. An alternating AC voltage is added causing the membrane to vibrate rapidly producing ultrasonic sound waves

When returning echoes hit the membrane, they cause the membrane to vibrate. This varies the distance between the electrodes, changing the capacitance and generates an electrical current

Advantages of the CMUT transducer include a wider bandwidth, lower cost and there is no need for a matching layer

Useful in handheld ultrasound devices (point of care) and intravascular ultrasound

Capacitive Micromachined Ultrasonic Transducer (CMUT) - Multiple Choice Questions

1. Which is **INCORRECT** concerning the CMUT transducer?
   A. Silicon based
   B. MEMS technology
   C. Converts electrical energy into sound waves
   D. Does not replace the piezoelectric crystal(s) technology
2. Which is **NOT** considered an advantage of the CMUT transducer
   A. Expensive
   B. Wider bandwidth
   C. Easier 3D creation
   D. No need for a matching layer

Sound Beam Formation

Definition: The sound beam width varies with the distance from the transducer

The sound beam is composed of four regions: near zone (Near field) (Fresnel), focus, focal zone, far zone (Far field) (Fraunhofer)

Near zone (Near field) (Fresnel): Distance from the transducer face to the focus – Sound beam narrows as it travels in the near zone

Focus (Focal point): Narrowest portion of the sound beam – Lateral resolution is best at the focus; Beam width at one near zone length: = ½ the transducer diameter; Beam width at 2 near zone lengths = transducer diameter

Focal zone: 2x the width of the focal point – lateral resolution is good in the focal region

Far zone (Far zone) (Fraunhofer): widest portion of the sound beam – sound beam width widens as it travels from the focal point – lateral resolution is poor in the far zone

Sound beam formation is based on Huygens principle – constructive and destructive construction

Sound Beam Formation

1. The region from the transducer face to the focus is called:
   A. Fresnel
   B. Focus
   C. Focal region
   D. Fraunhofer
2. The narrowest portion of the sound beam where lateral resolution is best is called the:
   A. Fresnel
   B. Focus
   C. Focal region
   D. Fraunhofer
3. The region where the sound beam width diverges is the:
   A. Fresnel
   B. Focus
   C. Focal region
   D. Fraunhofer
4. Sound beam formation is based on:
   A. Doppler effect
   B. Bernoulli equation (conservation of energy)
   C. Continuity principle (conservation of mass)
   D. Huygen's principle

5. The transducer diameter is 20 mm. The beam width at one near zone length is: __ mm.
    A. 40
    B. 20
    C. 10
    D. 5
6. The transducer diameter is 20 mm. The beam width at two near zone lengths is: __ mm.
    A. 40
    B. 20
    C. 10
    D. 5

Answers: 1.A; 2.B; 3.D; 4.D; 5.C; 6.B

Focusing

Definition: Focusing reduces the sound beam diameter in the near field – improves lateral resolution – increases the sound beam divergence (angle of divergence)

Focusing methods: Internal, External, Transmit electronic, Dynamic receive, Dynamic aperture (Variable receive)

Internal focusing: the piezoelectric element(s) is (are) curved)

External focusing: A curved lens is placed on the front of the transducer

Transmit focusing: the electrical pulses are curved (May be controlled by the sonographers by using the transmit focus button)

Dynamic receive: uses delay lines during reception

Dynamic aperture (Variable receive): alters the number of "live" elements receiving the returned echoes

Focusing – Multiple Choice Questions

1. _____ reduces the sound beam width in the near field improving lateral resolution but increases the angle of divergence.
    A. Focusing
    B. Frequency
    C. Huygen's principle
    D. Transmit gain
2. The piezoelectric element(s) is (are) curved. This is ____ focusing.
    A. Internal
    B. External
    C. Transmit
    D. Receive
    E. Dynamic aperture
3. A lens is placed on the surface of the transducer face. This is ___ focusing.
    A. Internal
    B. External
    C. Transmit
    D. Receive
    E. Dynamic aperture
4. The electrical impulses are curved. This is ___ focusing.
    A. Internal
    B. External
    C. Transmit
    D. Receive
    E. Dynamic aperture

5. Delay lines are used to “line up” the returning signals. This is __ focusing.
    A. Internal
    B. External
    C. Transmit
    D. Dynamic receive
    E. Dynamic aperture
6. The number of active piezoelectric elements are altered based on returning depth. This is__ focusing.
    A. Internal
    B. External
    C. Transmit
    D. Receive
    E. Dynamic aperture

Answers: 1.A; 2.A; 3.B. 4.C; 5.D; 6.E

Lateral Resolution (LATA – Lateral, Angular, Transverse, Azimuthal)

