Echocardiographic Evaluation of AV Hemodynamics and Morphology

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Aortic Stenosis

- **Etiology**
  - Congenital
    - **Bicuspid**
  - Acquired
    - **Degenerative**
      - Calcium deposition
      - AR : rare
      - DM, hypercholesterolemia
      - Smoking, HT, low HDL
    - **Rheumatic**
      - Commissure fusion
      - Cusp retraction & stiffening
      - MV involvement
      - AR : common

Bicuspid AS

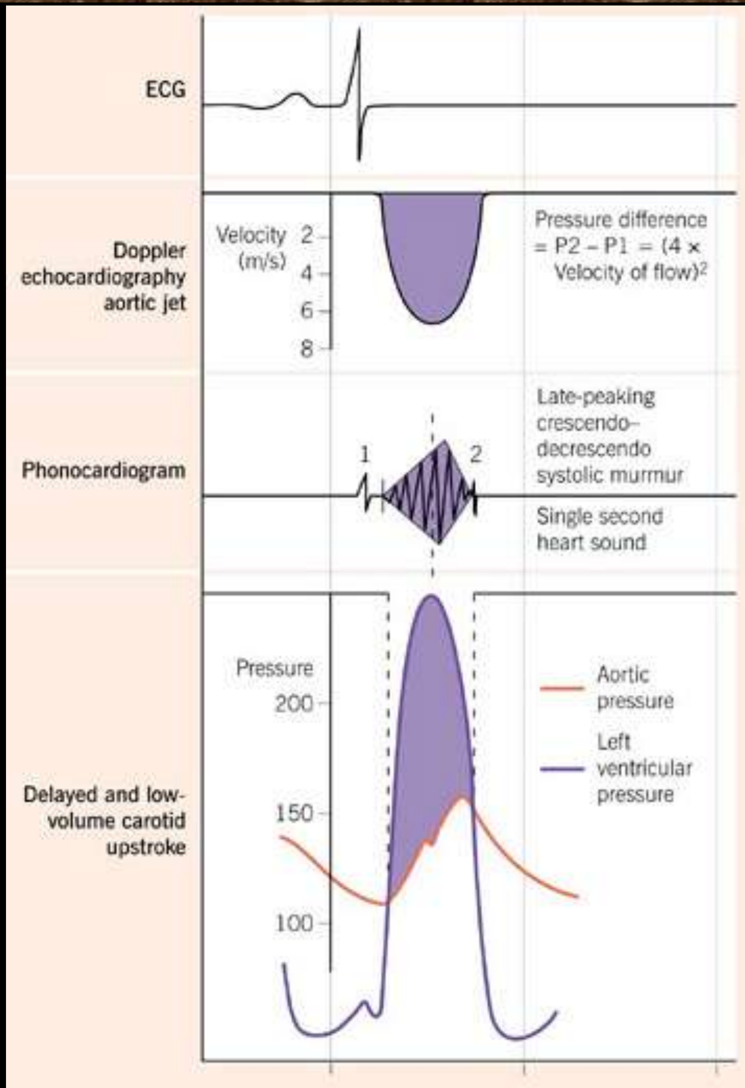

FR 39Hz
14cm
2D
56%
C 50
P Low
HGen
M3
P
R
1.7
3.4
JPEG
84 bpm

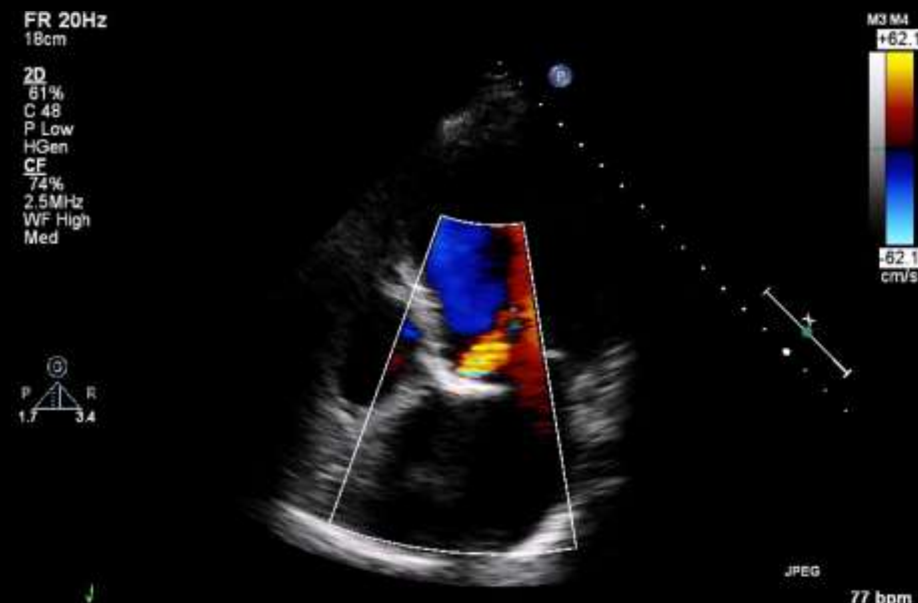

FR 39Hz
11cm
2D
55%
C 50
P Low
HGen
M3
P
R
1.7
3.4
JPEG
80 bpm

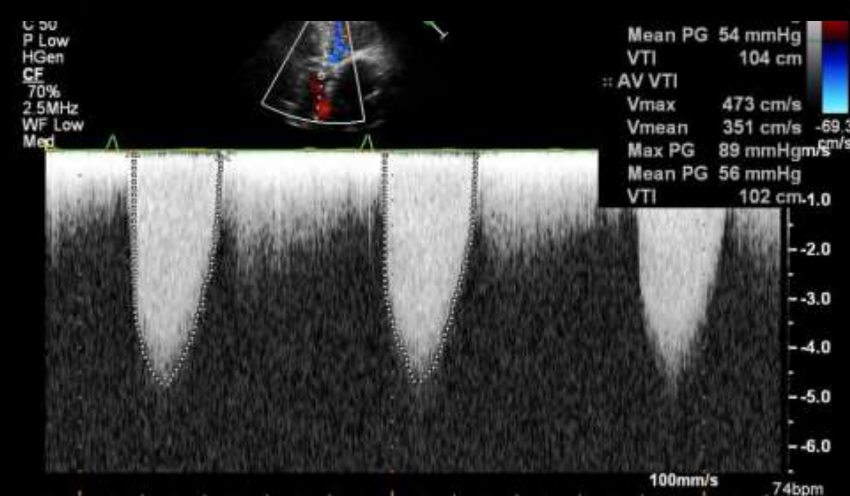
Degenerative AS

Rheumatic AS

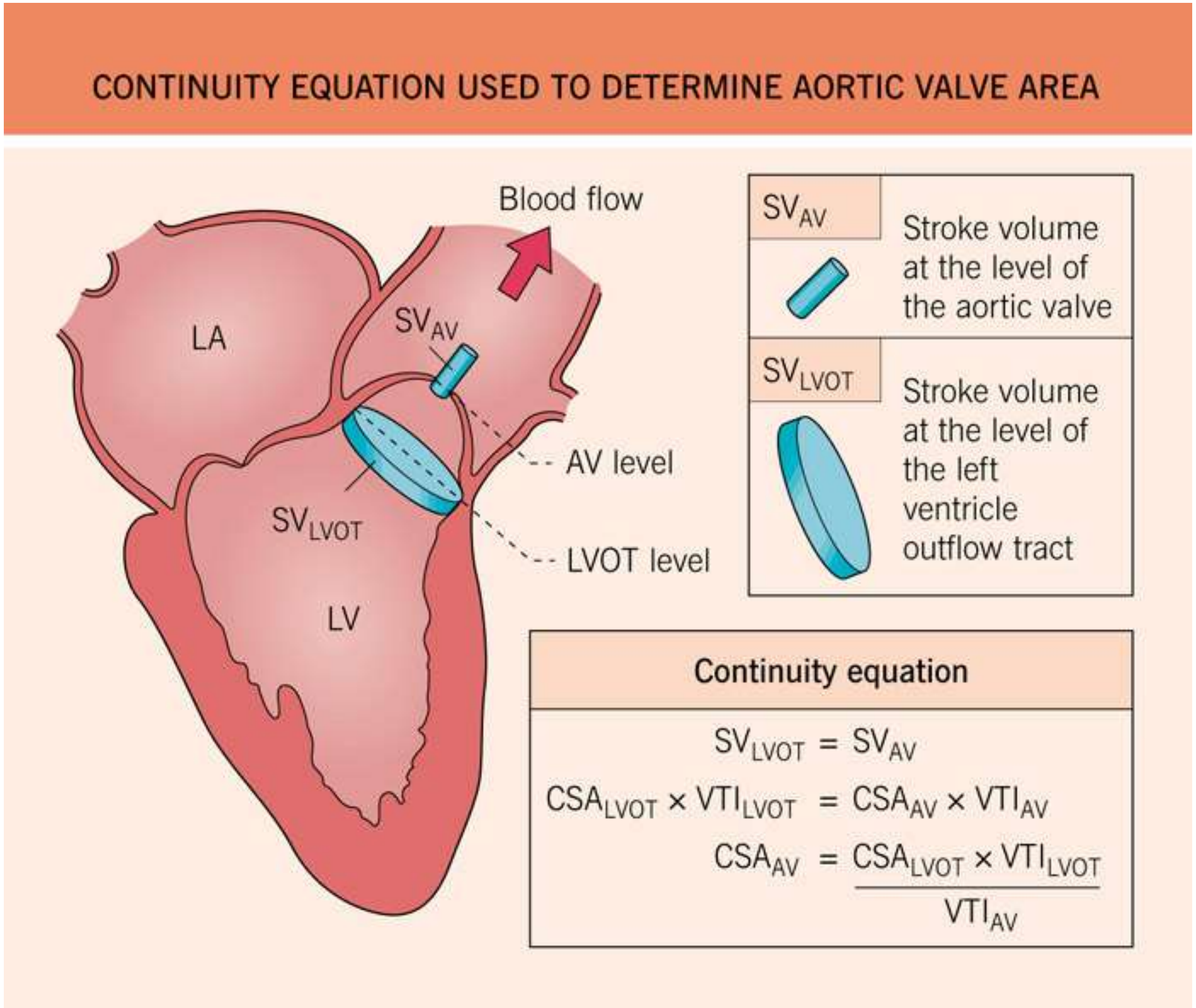
Hemodynamics



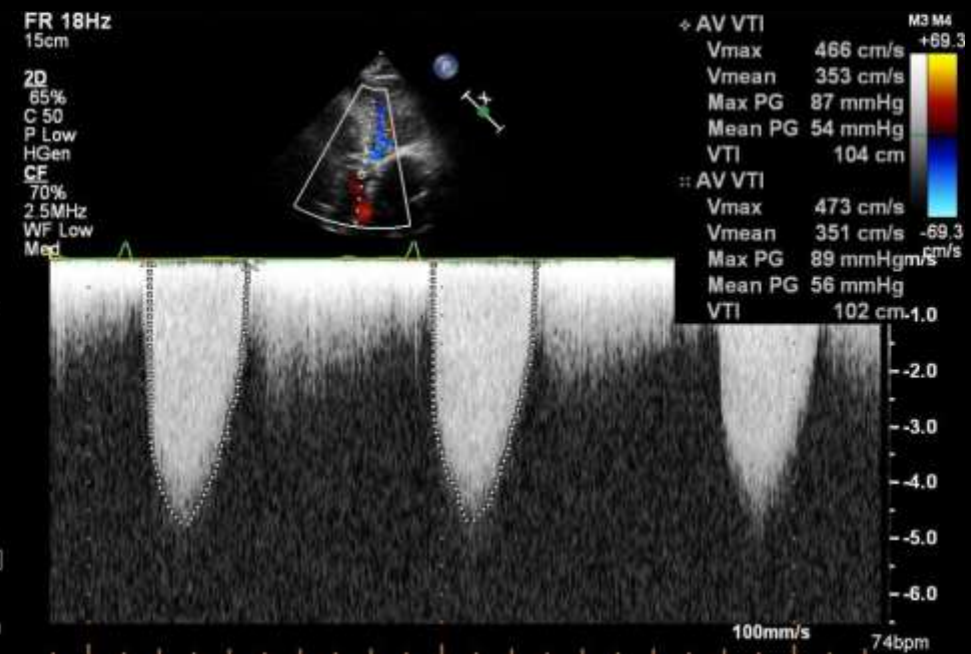


