Evaluation of Aortic Stenosis

Ferenc Puskas, MD, PhD
Assistant Professor
Division of Cardiothoracic Anesthesia
Department of Anesthesiology
University of Colorado at Denver and Health Sciences Center

Learning Objectives

- Pathophysiology of Aortic Stenosis, with Aortic Sclerosis as an early lesion
- Surrogate finding with AS, effecting surgical decision making
- Bicuspid Aortic Valve
- Doppler interrogation of the Aortic Valve
- What about the MR?
- How much leak is too much?

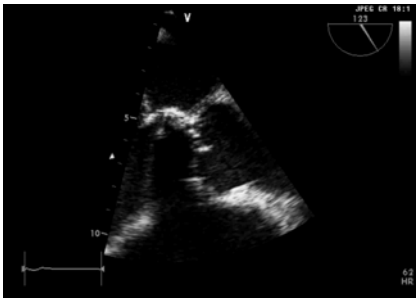
Aortic Stenosis

- Prevalence of 2% to 4% of adults over 65 years
- In the US over 50000 AVR per year
- Standard evaluation is echocardiography
- Symptom onset does not correspond to a single value in all patients
- Symptoms warrant AVR or
- Patient with moderate AS needs a cardiac surgery

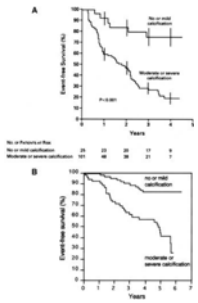
Aortic Sclerosis

- Irregular valve thickening without LV outflow obstruction
- 25% of adults over 65 yrs, 48% over 84 years
- Associated with a 50% increased risk for MI or cardiac death (without CAD)
- Antegrade Velocity < 2.5 m/s
- Maybe a surrogate marker for systemic inflammatory condition

Aortic Sclerosis



Effect of AoV Calcification



A. Patients with severe AS (jet velocity >4.0 m/s)
B. Patients with mild to moderate AS (jet velocity 2.5 to 4.0 m/s)

✓ Extent of valvular calcification significantly affected event free survival, with events defined as either death of valve replacement necessitated by symptom onset

Freeman, R. V. et al. Circulation 2005;111:3316-3326

Aortic Stenosis (Etiology)

- Acquired
  - Rheumatic
  - Degenerative (calcium)
  - Prosthetic
  - Infective endocarditis
- Congenital

Aortic Stenosis – Most Common Cause

- Calcification of normal trileaflet
- Calcification of congenital bicuspid valve
  - From the base of the cusp to the leaflet
  - Reduction of leaflet motion and effective valve are
  - Without commissural fusion

Stenotic BAV

Rheumatic AS – less common

- Fusion of commissures
- Scarring
- Eventual calcification
- Usually accompanied by Mitral valve disease

AS Associated Pathology

- ✓Left Ventricular hypertrophy (LVH)
- ✓Diastolic Dysfunction
- ✓Mitral Regurgitation
- ✓Aortic Root/Ascending Aortic Dilatation
- ✓Aortic Atherosclerosis
- ✓Other Valvular Calcification
- ✓Coronary Artery Disease

Goals of the Echo Study

- Etiology of AS
- Level of obstruction
- Valve calcification
- Leaflet motion
- Aortic root anatomy
- LV response to pressure overload

TEE assessment of severity

1. Aortic valve area (AoV)
   a. Planimetry
   b. Continuity equation
   c. Index
2. AoV gradient
   a. Mean
   b. Peak
3. Dimensionless index
4. LV function (LV Hypertrophy)

Severity of Aortic Stenosis

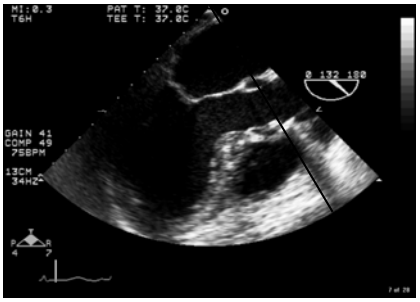
	Mild	Moderate	Severe
Jet velocity (m/sec)	< 3	3.0 – 4.0	> 4.0
Mean gradient (mmHg)	< 25	25 – 40	> 40
Valve area (cm^2)	> 1.5	1.0 – 1.5	< 1.0
Valve area index (cm^2/m^2)			< 0.6

Bonow et al. Circulation 2006;114;84-231

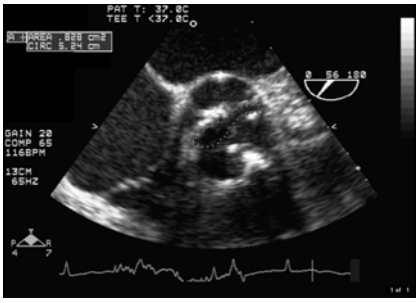
Planimetry

- Maximal Aortic Cusp Separation (MACS)
- Position leaflet tips at the center of two dimensional sector in the AV long axis view
- Rotate to AV short axis view, to ensure smallest orifice of aortic valve at leaflet tips