Definition: How close two structures may be **PERPENDICULAR** to the sound beam path and still be resolved as two separate reflectors – Determined by sound beam width – varies with the distance from the transducer because the sound beam width as it travels from the transducer

Formula: Lateral resolution (mm) = Sound beam width

How to improve: Increase transmit frequency (Higher frequencies produce a narrower sound beam)

Focus (Focusing reduces the sound beam width in the near field)

Increase transducer diameter (Larger transducers produce narrower sound beam width overall)

Lateral Resolution – Multiple Choice Questions

1. How close two structures perpendicular to the sound beam path and still be resolved is ___ resolution.
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational (slice thickness)
2. Which of the following would **NOT** improve lateral resolution?
    A. Increase transmit frequency
    B. Use tissue harmonic imaging
    C. Focus
    D. Decrease transducer diameter width

Answers: 1.B; 2.D

Axial Resolution (LARRD)

Definition: How close two structures may be **PARALLEL** to the direction of sound travel and still be resolved as two separate structures.

Formula: Spatial pulse length (SPL)/2

How to improve: Increase transmit frequency (higher frequencies produce shorter pulses)

Damp (Done by the manufacturer)

Spatial resolution (Detail Resolution) Axial resolution and lateral resolution are referred to as spatial resolution or detail resolution

Axial Resolution – Multiple Choice Questions

1. ____ resolution is how close two structures may be parallel to the sound beam direction of travel and still be resolved.
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational (Slice thickness)
2. The spatial pulse length is 4 mm. Determine the axial resolution. __ mm
    A. 8
    B. 4
    C. 2
    D. 1
3. The spatial pulse length for transducer A is 4 mm. The spatial pulse length for transducer B is 6 mm. The spatial pulse length for transducer C is 2 mm. Which transducer has the best axial resolution?
    A. A
    B. B
    C. C
    D. All are equal
4. The primary way the sonographer improves axial resolution is:
    A. Increase transmit frequency
    B. Focus
    C. Alter the image depth
    D. Narrow the display field of view

Answers: 1.A; 2.C; 3.C; 4.A

Transducer Types

Sector phased array – Small, square shaped transducer; all the piezoelectric elements are fired but with a slight time delay in order to beam steer and focus; most common transducer used in echocardiography

Linear phased array – Large transducer; piezoelectric arranged in a line and fired electronical time delays in order to beam steer and focus; most common transducer used in vascular ultrasound

Curved (Curvilinear) phased array – Arc-shaped transducer; operates similar to sector and linear phased array transducers; useful in abdominal applications

Pedof – small, dedicated CW Doppler transducer with two piezoelectric elements (one to transmit and one to receive); required for the evaluation of aortic stenosis

Transducer Types

1. The most common cardiac imaging transducer is the:
    A. Sector phased array
    B. Linear phased array
    C. Curvilinear
    D. Pedof
2. All the elements are fired electronically but with a slight time delay in order to beam steer and focus. This is a description of a:
    A. Phased array
    B. Linear sequential
    C. Curved linear sequential
    D. Pedof

3. Which transducer is required when acquiring Doppler information from the right parasternal window in a patient with aortic stenosis?
    A. Sector phased array
    B. Linear phased array
    C. Curvilinear phased array
    D. Pedof
4. The transmit frequency of an imaging transducer is primarily determined by the:
    A. Thickness of the piezoelectric element(s)
    B. Frequency of the driving voltage
    C. Type of transducer
    D. Manufacturer
5. The transmit frequency (center frequency) of a CW transducer (e.g.; Pedof) is the:
    A. Thickness of the piezoelectric element(s)
    B. Frequency of the driving voltage
    C. Type of transducer
    D. Manufacturer

Answers: 1.A; 2.A; 3.D; 4.A; 5.B

1-D, 1 .5 D, 2-D Arrays

Imaging 1-D array transducers are transducers comprised of a single row of piezoelectric elements such as seen in phased array, linear array, curvilinear array and tightly curved array transducers

Imaging 1.5 array transducers are multirow (matrix) transducers comprised of multiple rows (e.g.; 10 to 15 rows) of piezoelectric elements

Imaging 2-D matrix transducers are comprised of thousansds of tiny piezoelectric elements arranged in a grid (matrix) pattern (50 to 100 columns with 50 to 100 rows of piezoelectric elements) allowing for 3-D and 4-D ultrasound

