Challenges in assessing Aortic Stenosis

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No conflicts of interest
Why Measure Aortic Stenosis Severity?

• Follow and predict disease progression
• Inform decision making about timing of AVR

• Ensure AS is the *cause* of symptoms

Adams D. Surgical approach to aortic valve disease. In Otto and Bonow, Valvular Heart Disease, 3rd Ed, 2009
Decision Making in Aortic Stenosis

Key measures

- **AS-velocity** ($V_{\text{max}}$ in m/s)
- **Mean ΔP** (mmHg)
- **Valve Area** (AVA in cm$^2$)

Baumgartner et al, EAE/ASE Guidelines for Valve Stenosis, 2009
Doppler Echo Evaluation of Aortic Stenosis

AS Jet Velocity

Direct Measurement

Strongest predictor of clinical outcome
Doppler Echo Evaluation of Aortic Stenosis
Correct identification of flow signal

Aortic: 3.4 m/s

Mitral: 5.7 m/s

Tricuspid: 3.2 m/s
Doppler Echo Evaluation of Aortic Stenosis
Level and mechanism of obstruction
Importance of intercept angle

At an angle of 30°, a jet of 5 m/s would be measured as 4.3 m/s
Doppler Echo Evaluation of Aortic Stenosis

Importance of intercept angle

- Careful patient positioning
- Dedicated CWD transducer (smaller size, better signal)
- Multiple acoustic windows
- Careful angulation of beam
Doppler Echo Evaluation of Aortic Stenosis

Mean $\Delta P$: Simplified Bernoulli Equation

$$\Delta P = \frac{1}{2} \rho (v_2^2 - v_1^2) + \rho \left( \frac{dv}{dt} \right) + R (v)$$

$$\Delta P = 4(v_2^2 - v_1^2)$$

$$\Delta P = 4v^2$$

$$\Delta P_{\text{mean}} = \Sigma \frac{4v^2}{n}$$
Doppler Echo Evaluation of Aortic Stenosis

Doppler vs. Cath Gradients

Aortic Stenosis

- Maximum gradient
- Peak-to-peak gradient
- Mean gradient

Pressure (mm Hg)

Time (s)
Valve Hemodynamics: Pressure Recovery

Conservation of energy:

Kinetic energy $\rightarrow$ pressure

Most important with:

- Mild stenosis
- Small aortic root
- Congenital doming valve
Doppler Echo Evaluation of Aortic Stenosis

Effect of Δ flow rates

From: Burwash et al Circulation 1994
Doppler Echo Evaluation of Aortic Stenosis
Continuity Equation Valve Area

\[ A_2 = \frac{A_1 \cdot v_1}{v_2} \]

Transcatheter aortic valve implantation: Aortic annulus diameter for valve size
Transcatheter aortic valve implantation: Aortic annulus diameter for valve size

- Immediately adjacent and parallel to valve
- Septal endocardium to AMVL
- Used to size percutaneously implanted valves.
# Aortic Stenosis Severity

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AS Jet (m/s)</strong></td>
<td>0</td>
<td>&lt; 3</td>
<td>3-4</td>
</tr>
<tr>
<td><strong>Mean ΔP (mm Hg)</strong></td>
<td>&lt; 30</td>
<td>20-50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td><strong>AVA (cm²)</strong></td>
<td>&gt; 1.5</td>
<td>1.0-1.5</td>
<td>&lt; 1.0</td>
</tr>
<tr>
<td><strong>Indexed AVA (cm²/m²)</strong></td>
<td>&gt; 0.9</td>
<td>0.6-0.9</td>
<td>&lt; 0.60</td>
</tr>
<tr>
<td><strong>Velocity ratio</strong></td>
<td>&gt; 0.50</td>
<td>0.25-0.50</td>
<td>&lt; 0.25</td>
</tr>
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</table>

ASE/ESE Valve Stenosis Guidelines 2009
Aortic Stenosis Severity

56M with a bicuspid aortic valve who is physically active with no symptoms

AS Jet velocity 5.4 m/s
Mean $\Delta P$ 70 mm Hg
AVA 1.3 cm$^2$
56M bicuspid aortic valve
Doppler Echo Evaluation of Aortic Stenosis
Resolution of apparent discrepancies

AS jet > 4 m/s and AVA > 1.0 cm²

- LVOT diameter, compare with previous studies
- LVOT velocity (? flow acceleration)
- AR severity
- High cardiac output
  - LVOT stroke volume
  - 2D LV stroke volumes

Likely causes:
High cardiac output, Mod-Severe AR, Large body size
Aortic Stenosis Severity

73F with systolic murmur and exertional dyspnea. Pre-op evaluation for noncardiac surgery

AS Jet velocity
Mean ΔP
AVA

3.4 m/s
28 mm Hg
0.8 cm²
Aortic Stenosis Severity

73F with systolic murmur and exertional dyspnea. Pre-op evaluation for noncardiac surgery
Doppler Echo Evaluation of Aortic Stenosis
Resolution of apparent discrepancies

**AS jet ≤ 4 m/s and AVA ≤ 1.0 cm²**

- LVOT diameter, compare with previous studies
- LVOT velocity (? too far from valve)
- Index AVA (small body size)
- Low cardiac output (consider DSE)
  - LVOT stroke volume
  - 2D LV stroke volumes

Likely causes:
Low cardiac output, Severe MR, Small body size
84M with CHF and AS

AS jet 3.2 m/s

$\Delta P_{mean}$ 22 mmHg

AVA 1.0 cm$^2$
Is the primary problem the valve or the ventricle?