MACS



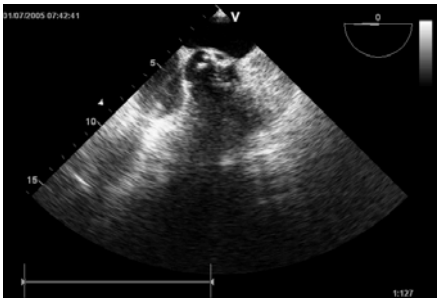
Planimetry



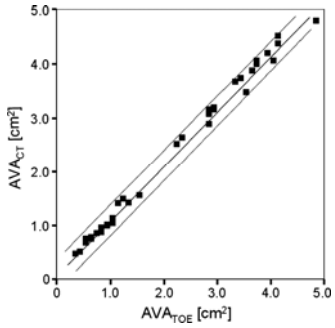
Planimetry Pitfalls

- Elusive measurement in AS
- Valve calcification causes
  - Reverberations
  - Shadowing
- Difficult to locate leaflet tips

Shadowing and Reverberations

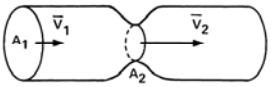


Scatter-plot with linear regression fit and 95% confidence intervals for AVA_{CT} (16 detector row CT) and AVA_{TEE} planimetry in 40 patients



Alkadhi, H. et al. Radiology 2006;240:47-55

Continuity Equation



$$Q = A_1\bar{V}_1 = A_2\bar{V}_2$$

$$\text{Therefore } \frac{A_1}{A_2} = \frac{\bar{V}_2}{\bar{V}_1}$$

FIGURE 1. Diagram illustrating the hemodynamic principle for determination of stenotic valve area. If A_1, $\bar{V}_1$, and $\bar{V}_2$ are known, the stenotic area A_2 can be derived as $Q/\bar{V}_2$. A = cross sectional area; $\bar{V}$ = mean velocity; Q = flow.

Zoghby et al. Circulation. 73,3:452:1986

Velocity of a moving column of fluid increases through areas of narrowing

Continuity Equation

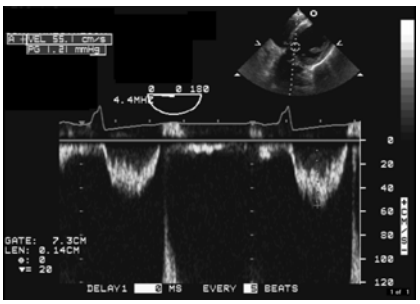
- Measure LVOT diameter just proximal to aortic leaflet attachment
- Measure LVOT flow (TVI) where diameter was measured

- AVA = CSA_{LVOT} x pkv_{LVOT}/pkv_{AoV}
  - ✓CSA = 0.785 x $diameter^2$
  - ✓pkv = peak velocity
  - ✓All cm/s!

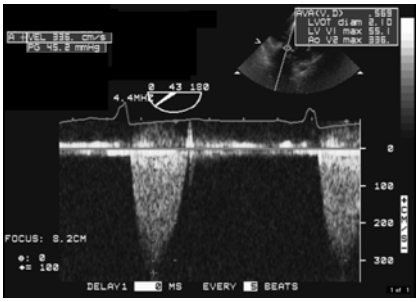
AoV Gradient

- Change in cross sectional flow leads to convective acceleration
- This velocity can be converted into pressure gradient using the modified Bernoulli equation:
  - Gradient = $4v^2$
    - Gradient: mmHg
    - v: velocity: m/s
- Locate maximal velocity
- Most clearly defined spectral velocity envelope

PWD LVOT



CWD AoV



Has been validated in several studies

Continuous-wave Doppler echocardiographic assessment of severity of calcific aortic stenosis: a simultaneous Doppler-catheter correlative study in 100 adult patients

PHILIP J. CURRIE, M.B.B.S., F.R.A.C.P., JAMES B. SEWARD, M.D., GUY S. REEDER, M.D., RONALD E. VLIETSTRA, MB.Ch.B, DENNIS R. BRESNAHAN, M.D., JOHN F. BRESNAHAN, M.D., HUGH C. SMITH, M.D., DONALD J. HAGLER, M.D., AND A. JAMIL TAJIK, M.D.

Circulation. 71;6:1162-1169.1985

Pressure recovery

- Increase of pressure downstream from a stenosis due to re-conversion of kinetic into potential energy
- Most important variable is the size of the aorta (clinically relevant in small size aorta < 3 cm)
- Marked overestimation of catheter gradients by Doppler
  - ✓ Bileaflet prosthetic valves
  - ✓ Coarctation of Aorta
  - ✓ HOCM
  - ✓ Fixed tunnel obstruction

Baumgartner et al. JACC 33;6, 1999.

Remember the Pitfalls

- Doppler equation (beam – blood flow angle < 20°
- High quality, complete spectral envelope does not guarantees that the angle of incidence is negligible
- Use multiple transducer positions
- Do not confuse with MR jet!