1-D, 1 .5 D, 2-D Arrays – Multiple Choice Questions

1. A transducer is comprised of a single row of piezoelectric elements. This is a ___ array transducer.
    A. 1-D
    B. 1.5 D
    C. 2-D
    D. 3-D
2. A transducer comprised of multiple rows (e.g.; 10 to 15 rows) of piezoelectric elements is a___ array transducer.
    A. 1-D
    B. 2-D
    C. 3-D
    D. 1.5 D
3. Which array (matrix) transducer provides for 3-D and 4-D ultrasound because it is comprised 50 to 100 rows and 1000 to 3000 piezoelectric elements?
    A. 1-D
    B. 1.5-D
    C. 2-D
    D. 3-D

Answers: 1.A; 2.D; 3.C

Range Equation
Definition: Predicts the time it takes for an ultrasound pulse to travel out and back to a reflector
Formula(s): 0.5 x (propagation speed (m/sec) x pulse round trip time (mm/us)
For soft tissue: Pulse round trip time (us)/13 us

Range Equation – Multiple Choice Questions

1. The pulse round trip time in soft tissue is 39 us. The reflector depth is: ___ mm or ___ cm.
    A. 10; 1
    B. 30; 3
    C. 90; 9
    D. 200; 20
2. The distance to a reflector is doubled. The pulse round trip time will:
    A. Halve
    B. Double
    C. Triple
    D. Quadruple

Answers: 1.B; 2.B

Pulse Repetition Frequency (PRF)
Definition: The number of pulses created per second
Units: kHz
Dependent upon image depth; increase image depth decrease PRF; decrease image depth increase PRF

Pulse Repetition Frequency (PRF) – Multiple Choice Questions

1. The number of pulses created per second is:
    A. PRF
    B. PRP
    C. PD
    D. SPL
2. The sonographer increases the image depth from 10 cm to 20 cm. The PRF will:
    A. Halve
    B. Double
    C. Triple
    D. Remain unchanged
3. The sonographer reduces the image depth from 20 cm to 10 cm. The PRF will:
    A. Halve
    B. Double
    C. Triple
    D. Remain the same
4. Yes or No: Increasing the PRF allows more scan lines which results in an increase in frame rate and improves temporal resolution.

Answers 1.A; 2.A; 3.B

Pulse Repetition Period (PRP)
Definition: The period of time from the onset of one pulse to the onset of the next pulse
Formula: 1/PRF
As image depth increases, PRP increases; As image depth decreases; PRP decreases

Pulse Repetition Period (PRP)

1. The time from the onset of one pulse to the onset of the next pulse is:
    A. PRF
    B. PRP
    C. PD
    D. SPL
2. The sonographer decreases image depth from 20 cm to 10 cm. The PRP will:
    A. Increase
    B. Decrease
    C. Remain unchanged
    D. Dependent on transmit frequency

Answers: 1.B; 2.C

Pulse Duration (PD)

Definition: The time it takes for one pulse to occur
Formula: T (us) x number of cycles in a pulse
Reduced by increasing the transmit frequency and by damping

Pulse Duration (PD)

1. The time it takes for one pulse to occur is:
    A. PRF
    B. PRP
    C. PD
    D. SPL
2. The sonographer increases the transmit frequency, PD will:
    A. Increase
    B. Decrease
    C. Remain unchanged
    D. Dependent on image depth
3. Yes or No: The shorter the pulse duration, the better the axial resolution.

Answers: 1.C; 2.C; 3.Yes

Spatial Pulse Length (SPL)

Definition: The length or distance of a pulse
Formula: wavelength (mm) x number of cycles in a pulse
Reduced by increasing the transmit frequency and by damping
Axial resolution (mm) = SPL/2

Spatial Pulse Length – Multiple Choice Questions

1. The distance or length of a single pulse is:
    A. PRF
    B. PRP
    C. PD
    D. SPL
2. The sonographer increases the transmit frequency, SPL will:
    A. Increase
    B. Decrease
    C. Remain unchanged
    D. Dependent on image depth

3. The sonographer alters the image depth, the SPL will:
    A. Increase
    B. Decrease
    C. Halve
    D. Remain unchanged
4. The SPL is 4 mm. The axial resolution is: ___ mm.
    A. 1
    B. 2
    C. 3
    D. 4
5. Yes or No: The shorter the SPL, the better the axial resolution.