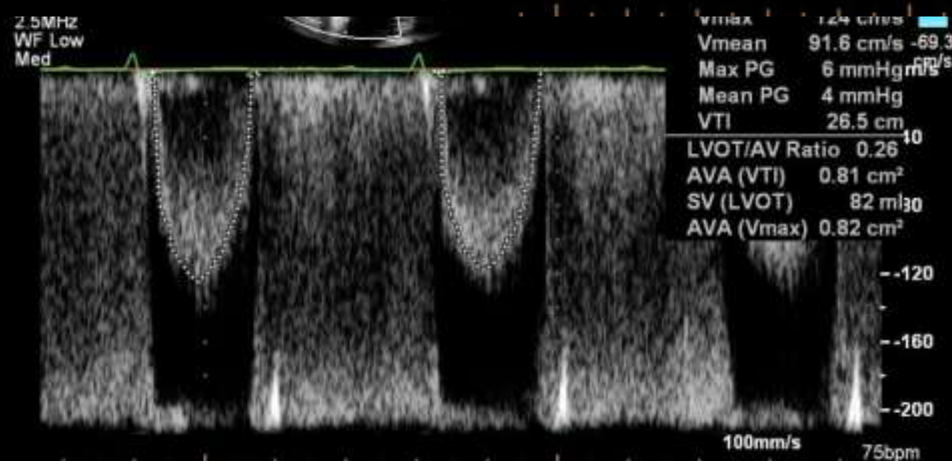


Measurement of AVA



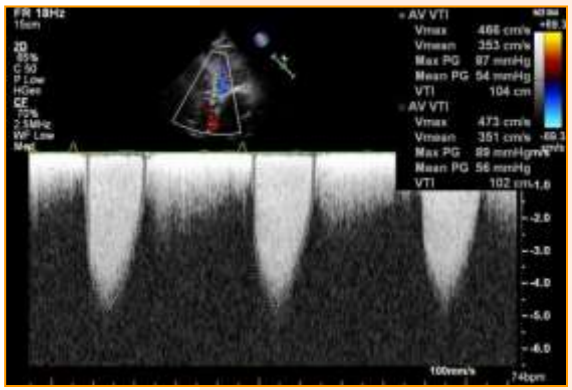
AVA by Continuity Equation

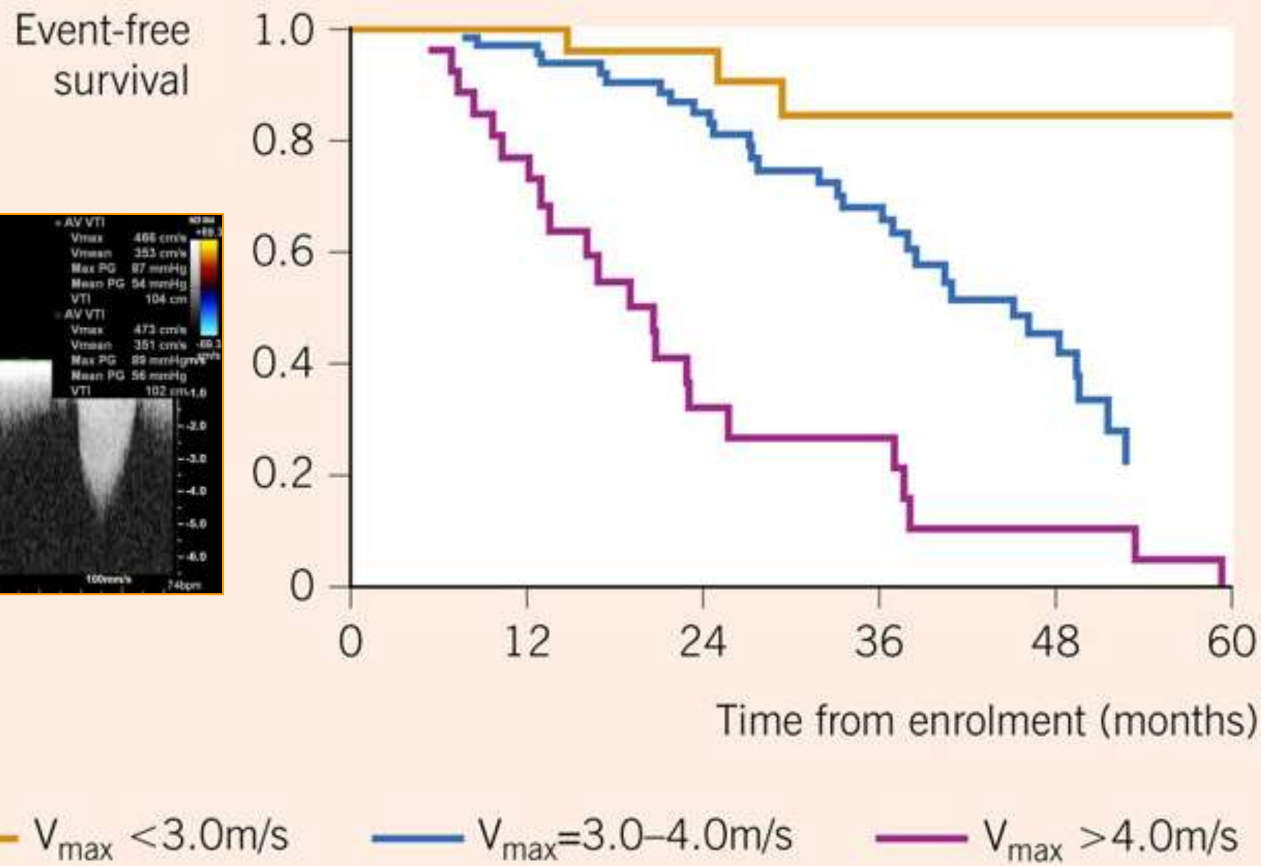




AVA by TEE Planimetry

Asymptomatic Severe AS





Otto et al. Circulation 1997;95:2262-70

Stages of AS

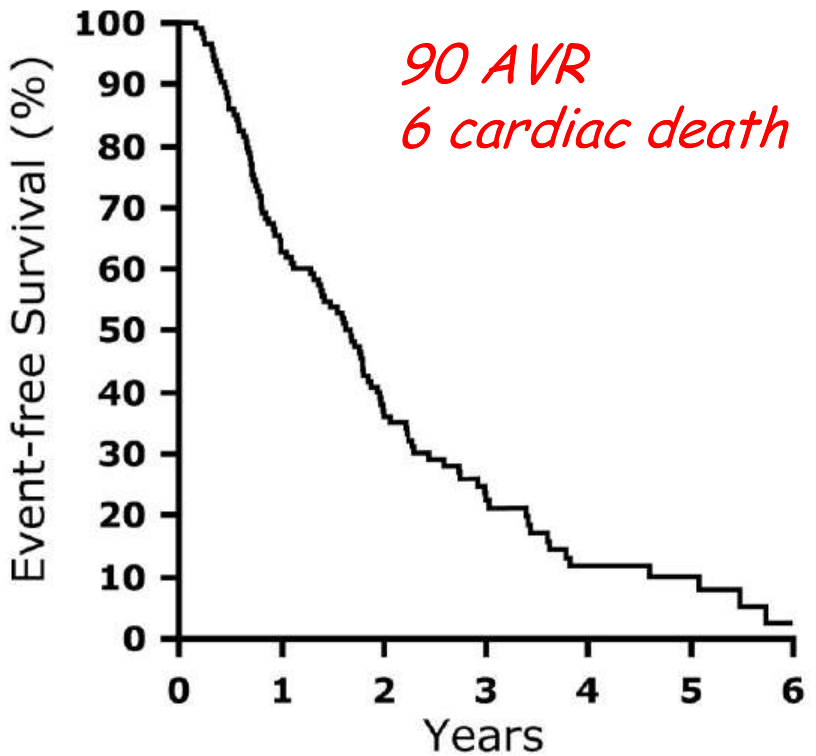
Table 8. Stages of Valvular AS

Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
A	At risk of AS	• Bicuspid aortic valve (or other congenital valve anomaly) • Aortic valve sclerosis	• Aortic V_{max} <2 m/s	• None	• None
B	Progressive AS	• Mild-to-moderate leaflet calcification of a bicuspid or trileaflet valve with some reduction in systolic motion or • Rheumatic valve changes with commissural fusion	• Mild AS: Aortic V_{max} 2.0–2.9 m/s or mean ΔP <20 mm Hg • Moderate AS: Aortic V_{max} 3.0–3.9 m/s or mean ΔP 20–39 mm Hg	• Early LV diastolic dysfunction may be present • Normal LVEF	• None
