Diagnostic approach to heart disease

- **Initial work up**
  - History
  - Physical exam
  - Chest radiographs
  - ECG

- **Special studies**
  - Echocardiography
  - Cardiac catheterization
Echocardiography principles

- Technique of producing images of the heart by means of reflected sound waves (echoes)
- Humans can hear sound waves with frequencies between 20 Hz and 20 Kilohertz (kHz), frequencies higher than this range are termed ultrasound
Principles of ultrasound

- Sound is a disturbance of a physical medium
- Propagated as a wave that represents local oscillations in air pressure
- Sound properties (physical characteristics)
  - Frequency: the number of oscillations per unit of time, high frequency = shorter wavelengths; low frequency = longer wavelength
  - Wavelength: distance between successive troughs or peaks (mm)
Echocardiography - image creation summary

- Ultrasound beam strikes a structure and some of it is reflected back to the transducer.
- Transducers usually use pulse wave US, in which the crystal “turns on” for a short time and then waits for a longer period for the reflected waves to return.
- When the reflected US strikes the crystal it oscillates the crystal which is turned into a voltage detected by the machine.
Echocardiography - image creation summary (continued)

- By using computer technology an US machine can detect numerous structures at once, creating a two-dimensional image.
- The machine can calculate the distance between the transducer and the structure by measuring the time it takes for the US beam to travel to the structure of interest and return to the transducer.
Types of echocardiography

- M-mode (motion mode)
- Two dimensional (2-D)
- Doppler mode
Two dimensional echo (2DE)

- Most often performed and easiest to understand
- Utilizing an ultrasound beam moving in a sector, 2DE creates a pie or fan shaped image
- Rapid repetitive interrogation by the transduce results in appearance of “real time” motion
- Displays anatomic and functional characteristics that are more anatomically intuitive than M-mode imaging.
Two dimensional echo

- Many potentially useful planes
- 4 chamber refers to visualization of the RA, RV, LA, LV
- 5 chamber adds the proximal aorta
- Long axis = sagittal image planes that parallel the longitudinal axis
- Short axis = transverse images (horizontal)
Echocardiographic views

RV=right ventricle
LV=left ventricle
RA=right atrium
LA=left atrium
AO=aorta
Echocardiographic views

Short axis views

Long axis views

RV=right ventricle
LV=left ventricle
RA=right atrium
LA=left atrium
AO=aorta
Short axis 2DE loops
Long axis 2DE loop
Left apical views
Left apical views
Two dimensional echo

- Advantages
  - Ability to detect motion perpendicular to beam, display size and shape of structures

- Disadvantages
  - Slower frame rate than M-mode results in lower image quality
M-mode echocardiography

- M-mode imaging utilizes only a single crystal to produce a single beam ("ice pick") which is pulsed at a high frequency at the heart.
- The information from successive US pulses is displayed before the preceding lines have decayed and the result is an image in which the x-axis is time and the y-axis is distance from the transducer.
M-mode echocardiography

- Advantages
  - Rapid sampling rate results in high resolution
  - Most accurate measurement of intracardiac dimensions and structures and accurate timing of cardiac events (valve closure, wall motion, etc.)

- Disadvantages
  - The one dimensional image makes it difficult to appreciate spatial relationships and 3-D shapes of objects.
M-mode echocardiography
M-mode uses

- Ventricular lumen size and wall thickness
- Shortening fraction
  \[ SF = \frac{LVID_d - LVID_s}{LVID_d} \times 100 \]
  - Index of contractility
  - Significantly altered by changes in afterload
M-mode echocardiography

![Graph showing the effect of body size on LV fractional shortening.](image)
M-mode echocardiography
M-mode echocardiography
Doppler echocardiography

- When a propagating wave is reflected from a moving object, a shift in frequency results.
- This frequency shift is related in a mathematical manner to the velocity of the moving object and is known as the Doppler principle.
- The computer can use this formula and the Doppler shift to calculate direction and velocity of moving parts (i.e. red blood cells or cardiac wall).
Doppler echocardiography

- A positive shift means flow is moving toward the transducer and a negative shift means blood is moving away.
Doppler Echocardiography

- **Pulsed wave Doppler**
  - Color Flow and Spectral
  - Assessment of blood flow in a specific region, but cannot assess high velocity flows

- **Continuous wave Doppler**
  - Assessment of blood flow “continuously” along the cursor line
  - Capable of measuring high velocity flows
Doppler echocardiography

- As the intercept angle, theta, deviates from 0, velocity will be underestimated.

- The 4 and 5 chamber 2DE views optimize the beam angle (for assessment of the MV, TV, and AOV) to minimize this error.
Aliasing phenomenon

- Nyquist limit = Maximal unambiguous velocity measurement
- Nyquist limit is exceeded when:
  - Doppler shift frequency > pulse repetition frequency / 2

Therefore, the higher the blood flow velocity and the greater the depth, the more likely aliasing will occur with PW Doppler
Pulsed wave Doppler

- Advantages:
  - Interrogation of blood velocity at a specific site

- Disadvantages:
  - As depth of interrogation increases, and blood velocity increases, the Nyquist limit may be exceeded resulting in aliasing, and the flow pattern is ambiguous.
Aortic flow  Pulmonary artery flow

[Image of flow tracings with annotations: PEP, ET, Valve Artefact, 1 m/sec]
Aliasing
Pulse Wave, MV flow

Doppler cursor
LA
Aliasing - color flow Doppler
Continuous wave Doppler

Advantages:

- Two crystals within the probe are constantly sending and receiving data so high velocity flow can be accurately measured.

Disadvantages:

- Flow velocity is measured along the entire Doppler beam, a specific region cannot be individually interrogated.
Continuous wave Doppler
Continuous wave Doppler
Continuous wave Doppler
Modified Bernoulli Equation

Pressure gradient = $4V^2$
Modified Bernoulli Equation

Pressure gradient $= 4V^2$

$PG = 4(5)^2$
$PG = 4(25)$
$PG = 100$
Special Echocardiographic techniques
Contrast echocardiography

- Gas bubbles in agitated saline are hyperechoic and may help locate abnormal flow patterns such as shunts.
- Bubbles are too large to cross capillary beds.
- Most typically used for right to left shunts:
  - Patent foramen ovale, Tetrology of Fallot, Pulmonic stenosis and atrial septal defect, or R to L patent ductus arteriosus.
Contrast echocardiography