Disclosures

- Nothing to disclose
Objectives

- Understand the use of echocardiography to assess aortic valve disease
- Apply clinical guidelines to management of aortic valve disease
Aortic Valve Anatomy

Source: Fuster V, O’Rourke RA, Walsh RA, Poole-Wilson
P: Hurst’s The Heart, 12th Edition: http://www.accessmedicine.com

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Selected Abnormalities of Aortic Valve

- **Aortic Stenosis**
  - Narrowing of the valve orifice

- **Aortic Regurgitation**
  - Incompetence of the valve
  - Blood “leaks” from aorta to left ventricle in ventricular diastole

- **Bicuspid Aortic Valve**

- **Endocarditis**
How to Assess the Aortic Valve

- Clinical History
- Physical Examination
- Echocardiography
  - Transthoracic
  - Transesophageal
- Angiography
- Cardiac CT (not regurgitation, though)
- MRI
Why do aortic valves become stenotic?

- **Valvular Stenosis**
  - Bicuspid valve with calcification
  - Age-related calcific aortic stenosis
  - Rheumatic
  - Rare causes: Congenital, Rheumatoid, Severe atherosclerosis (Hyperlipidemia), alkaptonuria

- **Supravalvular Stenosis**

- **Subvalvular Stenosis**
  - Discrete
  - Hypertrophic Cardiomyopathy
Normal aortic valve

Bicuspid aortic stenosis

Rheumatic aortic stenosis

Age related aortic stenosis

Braunwald 8th ed.
Normal trileaflet aortic valve echo
How to assess aortic stenosis by echo

- **2-D echo**
  - Planimetry – measure the valve orifice

- **Doppler Hemodynamics**
  - Continuity equation
  - Peak/Mean pressure gradient
Planimetry

Technically difficult, may overestimate valve area

Transthoracic  Transesophageal
Echo Doppler

- Echo probe generates sound wave
- Sound wave reflects off tissue/blood
- Echo probe has a time window to listen for these reflections
- Moving targets (blood) will create a frequency shift in the sound wave
- This frequency shift can be translated into a velocity
- Can measure the velocity of blood flow
Continuity equation

Without a nozzle, the water velocity inside the hose (1/2") is the same as after the hose.
Continuity equation

With a nozzle, the water velocity inside the hose (1/2") is lower than after the nozzle.

Nozzle reduces the orifice area.

- Know diameter of hose (1/2")
- Can measure velocity of water in the hose
- Can measure the velocity of water after the nozzle
- What is the effective orifice created by the nozzle?
Conservation of mass

Flow before nozzle = Flow after nozzle

Area of hose * velocity of water in hose = Orifice area * velocity of water after hose

\[ \text{Area} = \left( \frac{1}{2} \times \text{diameter} \right)^2 \times 3.14(\pi) \]

Can solve equation for orifice area
Continuity equation

- Now think of the aortic valve
- Can measure LVOT diameter
- Can measure LVOT velocity (or TVI)
- Can measure velocity (or TVI) after aortic valve

- Can solve for aortic valve orifice
- Simplified Bernoulli equation
  
  \[ 4v^2 = \text{mmHg pressure gradient} \]
DETERMINING THE STENOTIC AREA BY THE CONTINUITY EQUATION

\[ A_1 \times VT_{11} = A_2 \times VT_{12} \]

\[ A_2 = \frac{A_1 \times VT_{11}}{VT_{12}} \]
Case 1

- 77 year old African American Male
- Referred for evaluation of murmur
- Medical history: HTN
- Asymptomatic, able to walk up and down stairs, shovel snow
- BP 146/86
- Crescendo/Descrescendo 3/6 systolic murmur at left lower sternal border
LVOT VTI = 0.213 m
Vmax = 0.99 m/sec
Pk Grad = 3.9 mmHg
Mn Grad = 1.6 mmHg

PW: 1.75 MHz
<table>
<thead>
<tr>
<th>Aortic Valve</th>
<th>Aortic Doppler</th>
</tr>
</thead>
<tbody>
<tr>
<td>AoV Vmax</td>
<td>4.47 m/sec</td>
</tr>
<tr>
<td>AoV VTI</td>
<td>1.050 m</td>
</tr>
<tr>
<td>AoV Pk Grad</td>
<td>79.9 mmHg</td>
</tr>
<tr>
<td>AoV Mn Grad</td>
<td>45.3 mmHg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aortic Valve</th>
<th>AoV Continuity Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AoV VTI</td>
<td>0.99 m</td>
</tr>
<tr>
<td>Vmean</td>
<td>3.000 m/s</td>
</tr>
<tr>
<td>LVOT Diam</td>
<td>2.20 cm</td>
</tr>
<tr>
<td>AoV Area, VTI</td>
<td>0.77 cm²</td>
</tr>
<tr>
<td>AoV Area, Vmax</td>
<td>0.84 cm²</td>
</tr>
<tr>
<td>AoV Area, Vmean</td>
<td>0.72 cm²</td>
</tr>
<tr>
<td>AoV Area/BSA, VTI</td>
<td>0.32 cm²/m²</td>
</tr>
<tr>
<td>AoV Area/BSA, Vmax</td>
<td>0.35 cm²/m²</td>
</tr>
<tr>
<td>AoV Area/BSA, Vmean</td>
<td>0.30 cm²/m²</td>
</tr>
</tbody>
</table>