C: Asymptomatic severe AS					
C1	Asymptomatic severe AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically is ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) • Very severe AS is an aortic V_{max} ≥5 m/s or mean ΔP ≥60 mm Hg	• LV diastolic dysfunction • Mild LV hypertrophy • Normal LVEF	• None: Exercise testing is reasonable to confirm symptom status
C2	Asymptomatic severe AS with LV dysfunction	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2)	• LVEF <50%	• None
D: Symptomatic severe AS					
D1	Symptomatic severe high-gradient AS	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s or mean ΔP ≥40 mm Hg • AVA typically ≤1.0 cm^2 (or AVAi ≤0.6 cm^2/m^2) but may be larger with mixed AS/AR	• LV diastolic dysfunction • LV hypertrophy • Pulmonary hypertension may be present	• Exertional dyspnea or decreased exercise tolerance • Exertional angina • Exertional syncope or presyncope
D2	Symptomatic severe low-flow/low-gradient AS with reduced LVEF	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1.0 cm^2 with resting aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Dobutamine stress echocardiography shows AVA ≤1.0 cm^2 with V_{max} ≥4 m/s at any flow rate	• LV diastolic dysfunction • LV hypertrophy • LVEF <50%	• HF • Angina • Syncope or presyncope
D3	Symptomatic severe low-gradient	• Severe leaflet calcification	• AVA ≤1.0 cm^2 with aortic V_{max} <4 m/s or	• Increased LV	• HF

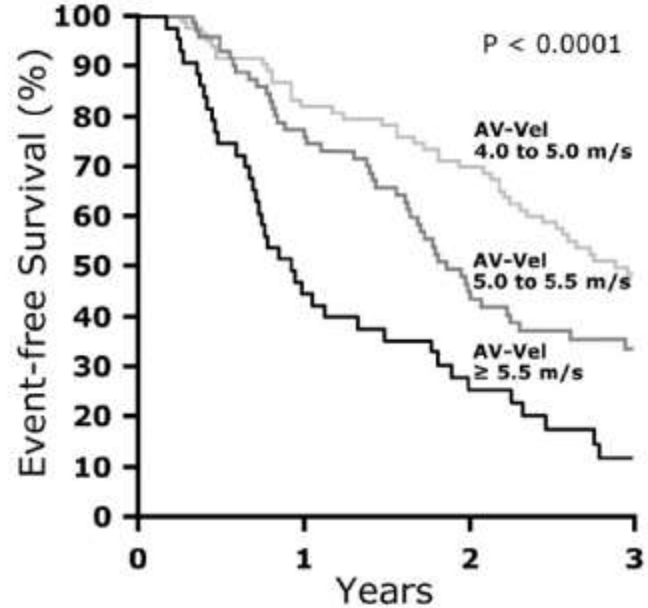
2014 AHA/ACC Guideline

Very Severe AS

- **116 consecutive asymptomatic patients with very severe isolated AS (AV-Vel > 5.0 m/s)**