Answers: 1.D; 2.B; 3.D.; 4.B; 5.Yes

Duty Factor (DF)

Definition: The time the machine is actually spending creating a pulse of ultrasound
Formula: PD/PRP
For CW, the PD is 1 or 100%
For PW, the PD is less than 1 (for imaging ultrasound, the DF is less than 1%)

Duty Factor (DF)

1. The percentage of time the ultrasound machine spends producing a pulse of ultrasound is:
    A. PRF
    B. PRP
    C. PD
    D. SPL
    E. DF
2. The DF for CW ultrasound is: ___%
    A. 1
    B. 10
    C. 50
    D. 100
3. The DF for imaging ultrasound is: __ %.
    A. 1
    B. 10
    C. 50
    D. 100

Answers: 1.E; 2.D; 3.A

Transmit Gain (Output Power; Power)

Definition: Determines the amount of sound energy emitted by the transducer; controlled by the sonographer
Units: Decibels (dB)
Improves image depth, increases the brightness (amplitude) of the returning signals, affects the entire display but may increase the risk of bioeffects; affects Mechanical Index (MI)
ALARA – As Low As Reasonably Achievable – is the guide for the amount of transmit gain that should be used during an ultrasound examination

Transmit Gain (Output Power) – Multiple Choice Questions

1. The amount of sound energy emitted by the transducer is determined by:
    A. Transmit gain
    B. Gain
    C. Receiver gain
    D. Overall gain
2. ALARA is the guide for:
    A. Time gain compensation (TGC)
    B. Gain
    C. Transmit gain
    D. Overall gain
3. Which of the following is affected by transmit gain?
    A. Mechanical index (MI)
    B. Image depth
    C. Frame rate
    D. Brightness (amplitude) of the returning signal

Answers: 1.A; 2.C; 3.A

Receiver Gain (Gain, Overall Gain)

Definition: Amplifies the strength (amplitude) of the returning signals; controlled by the sonographer; affects entire display

Units: Decibels (dB)

Preferred gain to use when choice is between transmit gain and receiver gain because using receiver gain reduces the risk of bioeffects

Receiver Gain (Overall Gain, Gain) – Multiple Choice Questions

1. Which gain amplifies the returning signal regardless of image depth?
    A. Transmit gain
    B. Output power
    C. Gain
    D. Power
2. Which gain is the preferred gain especially when trying to reduce the risk of bioeffects?
    A. Gain
    B. Transmit gain
    C. Output power
    D. Power

Answers: 1.C; 2.A

Time Gain Compensation (TGC) (Depth Gain Compensation (DGC)

Definition: Compensates for attenuation by allowing the sonographer to adjust the brightness (amplitude) of the returning signals at particular depth; controlled by the sonographer by using slide pods

Units: Decibels (dB)

Time Gain Compensation (TGC) Depth Gain Compensation (DGC) – Multiple Choice Questions

1. Which gain allows the sonographer to control the amplitude of the returning signals at particular depths?
    A. Gain
    B. Transmit gain
    C. Overall gain
    D. Time gain compensation (TGC)
2. The sonographer notes that one section of the display is too bright. To adjust this particular depth, the sonographer should choose:
    A. TGC
    B. Gain
    C. Transmit gain
    D. Power

Answers: 1.D; 2.A

Dynamic Range (Compression)

Definition: Dynamic range instrument control affects the number of shades of gray displayed

Units: Decibels (dB)

Increasing dynamic range – reduces compression (reduces contrast – black and white) – increases the number of gray shades displayed

Decreasing the dynamic range – increases compression – reduces the number of gray shades displayed

Dynamic Range (Compression) Multiple Choice Questions

1. The range of echo amplitude displayed is:
    A. Amplitude
    B. Dynamic range
    C. Gain
    D. Overall gain
2. The sonographer increases the dynamic range. What will occur?
    A. Image depth increases
    B. Number of shades of gray displayed increases
    C. Increase in amplitude of returning echoes from a certain depth only
    D. Improved temporal resolution
3. The sonographer reduces the dynamic range. What will occur?
    A. Image depth increases
    B. Number of shades of gray displayed decreases
    C. Increase in amplitude of returning echoes from a certain depth only
    D. Improved temporal resolution
4. Which of the following does **NOT** have decibels (dB) as the units?
    A. Transmit gain
    B. Overall gain
    C. Time gain compensation
    D. Dynamic range
    E. Frequency

Answers: 1.B; 2.B.; 3.B; 4.E

Rejection
Definition: Reduces or eliminates low level amplitude signals/electronic noise
Units: dB

Rejection – Multiple Choice Questions

1. Which of the following ultrasound instrument controls eliminates low level amplitude signals/electronic noise?
    A. Transmit gain
    B. Gain
    C. TGC
    D. Dynamic range
    E. Rejection

Answer: 1.E

Brightness Mode (B-Mode)
Definition: Displays returning reflections as bright dots; the brighter the dot the greater the amplitude of the returning signal

Brightness Mode (B-Mode)

1. Which mode displays returning signals as bright dots with the brighter the dot the greater the amplitude of the returning signal?
    A. A-Mode
    B. B-Mode
    C. C-Mode
    D. M-Mode

Answers: 1.B

M-Mode (TM-Mode; Time-Motion Mode)
Definition: A B-mode operation which displays reflector motion and depth over time; Advantage: Excellent temporal resolution; Disadvantage: "Ice-pick" view of the anatomy

