**Stress Echocardiography**  
(Chapter 7)

**History**
- Johann Christian Doppler (1803-183)
  - relationship between frequency shift and velocity
  - Doppler effect
- WW11
  - development of radar and sonar
- Late 60s
  - used to monitor flow velocities in the heart

**Doppler measurements**
- Blood flow velocity and direction of flow can be determined from the frequency of sound
  - increasing frequency—flow towards the probe
  - decreasing frequency—flow away from the probe

**Clinical uses : the heart**
- Cardiac structures
  - chamber size, volume, wall thickness
- Cardiac function
  - cardiac output, contractility
- Wall motion
- Valve function

**Clinical Uses : the vasculature**
- Vessel wall thickness
- clots (DVTs)
- Aneurisms
- Stroke damage

**Other clinical uses:**
- Identify congenital abnormalities
- Fetal imaging
- Organ imaging
- Measures of vascular function
- Cardiac hypertrophy
  - screening test for athletes
Research Applications

- Contrast echo
  - to identify patent foramen ovale
  - screening for divers
- Bubble detection
  - for decompression sickness
- Cardiac atrophy
  - spaceflight
  - disease

Types of Doppler imaging

- Cardiac imaging
- Trans-esophageal imaging
- Contrast echo
- Transcranial doppler
- Vascular imaging

M-mode images (motion mode)

- One dimensional slices of the heart (single beam of sound)
- Measures vessel and chamber diameters, wall thickness

2-Dimensional images (D mode)

- Video or still images of the contracting heart (fan-shaped wedge of sound)
- Identifies abnormal wall motion, valve motion
- Assesses cardiac contractility
  - ejection fraction, ESV, velocity of fiber shortening
- Assesses cardiac filling

2-D image in the long axis parasternal view

Color Doppler Imaging

- Mitral regurgitation. Flow moving backward from the transducer is blue
- Ventricular septal defect. Red jet across the septum represents the defect. Velocity curve on the right
Continuous wave Doppler to measure cardiac output

1. Measure diameter of the aorta (m-mode)
2. Measure velocity of flow from the aorta at peak systole (2-D image)
3. Calculate the volume of flow
   Cross sectional area x velocity
Assumptions
   - Probe angle is critical

Cardiac Output from 2-D measurements

1. EKG gating
2. Measure LVV at end diastole
3. Measure LVV at end systole
4. Calculate SV, (EDV - ESV)
5. Calculate Q, (HR x SV)
Assumptions:
   - ellipsoid shape of the heart

Stress Echo Testing: to assess cardiac function

- Treadmill
  - Measurements obtained before and after exercise.
- Cycle
  - Measurements before and after supine exercise. Special cycle designed to turn to the left lateral position.
- Pharmacological testing
  - Dobutamine dominant stressor in US

Echo Advantages over EKG

- Greater sensitivity than regular stress testing (85% vs 68%)
- Greater specificity than regular stress testing (85-90% vs 60-90%)
- Can be used in patients with BBB, WPW, on digitalis, LV hypertrophy
- Can identify specific wall motion, ischemic and valve problems

Review of applications for exercise stress testing

- Cardiac output measurements
- Cardiac function (EF)
- Screening; athlete’s heart vs. cardiac hypertrophy
- Follow-up test for cardiac ischemia
- Muscle blood flow

Vascular imaging

- Combines m-mode to measure vessel diameter and blood velocity to calculate blood flow (vel x area)
- Color Doppler—color varies with velocity. Useful for identifying diseased heart valves or occluded vessels
Endothelium:
Single layer of cells

Endothelium:
Basement membrane

Endothelium:
Elastic fibers

Endothelium:
Smooth muscle

Endothelium:
Connective tissue

Endothelium: Normal Function

- Endocrine organ
  - Produces and responds to a variety of chemical and physical stimuli

- Maintains circulatory homeostasis
  - Responds to changes in hemodynamics
  - Regulates vascular tone

- Mediates anti-atherogenic properties
### Endothelium: Vasoactive Agents

<table>
<thead>
<tr>
<th>Vasodilators</th>
<th>Vasoconstrictors</th>
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</thead>
<tbody>
<tr>
<td><strong>NO</strong></td>
<td><strong>Endothelin</strong></td>
</tr>
<tr>
<td><strong>Bradykinin</strong></td>
<td><strong>Angiotensin II</strong></td>
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<tr>
<td><strong>Prostacyclin</strong></td>
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<tr>
<td><strong>C-type natriuretic peptide</strong></td>
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</tbody>
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### Nitric Oxide

**KEY** endothelial derived relaxing factor
- Synthesized from L-arginine by action of NOS, diffuses out of cell, causes smooth muscle to relax (by indirectly activating myosin)
- Bioactivity of NO used to represent endothelial function

### Assessment of Endothelial Function

- Used to test for PAD
- Vasodilatory or vasoconstrictive response
  - Pharmacological agonists
    - Nitroprusside—stimulates NO and dilation
  - Mechanical stimuli
    - Occlusion—increases intravascular pressure and stimulates dilation

### Conclusions: echo Doppler

- Cardiac measurements
  - Assess cardiac dimensions (disease/athletes)
  - Evaluate wall motion and valve function
  - Assess cardiac contractility
    - Rest and exercise (stress echo)
- Peripheral vascular measurements
  - Assess vascular health
  - Research on exercise benefits