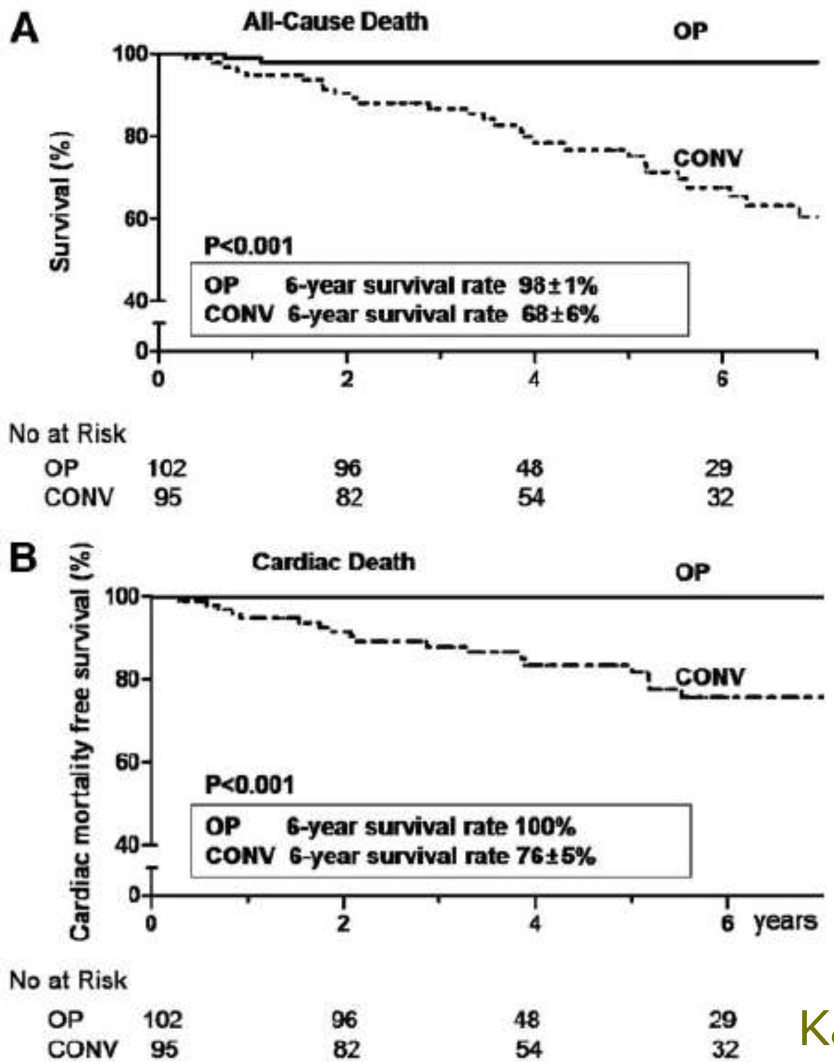
Pts. at risk: 116 73 40 23 9 6 2



Patients with AV-Vel from 4.0 to 5.0 m/s
Pts. at risk: 82 69 59 38
Patients with AV-Vel from 5.0 to 5.5 m/s
Pts. at risk: 72 53 29 18
Patients with AV-Vel ≥ 5.5 m/s
Pts. at risk: 44 20 11 5