M-Mode (TM Mode; Time-Motion Mode)

1. The primary advantage of M-mode is: ____ resolution.
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational (slice thickness)
2. M-mode combined with color flow Doppler is referred to as:
    A. Three-dimensional
    B. CMM
    C. B-mode
    D. TDI
    E. 3-D

Answers: 1.C; 2.C

Two-Dimensional (2-D)

Two dimensional (2-D) (two-D) (distance and width) is a B-mode operation which uses bright dots to demonstrate reflector depth and motion. The amplitude of the returning reflection is demonstrated by brightness – the brighter the dot – the greater the amplitude (strength) of the returning reflection. This is referred to as the gray scale. The y axis represents depth (distance), the x axis is width and the z axis the gray scale (brightness of the B-mode dot). Two-dimensional is the fundamental imaging modality of clinical imaging ultrasound.

2-D – Multiple Choice Questions

1. Which is **INCORRECT** concerning two-dimensional imaging?
    A. B-mode operation
    B. Brighter the dot, the greater the amplitude pf the returning signal
    C. X axis is width; y axis is depth (distance); z axis is gray scale
    D. M-mode is the preferred choice for making echocardiography measurements

Answer: 1.D

Three-Dimensional (3-D) – Four-Dimensional (4-D)

Three-dimensional is accomplished by taking multiple 2D scans of an area from various angles and piecing ("stitching") them together using advanced computer software.

Four-dimensional (4-D) ultrasound is 3-D imaging with the addition of time which allows for the display of real time imaging (motion) of structures

Advantages of 3-D ultrasound include improved spatial visualization, allows for volume measurements (e.g.; ejection fraction)

Disadvantages of 3-D ultrasound include higher cost of equipment, poorer spatial (e.g.; axial resolution, lateral resolution), lower frame rates and PW and CW Doppler is not feasible

Three-Dimensional (3-D) – Four-Dimensional (4-D) – Multiple Choice Questions

1. A series of 2-D slices of a structure (e.g.; heart) are stitched together. This will result in _____ imaging.
    A. M-mode
    B. 2-D
    C. 3-D
    D. Doppler
2. 3-D with real time imaging (motion) displayed is:
    A. M-mode
    B. 2-D
    C. 3-D
    D. 4-D
3. Which is **NOT** considered a disadvantage of 3-D ultrasound?
    A. High cost
    B. Poorer image quality
    C. Lower frame rate
    D. Improved volume measurements

Answers: 1.C; 2.D; 3.D

Temporal Resolution

Definition: Ability to resolve fast moving structures accurately

Temporal resolution is determined by frame rate (units: Hertz Hz)

How to improve – Increase the frame rate: Reduce image depth; Reduce field of view; Reduce the number of focuses; Decrease scan line density; Interpolation

Temporal Resolution – Multiple Choice Questions

1. Which resolution is determined by frame rate (the higher the frame rate the better this resolution)?
    A. Axial
    B. Lateral
    C. Temporal
    D. Contrast
    E. Elevational (Slice thickness)
2. Which of the following will **NOT** improve frame rate and improve temporal resolution? Decrease:
    A. Image depth
    B. Field of view
    C. Number of focuses
    D. Gain
    E. Scan line density
3. Which imaging modality has the best temporal resolution?
    A. A-Mode
    B. B-Mode
    C. M-Mode
    D. C-Mode
4. Which type of focusing directly affects the frame rate and temporal resolution?
    A. Internal
    B. External
    C. Transmit focus
    D. Dynamic receive
    E. Dynamic aperture

Answers: 1.C; 2.D; 3.C; 4.C

Doppler

Doppler effect: There will be a change in the frequency of sound relative to the motion of the source and/or the observer

Doppler shift: The difference between the transmit frequency and the received frequency

Doppler formula: Doppler shift (Fd) (Fd = 2 x Transmit frequency (f_0) x Red blood cell velocity x Cosine of the angle/c

The cosine of 0 degrees: 1 (preferred Doppler incident angle – 0 degrees parallel); Cosine of 20 degrees: .94; Cosine of 60 degrees: .5; Cosine of 90 degrees: 0

Fast Fourier transform (FFT) Rapid method used to display returning Doppler signal (PW, CW, High PRF); x axis: time (duration) of flow; y axis: velocity (frequency shift); z axis: amplitude (gray shade) of the returning signal

Spectral broadening: Increase in the width of the spectral waveform (tracing) which results in window fill-in; Spectral broadening indicates disturbed/turbulent flow (PW, High PRF – Not CW Doppler)