In the setting of ↓LV fx

- Consider other causes of myocardial dysfunction
- Look at valve anatomy and calcification
- Compare stenotic valve to prosthetic valve hemodynamics
- Evaluate valve area with changing flow rates
AS with LV systolic dysfunction
Low gradient aortic stenosis

**Definition**

\[
\text{AVA} \ < \ 1.0 \ \text{cm}^2 \\
\Delta P_{\text{mean}} \ < \ 30 \ \text{mm Hg} \\
V_{\text{max}} \ < \ 3.5 \ \text{m/s}
\]

Primary LV dysfunction with moderate AS

Pseudostenosis

Severe AS with afterload mismatch

“True” stenosis

Pseudostenosis

Nishimura 2002
84M with CHF and AS

EF 25%

EF 42%
84M with CHF and AS

**Baseline**
- BP: 115/45
- HR: 63
- AS Jet: 3.3 m/s
- Mean ΔP: 26 mmHg
- AVA: 1.03 cm²

**Dobutamine**
- BP: 126/46
- HR: 70
- AS Jet: 3.8 m/s
- Mean ΔP: 35 mmHg
- AVA: 1.01 cm²
AS with LV systolic dysfunction
Low gradient aortic stenosis

With dobutamine stress

**Definition of Severe AS**

- $\text{AVA} < 1.0 \text{ cm}^2$ *with*
- $\Delta P_{\text{mean}} > 40 \text{ mm Hg}$ *or*
- $V_{\text{max}} > 4.0 \text{ m/s}$

*At any flow rate*

**Lack of contractile reserve**

$\uparrow \text{LV-ejection fraction or}$

$\text{Stroke volume} < 20\%$

Baumgartner et al, EAE/ASE Guidelines for Valve Stenosis, 2009
Doppler Echo in Aortic stenosis: LVH with dynamic mid-cavity obstruction

79F with dyspnea and a heart murmur. Outside studies showed sub-aortic and valve gradients.
Doppler Echo in Aortic stenosis:
LVH with dynamic mid-cavity obstruction

79F with dyspnea and a heart murmur.
Outside studies showed sub-aortic and valve gradients.
Continuous Wave Doppler Spectra
Aortic Valve (Post-PVC)
Doppler Echo in Aortic stenosis:
LVH with dynamic mid-cavity obstruction

79F with dyspnea and a heart murmur. Outside studies showed sub-aortic and valve gradients.
Cardiac Catheterization

Simultaneous LV and Central Aortic Pressure Tracings
Impact of systemic hypertension in AS

Doppler Echo Evaluation of Aortic Stenosis
A Step by Step Approach

Step 1: AS Jet Velocity

Step 2: Mean pressure gradient

Step 3: Continuity equation valve area

Step 4: Clinical correlation
59 year old man with ↑DOE and angina

Moderate AS and moderate AR

LV EF 64%
No RWMA

\( V_{\text{max}} \) 3.7 m/s, Mean \( \Delta P \) 33 mm Hg, AVA 1.2 cm\(^2\)

Are his symptoms due to AS?
Why Measure Aortic Stenosis Severity?

- Ensure AS is the cause of symptoms
Moderate aortic stenosis

Symptoms

- Yes
  - LV Ejection Fraction
    - < 50%
      - Additional AS evaluation*
    - Normal
      - Dx & Rx other causes of symptoms
- No
  - Symptoms persist
  - Symptoms resolve

Consider AVR
Pre-operative angiography

Patient education, Cardiac risk factor modification, Clinical F/U, Annual Echo
Evaluation of Aortic Stenosis

Clinical history & physical exam

Echo F/U
Severe AS – 1 yr
Mod AS – 2-3 yr
Mild AS – 3-5 yr

ECHO

Exercise stress (IIb)

Dobutamine Stress (IIa)

Invasive hemodynamics

Coronary Angio

Change in clinical status

Low output

Non-diagnostic

Pre-op

?symptoms
Is the patient symptomatic?
LISTEN TO THE PATIENT

Symptom (simp’tum):
Any subjective evidence of disease or a patient’s condition, i.e. such evidence as perceived by the patient. *

Normal body sensation or “aches and pains” of daily life

A possible indicator of a serious problem that should be reported.

* Dorland’s Medical Dictionary
Evaluation of AS Severity
Detection of symptom onset

Cumulative proportion of symptom-free survival

- No symptoms
- Limiting symptoms

Time (months)

At risk

No symptoms
Limiting symptoms

Das, Rimington, Chambers. Eur Heart J 2005

Symptoms provoked on exercise testing
Prognosis in severe asymptomatic AS  
Role of long axis LV fx and BNP

N=126, mean age 67±10 yrs, 40% female. 
AVA ≤ 1.2 cm², normal EF, NSR, normal renal function 
Symptoms or AVR in 49% at 20 months

<table>
<thead>
<tr>
<th>Data at Inclusion</th>
<th>Cutoff Value</th>
<th>Area Under Curve</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA area (cm²/m²)</td>
<td>≥12.4</td>
<td>0.90</td>
<td>83.9%</td>
<td>90.6%</td>
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<tr>
<td>S-velocity (cm/s)</td>
<td>≤4.5</td>
<td>0.87</td>
<td>88.7%</td>
<td>82.8%</td>
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<tr>
<td>A-velocity (cm/s)</td>
<td>≤9</td>
<td>0.81</td>
<td>80.6%</td>
<td>75%</td>
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<tr>
<td>E/E’</td>
<td>&gt;13.8</td>
<td>0.67</td>
<td>42%</td>
<td>88%</td>
</tr>
<tr>
<td>BNP (pg/ml)</td>
<td>≥61</td>
<td>0.89</td>
<td>82%</td>
<td>93.7%</td>
</tr>
</tbody>
</table>

Lancellotti et al. Am J Cardiol 2010