Circulation. 2010;121:151-156

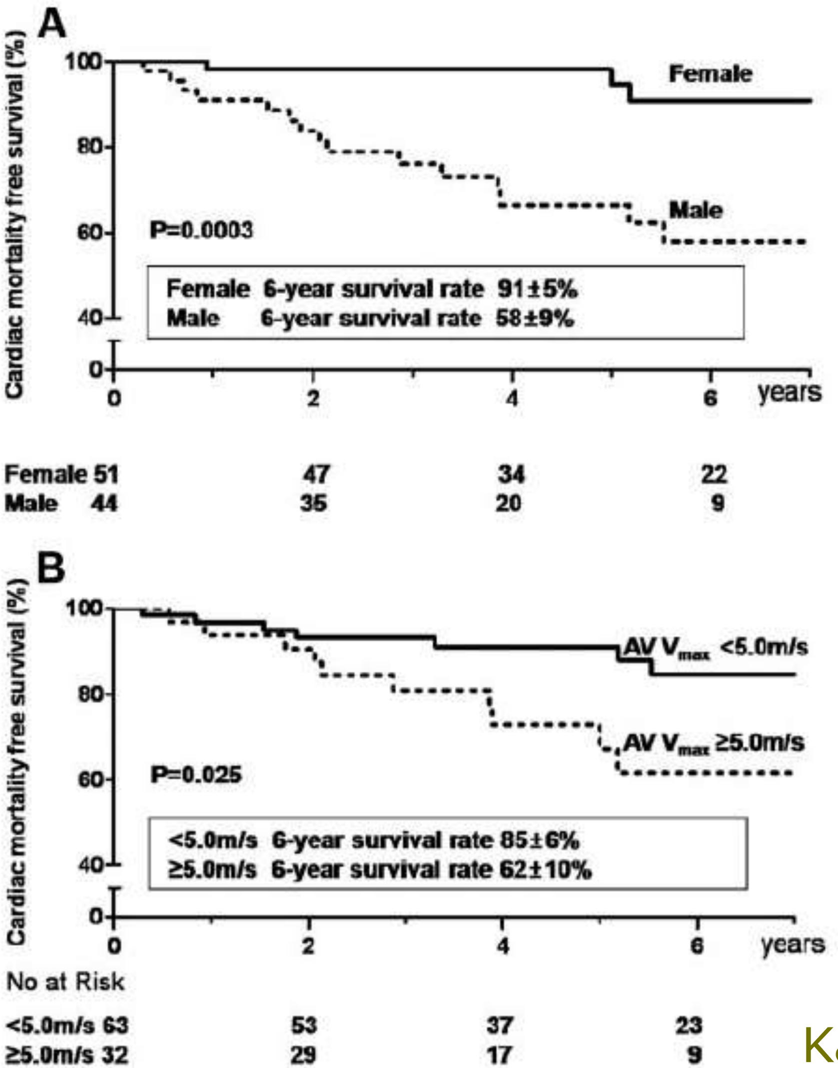
Asymptomatic Very Severe AS

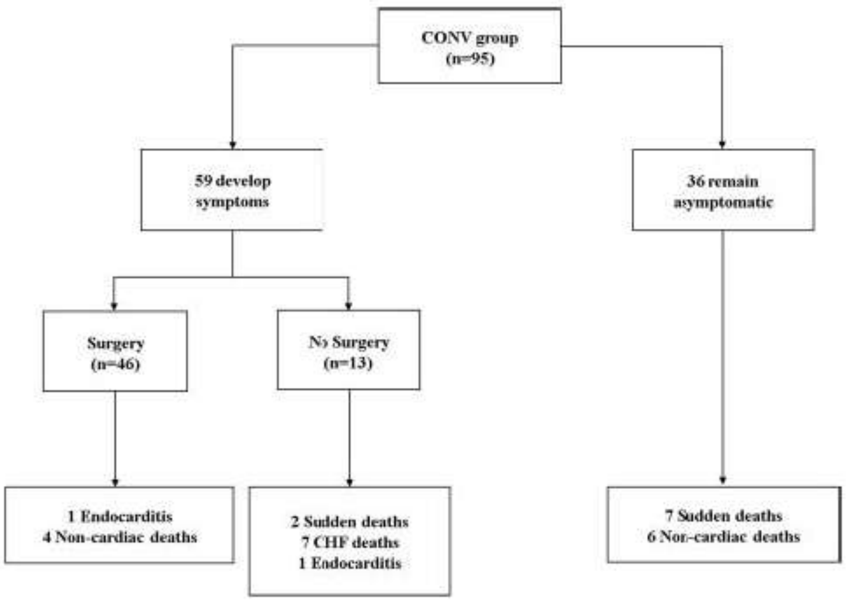


AVA ≤ 0.75 cm^2 & (Vmax ≥ 4.5 m/s or mean PG ≥ 50 mm Hg)

Kang DH, Circulation. 2010 ;121:1502-9.

Asymptomatic Very Severe AS





Kang DH, Circulation. 2010 ;121:1502-9.

Timing of Intervention for AS

Table 9. Summary of Recommendations for AS: Timing of Intervention

Recommendations	COR	LOE	References
AVR is recommended with severe high-gradient AS who have symptoms by history or on exercise testing (stage D1)	I	B	(9, 91, 134, 135)
AVR is recommended for asymptomatic patients with severe AS (stage C2) and LVEF <50%	I	B	(136, 137)
AVR is indicated for patients with severe AS (stage C or D) when undergoing other cardiac surgery	I	B	(108, 138)
AVR is reasonable for asymptomatic patients with very severe AS (stage C1, aortic velocity ≥5.0 m/s) and low surgical risk	IIa	B	(139, 140)
AVR is reasonable in asymptomatic patients (stage C1) with severe AS and decreased exercise tolerance or an exercise fall in BP	IIa	B	(25, 47)
AVR is reasonable in symptomatic patients with low-flow/low-gradient severe AS with reduced LVEF (stage D2) with a low-dose dobutamine stress study that shows an aortic velocity ≥4.0 m/s (or mean pressure gradient ≥40 mm Hg) with a valve area ≤1.0 cm^2 at any dobutamine dose	IIa	B	(43, 141, 142)
AVR is reasonable in symptomatic patients who have low-flow/low-gradient severe AS (stage D3) who are normotensive and have an LVEF ≥50% if clinical, hemodynamic, and anatomic data support valve obstruction as the most likely cause of symptoms	IIa	C	N/A
AVR is reasonable for patients with moderate AS (stage B) (aortic velocity 3.0–3.9 m/s) who are undergoing other cardiac surgery	IIa	C	N/A
AVR may be considered for asymptomatic patients with severe AS (stage C1) and rapid disease progression and low surgical risk	IIb	C	N/A

AS indicates aortic stenosis; AVR, aortic valve replacement by either surgical or transcatheter approach; BP, blood pressure; COR, Class of Recommendation; LOE, Level of Evidence; LVEF, left ventricular ejection fraction; and N/A, not applicable.