Aliasing: Problem of PW and Color flow Doppler – If the magnitude of the Doppler shift exceeds the Nyquist Limit (PRF/2) aliasing will occur; referred to as wrap-around

Nyquist Limit: PRF/2; predicts when aliasing will occur
PW Doppler: Uses a sampling gate (sample volume); Advantage: Range resolution (range discrimination); Disadvantage: Aliasing
CW Doppler: No inherent sampling rate which means no aliasing; Advantage: No Nyquist limit; Disadvantage: Range ambiguity
Doppler high-pass filter: Eliminates high amplitude (e.g.; wall motion, valve motion), low velocity flow

Doppler – Multiple Choice Questions

1. There will be a change in the frequency of sound relative to the motion of the source and/or the observer is the:
    A. Doppler effect (principle)
    B. Doppler shift
    C. Bernoulli principle
    D. Poiseuille's law
2. The train whistle is moving towards the observer. There will be an increase in:
    A. Frequency
    B. Period
    C. Velocity
    D. Propagation speed
3. The train whistle is moving away from the observer. There will be a decrease in:
    A. Frequency
    B. Velocity
    C. Propagation speed
    D. Direction
4. The difference between the transmit frequency and the returning frequency is the:
    A. Doppler shift
    B. Doppler effect (principle
    C. Bernoulli principle
    D. Poiseuille's law
5. The transmit frequency is 2,000,000 Hz. The returning frequency shift detected from moving red blood cells is 2, 001,000. Which is **INCORRECT**?
    A. Blood flow is moving towards the transducer
    B. Blood flow information will be placed above the zero baseline
    C. The frequency shift is in the audible range
    D. The Doppler shift is negative
6. There is an increase in red blood cell velocity. The magnitude of the Doppler shift will:
    A. Increase
    B. Remain unchanged
    C. Decrease
    D. Oscillate
7. The sonographer increases the Doppler transmit frequency from 2.5 MHz to 5.0 MHz. The magnitude of the Doppler shift will:
    A. Alias
    B. Double
    C. Halve
    D. Quadruple

8. To maximize the Doppler shift (velocity), the Doppler incident angle should be: ___ degrees.
    A. 0 (parallel)
    B. 20
    C. 60
    D. 90 (perpendicular)

9. ____ performs spectral analysis for conventional (PW, CW, high PRF) Doppler.
    A. Autocorrelation
    B. Fast Fourier transform (FFT)
    C. B-mode
    D. Three dimensional
10. The x axis of the FFT spectral display demonstrates
    A. Time (duration) of blood flow
    B. Magnitude of the Doppler shift (velocity)
    C. Amplitude (gray shades)
    D. Direction
11. The y axis of the FFT spectral display demonstrates:
    A. Time (duration) of blood flow
    B. Magnitude of the Doppler shift (velocity)
    C. Amplitude (gray shades)
    D. Direction
12. The z axis of the FFT spectral display demonstrates:
    A. Amplitude (strength) of the returning signals
    B. Velocity
    C. Direction
    D. Duration of blood flow
13. Vertical thickening of a spectrum with window fill-in suggests:
    A. Laminar flow
    B. Parabolic flow
    C. Inlet (plug) flow
    D. Turbulent flow
14. The Doppler wall filter is a ____ pass wall filter because it eliminates high amplitude, low velocity signals.
    A. High
    B. Medium
    C. Low
    D. Zero
15. The primary advantage of PW Doppler is:
    A. Range ambiguity
    B. Range resolution
    C. Aliasing
    D. Dynamic range
16. The primary disadvantage of PW Doppler is:
    A. Aliasing
    B. Range resolution
    C. Range discrimination
    D. Range ambiguity

17. The primary advantage of CW Doppler is:
    A. Range ambiguity
    B. Range discrimination
    C. Range resolution
    D. No inherent Nyquist limit
18. The primary disadvantage of CW Doppler is:
    A. Range discrimination
    B. Range resolution
    C. Range ambiguity
    D. Nyquist limit
19. The formula for the Nyquist limit is:
    A. SPL/2
    B. PRF/2
    C. N x wavelength
    D. 1/PRF
20. For a PW Doppler examination, the Doppler PRF is 4000 Hz. The detected Doppler shift is 3000 Hz.
    A. Aliasing will **NOT** occur
    B. Aliasing will occur
    C. The returning signals will be placed entirely above the baseline
    D. The returning signals will be placed entirely below the baseline
21. The Doppler PRF is 10 kHz. The returning Doppler shift from a stenotic valve is 4 kHz.
    A. Aliasing will **NOT** occur
    B. Aliasing will occur
    C. CW Doppler will be required to resolve the peak velocity
    D. The Doppler shift is positive
22. Which of the following will **NOT** help avoid the problem of aliasing?
    A. Increase the Doppler velocity scale
    B. Decrease image depth
    C. Decrease transmit frequency
    D. Shift the zero baseline
    E. Decrease the Doppler incident angle