Doppler Imaging of AS

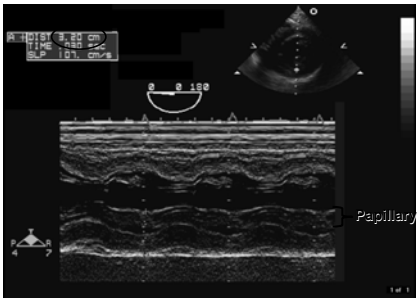
- Dimensionless index
  - $Area_{LVOT} \times (TVI_{LVOT}/TVI_{AoV}) = Area_{AoV}$
  - $TVI_{LVOT}/TVI_{AoV} < 0.3$ = Severe AS

Left Ventricular Hypertrophy

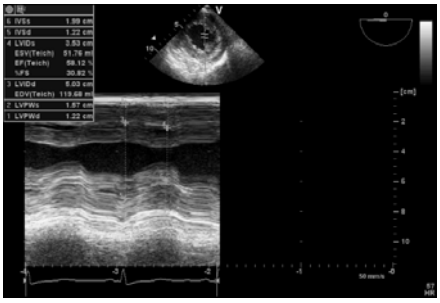
	Women				Men			
	Nml	Mild	Mod	Sev	Nml	Mild	Mod	Sev
Septal thickness	**0.6-0.9**	**1.0 – 1.2**	**1.3 – 1.5**	**≥ 1.6**	**0.6 – 1.0**	**1.1 – 1.3**	**1.4 – 1.6**	**≥ 1.7**
Posterior wall thickness	**0.6-0.9**	**1.0 – 1.2**	**1.3 – 1.5**	**≥ 1.6**	**0.6 – 1.0**	**1.1 – 1.3**	**1.4 – 1.6**	**≥ 1.7**

Lang et al. J Am Soc Echocardiogr 2005; 18: 1440

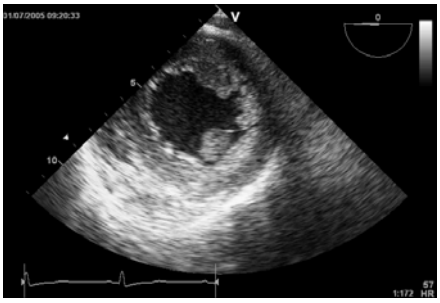
Evaluation of Left Ventricular Hypertrophy (LVH)



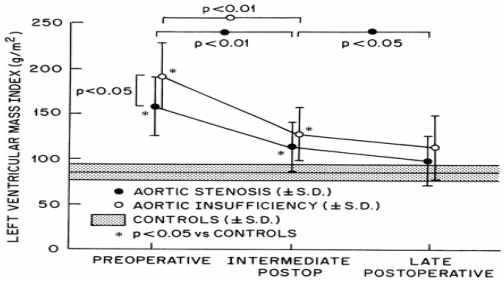
Evaluation of Left Ventricular Hypertrophy (LVH)



LVH transgastric short axis



Effect of AVR on LVH



Monrad et al. Circulation. 1988;77:1345–1355

Mitral Regurgitation (MR) and AS

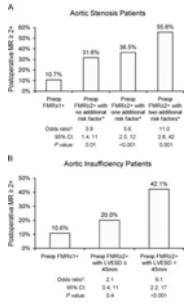
- Frequently associated
- Abnormal loading conditions
- Surgical treatment of MR during AVR is controversial
- MR can potentially regress after AVR

Mitral Regurgitation (MR) and AS

- 30 patients with normal LV function for AVR pre and post TTE and TEE (comparatively and prospectively)
- Moderate MR regresses early after AVR (only the regurgitant jet area, not jet width)
- Predictors for improvement: Left ventricular mass
- Predictive factors of fixed MR: Mitral calcification and/or left atrial dilation

Tassan-Mangina et al. Clinical Cardiology. 26(3):127-31, 2003

Effects of Functional Mitral Regurgitation (FMR) at the Time of Aortic Valve Replacement on Postoperative MR
(mean of 18 months postoperatively)



Additional risk factors are:
- ✓**Left atrial diameter <5 cm**
- ✓**Peak aortic gradient <60 mm Hg**
- ✓**Mean aortic gradient <40 mm Hg**
- ✓**Atrial fibrillation**

Ruel, M. et al. Circulation 2006;114:I-541-I-546

Severity of MR following AVR – impact on survival

- 196 patients with isolated AVR and MR was followed for average of 2 years
- MR improved 1-2 grades in 48% of patients
- 2+ MR: 43% improved, 36% unchanged and 21 % worsened
  - Survival: 98%
- 3+ MR: 38% unchanged
  - Survival: 78%
- Conclusion: Repair moderate to severe MR during AVR

Moazami et al. J Card Surg. 2004 19(5). 444-8

What to tell the Surgeon?

- Identify 3+ to 4+ MR during AVR
- Look for surrogate findings:
  - Mitral leaflet pathology
  - Calcified Mitral Annulus
  - LV dysfunction/Hypertrophy
  - LA size
  - Assess Aortic gradients (low gradient predictor of LV dysfunction)

Evaluation of Aortic Stenosis

Thank you!