2014 AHA/ACC Guideline

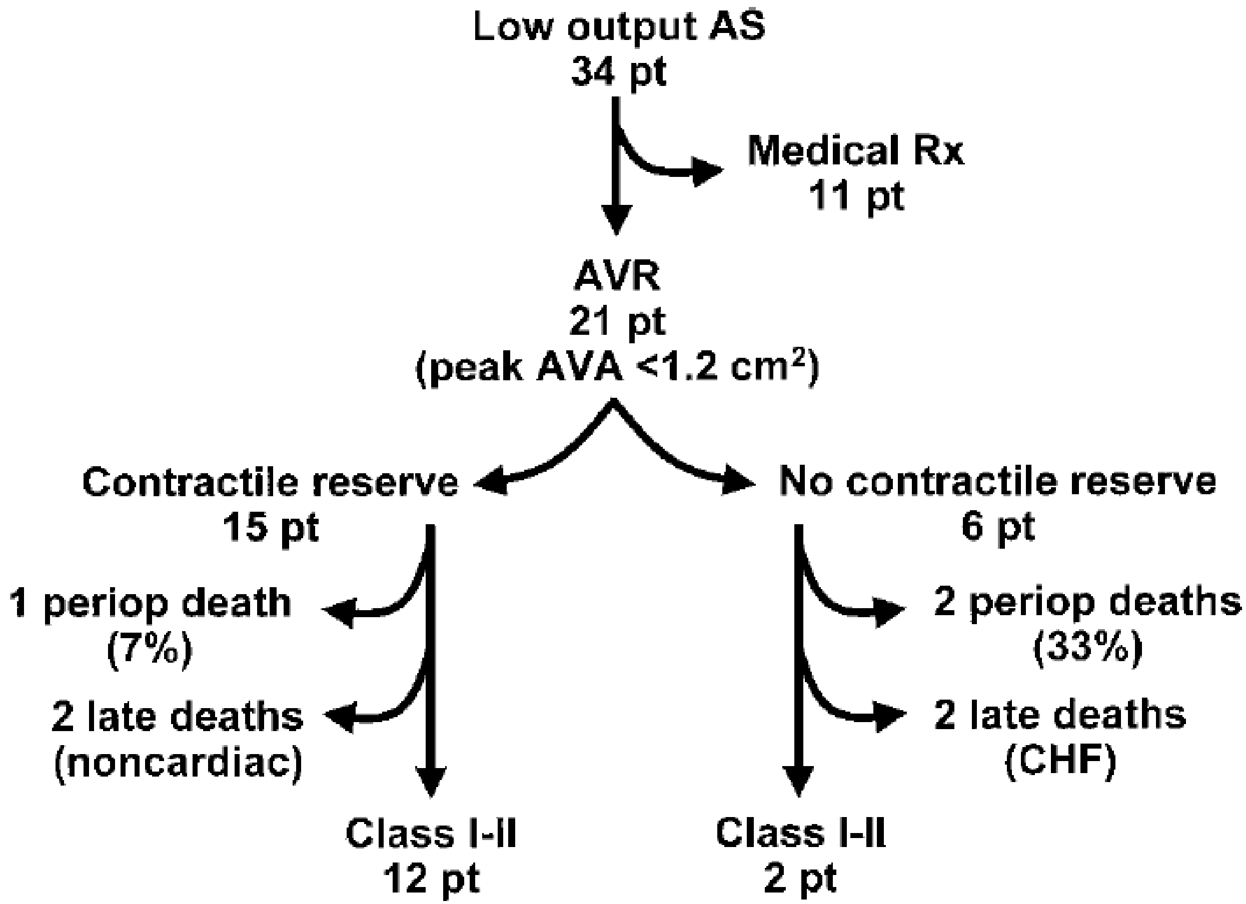
Tight AS with Severe LV dysfunction

peak PG > 50 mmHg
mean PG > 30-40 mmHg

- yes → **surgery**
- no → **dobutamine stress echocardiography**
  - yes (contractile reserve: WMSI increase > 20%, SV increase > 20%)
    - AVA $\Rightarrow$, PG $\Uparrow$ → **surgery**
    - AVA $\Uparrow$ > 0.3 cm^2, PG $\Rightarrow$ → pseudostenosis → **medical management, heart transplantation**
  - no → **?**

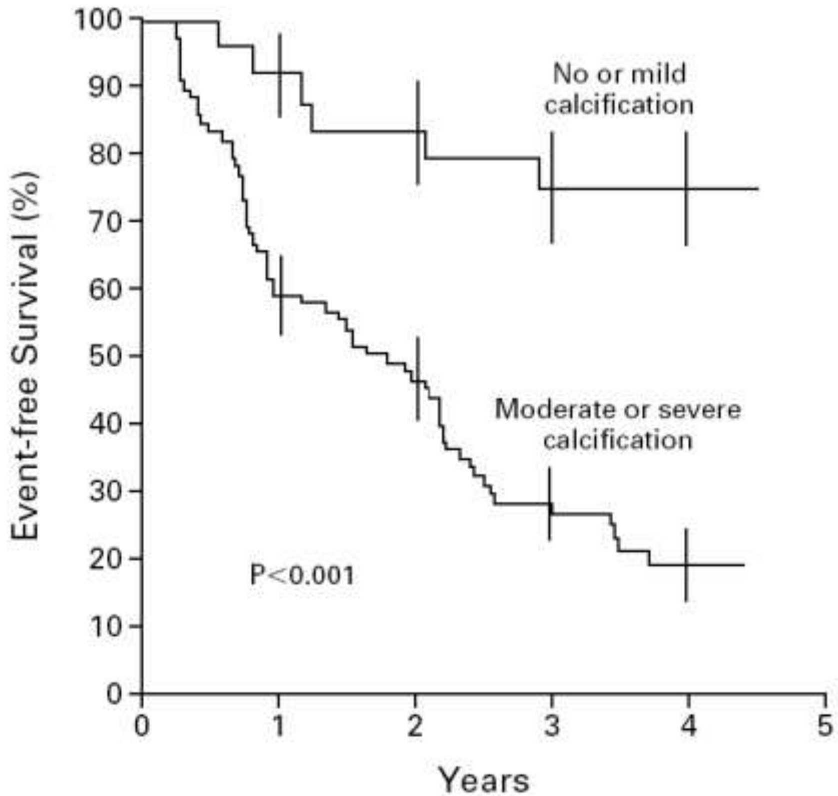
deFilippi et al. Am J Cardiol 1995;75:191-195