Answers: 1.A; 2.A; 3.A; 4.A 5.D; 6.A; 7.B; 8.A; 9.B; 10.A; 11.B; 12.A; 13.D; 14.A; 15B; 16.A; 17.D; 18.C; 19.B; 20.B; 21.A; 22.E

Color Flow Doppler

Color flow Doppler is a PW Doppler technique using hundreds of sample gates (multigate) along each line of color to detect blood flow direction, velocity and character (e.g.; laminar, turbulent) of blood flow

Autocorrelation is the rapid technique used by color flow Doppler to convert Doppler shift information into color

Packet size is the number of ultrasound pulses sent down one line of color to detect Doppler shift information; A minimum of three pulses must be sent down one line of color because autocorrelation is an averaging technique; Increase packet size-Improve the estimation of the mean velocity-Decrease the frame rate

Color flow Doppler depicts the mean velocity not the peak velocity of blood flow

Color maps: Directional – Uses only the color blue and red; provides direction of blood flow only

Enhanced (hue) map– Uses shades of blue and shades of red; provides direction, mean velocity and character of blood flow; A mosaic of color suggests turbulent flow; The brighter the color, the higher the mean velocity; The color black indicates no Doppler shift detected or a reversal of flow direction

Variance map – Uses green folded onto an enhanced map to depict turbulent flow

Power Doppler map – Displays only the amplitude of the returning signal; **NOT** angle dependent

Color flow Doppler has lower frame rates compared to two-dimensional imaging because of the requirement of the packet size be at least three for each line of color; two-dimensional imaging requires only one pulse per scan line

To improve the color flow Doppler frame rate:

Reduce the field of view

Reduce the image depth

Reduce the packet size

Color gain affects the amount of color flow displayed; Increase the color gain until speckling occurs then reduce the gain until the speckling is eliminated

The color velocity scale (PRF) controls the amount of color displayed: Increase the color velocity reduces the amount of color flow displayed (recommended range for echocardiography: 50 to 70 cm/sec); Decrease the color flow velocity scale adds more color to the display (useful when evaluating low flow states such as pulmonary veins, hepatic veins)

Color flow Doppler aliases at lower velocities compared to PW Doppler because of lower PRF's

Color Flow Doppler – Multiple Choice Questions

1. Which of the following is **INCORRECT** concerning color flow Doppler?
    A. CW Doppler technique
    B. Multigate
    C. Aliasing can occur
    D. Lower frame rates than two-dimensional imaging
    E. Depicts the mean velocity of blood flow
2. The rapid technique which converts Doppler shift information into color is:
    A. Fast Fourier Transform (FFT)
    B. Autocorrelation
    C. Time interval histogram
    D. TDI

3. The number of pulses sent to create one line of color flow Doppler (minimum of three pulses per scan line) is called:
    A. Sample volume
    B. Sample gate
    C. Packet size
    D. TDI
4. Which of the following is **INCORRECT** concerning how to increase the color flow Doppler frame rate?
    A. Reduce the field of view
    B. Reduce image depth
    C. Reduce packet size
    D. Increase color gain
5. Which of the following would increase the amount of color flow Doppler displayed?
    A. Increase two-dimensional transmit gain
    B. Reduce color flow Doppler gain
    C. Decrease the color flow Doppler velocity scale
    D. Increase the field of view width
6. Which color flow Doppler map uses green to depict turbulent flow?
    A. Intensity
    B. Directional
    C. Enhanced (hue)
    D. Variance
7. Which of the following acronyms is used to explain how the direction of blood flow is shown with color flow Doppler?
    A. ASH
    B. SAM
    C. BART
    D. IHSS
8. Which of the following is best to use when examining for the presence of low velocity blood flow?
    A. Transmit gain
    B. Gain
    C. Decrease the color flow Doppler velocity scale
    D. Change color flow Doppler maps

Answers: 1.A; 2.B; 3.C; 4.D; 5.C; 6.D; 7.C; 8.C

Ultrasound Artifacts

Reverberation: Multiple echoes, equally spaced; associated with structures close to the transducer (e.g.; chest wall)

Comet tail: A type of reverberation associated with a highly reflective structure (e.g.; bullet, BB, prosthetic heart valve)

Ring down: A type of reverberation associated with a gas bubble

Shadowing: Low amplitude echoes located behind a highly reflective structure (e.g. calcific plaque, mitral annular calcification)

Enhancement: Increase in the amplitude (strength) of reflections from structures located behind a low reflective structure (e.g. fluid fill cyst)