See Reference Manual for information on editing measurements, results and calculations.
Severe aortic stenosis

- Aortic valve area <1.0cm²
- Peak aortic velocity >4.0m²
- Mean aortic valve gradient >40 mmHg
Pathophysiology of Aortic Stenosis

- Previously felt to occur as a normal process of aging, related to mechanical stress on normal valve
- Current theory involves inflammatory process with T lymphocyte and macrophage infiltration with lipid accumulation, resulting in bone formation (calcification)
Prevalence of Aortic Stenosis

At age 65

- 29% have aortic sclerosis
  - Irregular thickening of leaflets
  - Mild/early form of stenosis
- 2% have aortic stenosis
Risk factors for AS

- Genetic – familial clustering noted in some cases
- Elevated LDL
- Elevated Lp(a)
- Diabetes
- Smoking
- Hypertension
Pathphysiology of Aortic Stenosis

- Valve orifice area slowly declines over time
- Symptoms progress gradually
- LV pressure overload results in concentric hypertrophy
- Increased LV wall mass, diastolic dysfunction
Symptoms of AS (Severe)

- Exertional Dyspnea/Heart failure
- Chest pain
  - 50% with significant coronary atherosclerosis
- Syncope
  - Vasodilation with fixed cardiac output
Physical Examination of AS

- Palpation of the carotid upstroke
  - *Parvus et tardus*
- Systolic murmur
  - Crescendo-decrescendo
- Heart failure
  - Crackles in lung fields
  - Jugular venous distension
  - Edema
FINDINGS IN PATIENTS WITH AORTIC STENOSIS

**ECG**

**Doppler echocardiography aortic jet**
- Velocity (m/s)
  - 2
  - 4
  - 6
  - 8
- Pressure difference:
  \[ P_2 - P_1 = (4 \times \text{Velocity of flow})^2 \]

**Phonocardiogram**
- Late-peaking crescendo-decrescendo systolic murmur
- Single second heart sound

**Delayed and low-volume carotid upstroke**
- Pressure
  - 150
  - 100
  - 50
- Aortic pressure
- Left ventricular pressure

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Management of Asymptomatic Severe Aortic Stenosis

- Up to 33% remain asymptomatic for 5 years
- Without symptoms, prognosis is generally good
  - Risk of sudden death 1-2%/year
- Consider exercise testing under direct cardiologist supervision
  - Verify “asymptomatic”
  - Assess for fall in blood pressure

Does statin treatment affect AS?

- Retrospective studies show slowing of progression.
- Prospective (atorvastatin) study showed no benefit in advanced calcific aortic stenosis.
- Prospective (rosuvastatin) study showed slowing of progression in less severe aortic stenosis.
- Ongoing prospective trial using ezetimide (Zetia).


Case 1 management

- Exercised for 9 minutes on treadmill
  - Manual modified protocol
  - 6.8 METS
  - 83% maximum predicted heart rate
  - Good rise in blood pressure
  - Mild shortness of breath symptoms

- Started on Beta blocker
Case 1 Plan

- Remains asymptomatic 1 year later
- Plan for clinical follow-up every 6 months
- If other heart surgery (CABG) indicated, valve will be replaced
Case 2

- 48 year old male
- Heart murmur appreciated on physical examination
- Mild shortness of breath with exertion
  - Climbing 3 flights of stairs
  - No Chest pain
- Overweight, quit smoking recently
- DM, HTN, HLP
A closer look at the aortic valve
**Ao Valve**

- AoV PV: 4.4 m/s
- Mean Grad: 44.5 mmHg
- AoV VTI: 112 cm

**LVOT Dia:** 2.4 cm
**PGr:** 77.4 mmHg
**AV Area:** 1.1 cm²

**Freq:** 2.0 MHz
**WF Low:**
**Dop 71% Map 3:**
**PRF 20000 Hz:**

**APEX**
Bicuspid Aortic Valve

- Moderate to severe aortic stenosis
  - Aortic valve area 1.1 cm\(^2\)
  - Mean pressure gradient 44.5 mmHg
  - Peak velocity 4.4 m/s
- Mild aortic valve regurgitation
- Dilated of aortic root (4.3 cm)
Bicuspid aortic valve

- 1-2% Incidence in live births
- Male predominance (up to 80%)
- Association with disorders of aorta
  - Coarctation
  - Dilatation/aneurysm
  - Dissection
- Symptomatic stenosis develops around age 50
- Familial form with autosomal dominant inheritance (NOTCH1 gene mutation)

Management of Moderate Bicuspid Aortic Stenosis

- If there is aortic dilatation (>4.0cm)
  - Beta Blockers unless contraindicated
    - Moderate to severe regurgitation
  - Echo every year
  - Surgery if aortic root >5.0cm or >0.5cm/1 year

- Without aortic dilatation
  - No specific medical therapy
  - Echo every 1-2 years or if clinical change

Case 2 plan of care

- On statin for hyperlipidemia
- Treatment of DM, HTN (ARB)
- Aspirin 81mg daily
- Followup office and echo in 6 months
Another example of Bicuspid Aortic Valve
Case 3

- 44 year old white male
- Referred for loud murmur
- Spouse started hearing his heart at night about 1 month ago
- Asymptomatic, physically active, able to climb stairs
- No smoking, DM, HTN
- 6/6 loud holodiastolic murmur
Transthoracic Echo
AR Slope = 2.5 m/sec²
P½ Time = 401 msec
Decel Time = 1382 msec
Indications for Valve replacement in Aortic regurgitation

- Connective tissue disease with aortic root dilatation (25%)
- Congenital, including bicuspid (13%)
- Infective endocarditis (10%)
- Age-related calcific degeneration (7%)
- Other/Unknown/Idiopathic (35%)
  - Trauma, rheumatic, syphillis, aortic dissection, fenfluramine + phentermine, Antiphospholipid syndrome

Crawford & DiMarco, 2nd ed
How to assess aortic regurgitation

- History
- Physical
- Echocardiogram
- Angiography
- MRI
Echocardiographic evaluation of aortic regurgitation

- Color Doppler
  - Jet area
  - Jet height
  - PISA ERO
- Pressure ½ time
- Regurgitant fraction, volume
- Descending thoracic aortic flow reversal
- Left ventricular EF and dimensions
- No single criteria is perfect
- Eccentric jets are often worse than calculated/estimated
Color doppler

- Visual inspection
- Also Jet area and jet height

Mild

Moderate

Severe
Pressure $\frac{1}{2}$ time

- Measurement of time it takes for aortic pressure to equalize to ($\frac{1}{2}$) left ventricular pressure

- Variable thresholds in literature!
  - <300ms consistent with severe regurgitation
  - 300-500ms moderate
  - >500ms mild
Flow reversal in descending thoracic aorta
Case 3 management

- Severe posteriorly eccentric aortic regurgitation
- LV diastolic dimension 6.9cm
- EF 60-65%

- No clear etiology
- Blood cultures obtained
  - 2 of 2 initially positive gram + cocci
  - 1 of 4 subsequently positive gram + cocci
  - Initially admitted, treated with IV antibiotics
  - Blood cultures staph, all different species
  - Antibiotics stopped, no symptoms
Criteria for Surgery?

- Asymptomatic Severe Aortic regurgitation
  - EF <50%
  - Systolic dimension >5.5cm
  - Diastolic dimension >7.5cm

Guidelines are complicated, but become more vigilant about surveillance when
- Systolic dimension >5.0cm
- Diastolic dimension >7.0cm

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Issues not addressed in guidelines

- Noncoronary cusp prolapse with severe eccentric jet hitting anterior leaflet of the mitral valve
  - ? Possibility to distort Mitral valve architecture
- Unclear etiology
- Lifestyle
  - Both patient and spouse hear the murmur
Referred for elective surgery

- Mechanical or bioprosthetic valve?
- Intraoperatively, torn noncoronary cusp noted
- Overall stable postoperative course
Case 4

- Male in mid 40’s
- History of automobile accident with orthopedic trauma
- Several years afterward, noted to have murmur
- Echo showed aortic regurgitation
- Overall asymptomatic
- Does not want to take medications
Echo 8 years later...
Management

- LV diastolic dimension 7.6cm
- EF 55-60%
- Class 2A indication for surgery by guidelines

- Vasodilator therapy (Nifedipine, ACE inhibitors) are a Class 2B indication

- Pt declines surgery and medications
- 6-12 month clinical and echo followup

5 years later after last echo
As time passes...

- **Initial**
- **5 Years Later**

LVH decreases
LV diastolic dimension decreases
As time passes...

- Initial
- 5 Years Later

Pressure $\frac{1}{2}$ Time decreases
Correlating with worse regurgitation
As time passes...

- Initial
- 5 Years Later
Variable natural history

- **Asymptomatic patients with normal LV function**
  - <6%/year have symptoms and/or LV dysfunction
  - <3.5%/year progress to asymptomatic LV dysfunction
  - <0.2%/year have sudden cardiac death

- **Asymptomatic patients with LV dysfunction**
  - >25%/year progress to have symptoms

- **Symptomatic Severe Aortic Regurgitation**
  - >10%/year mortality rate
Conclusion

Case illustrations of decision making for
- Asymptomatic severe aortic stenosis
- Moderate bicuspid aortic stenosis with aortic root dilatation
- Asymptomatic severe aortic regurgitation

Symptoms + Severe AS or AR = Surgery

No clear medical management
- Consider Beta blockers for aortic root dilatation
- Statins for mild-moderate aortic stenosis?