Grating lobe: Extraneous sound beams originating from the primary sound beam; associated with phased array transducers; apodization is the process used to reduce grating lobes

Propagation speed error: Occurs when the medium sound is traveling through is not 1540 m/sec

Ultrasound Artifacts

1. Multiple echoes, equally spaced usually located in the near field are:
    A. Reverberations
    B. Comet tail
    C. Ring down
    D. Grating lobes
2. Multiple echoes, equally spaced caused by a highly reflective structure such as a bullet is:
    A. Reverberations
    B. Comet tail
    C. Ring down
    D. Grating lobes
3. Multiple echoes, equally spaced due to a gas bubble is:
    A. Reverberations
    B. Comet tail
    C. Ring down
    D. Grating lobes
4. Extraneous sound beams originating from the primary sound beam are and are associated with phased array transducers:
    A. Reverberations
    B. Comet tail
    C. Ring down
    D. Grating lobes
5. The technique used to eliminate grating lobes is:
    A. Apodization
    B. Autocorrelation
    C. FFT
    D. Polarization
6. The propagation speed of a medium is 1450 m/sec. The reflections will be placed too: ____ to the transducer.
    A. Close
    B. Far
    C. Not affected
    D. Cannot be predicted
7. The reduction in the amplitude of returning echoes due to a highly reflective structure is called:
    A. Shadowing
    B. Enhancement
    C. Slice thickness
    D. Propagation speed error
8. The increase in the amplitude in returning echoes due to a weak reflective structure (e.g.; fluid filled cyst) is called:
    A. Shadowing
    B. Enhancement
    C. Slice thickness
    D. Propagation speed error

9. Which ultrasound artifact does **NOT** provide anatomical information?
    A. Shadowing
    B. Enhancement
    C. Slice thickness
    D. Ring down

Answers: 1.A; 2.B; 3.C; 4.D; 5.A; 6.B; 7.A; 8. B; 9.C

Quality Assurance (QA)

Definition: Composed of three factors: Routine preventative maintenance; Routine performance tests; Acceptance testing

Quality Assurance – Multiple Choice Questions

1. How often should quality assurance be performed in the ultrasound laboratory?
    A. Daily
    B. Weekly
    C. Monthly
    D. According to the recommendations of the manufacturer

Answer: 1.D

Bioeffects

Definition: Three primary mechanisms: Thermal; Cavitation (stable, transient), Direct mechanical

How to reduce the risk: Reduce scan time (best way); ALARA

Stable cavitation: Expansion and contraction of a gas bubble; may result in microstreaming

Transient cavitation: Implosion of a gas bubble; more harmful than stable cavitation

Mechanical Index (MI): Required to be displayed on the image display; affected by transmit gain; FDA maximum is 1.9; MI is to be kept as low as possible; 0.3 for transpulmonary contrast exams to avoid destruction of the gas bubble

Thermal index soft tissue (TIS): Theoretical temperature increase while scanning; displayed on the ultrasound image display (Other thermal measurements: Thermal Index Bone (TIB); Thermal Index Cranial (TIC)

The maximum allowable increase in temperature is 2 degrees Centigrade (C); stop scanning if 2 degrees C is exceeded

Danger of using a cracked transducer: Electrical shock

Bioeffects – Multiple Choice Questions

1. The best way to reduce the risk of bioeffects is:
    A. Increase transmit gain
    B. Decrease scan time
    C. Use unfocused transducers only
    D. Scan at the maximum mechanical index
2. Which gain is governed by the ALARA principle?
    A. Transmit gain
    B. Gain
    C. Receiver gain
    D. Overall gain
    E. Time gain compensation (TGC)

3. The expansion and contraction of a gas bubble which may result in microstreaming is:
    A. Stable cavitation
    B. Unstable cavitation
    C. Transient cavitation
    D. Direct mechanical
4. The implosion of a gas bubble with a significant release of energy which may result in significant tissue damage is:
    A. Direct mechanical
    B. Stable cavitation
    C. Transient cavitation
    D. Unstable cavitation
5. There is swirling of transpulmonary contrast at the apex of the left ventricle. Which of the following would be **LEAST** useful to eliminate the swirling?
    A. Move the transducer focus
    B. Alter the MI
    C. Inject more contrast
    D. Decrease the image depth
6. The maximum allowable increase in temperature during an ultrasound exam is___ C.
    A. 0.5
    B. 1
    C. 2
    D. 3

7. The risk of using a cracked transducer is:
    A. Lower frame rates
    B. Electrical shock
    C. Higher MI
    D. Increase in TIC

Answers: 1.B; 2.A; 3.A; 4.C; 5.D; 6.C; 7.B