Tight AS with Severe LV dysfunction



Nishimura et al. Circulation 2002;106:809-813

Asymptomatic Severe AS

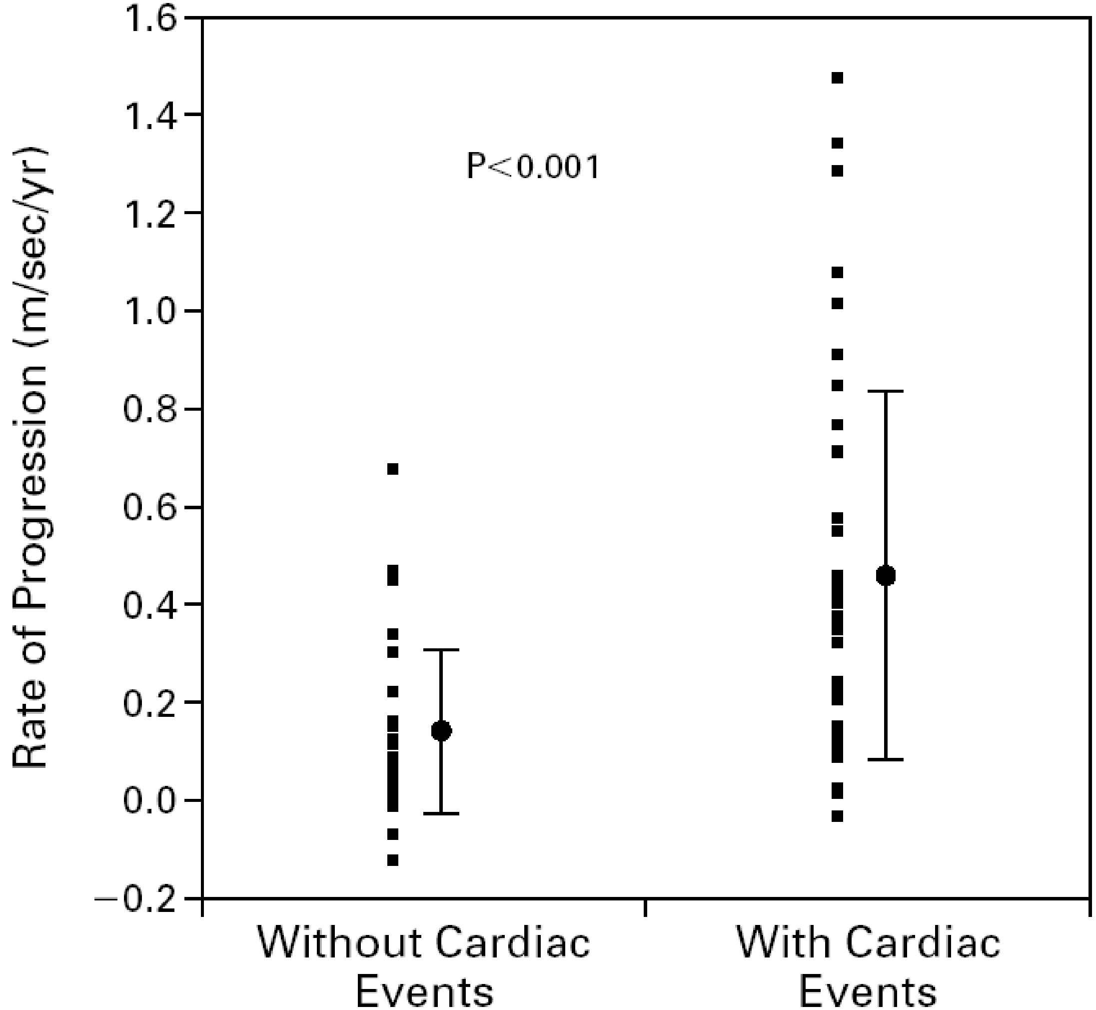


No. of Patients at Risk

No or mild calcification	25	23	20	17	9
Moderate or severe calcification	101	48	38	21	7

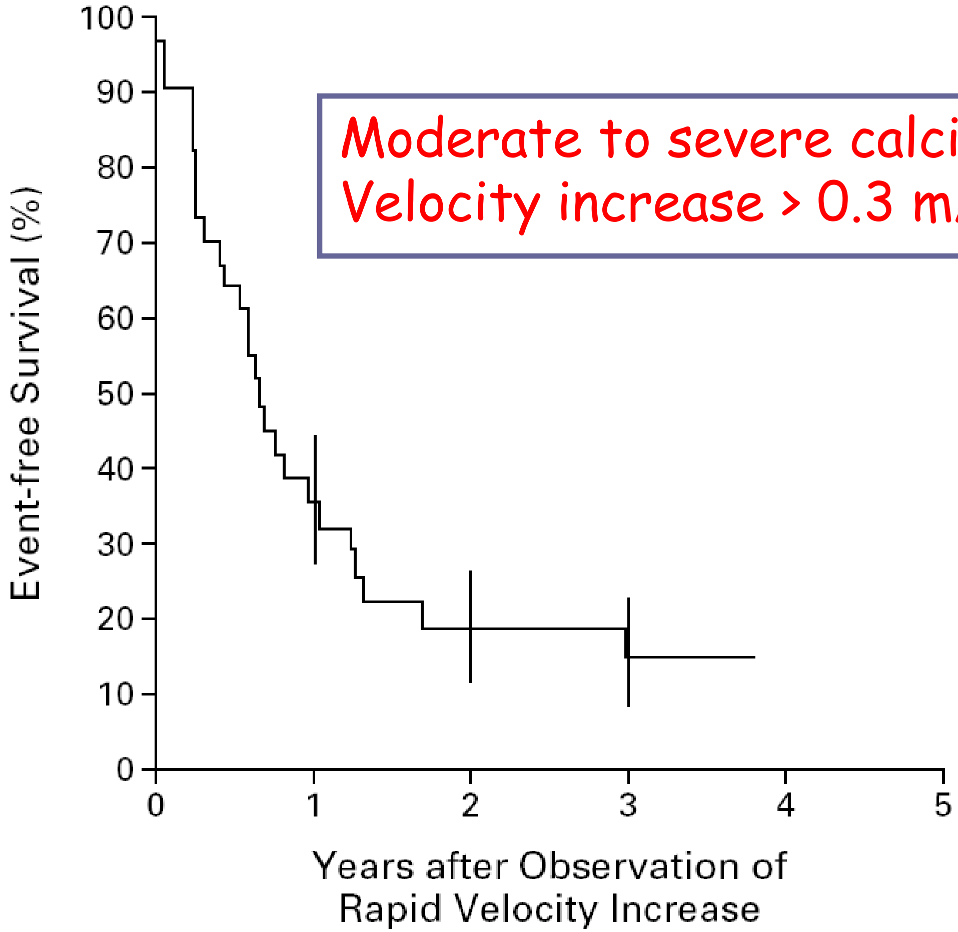
N Engl J Med 2000;343:611-7

Asymptomatic Severe AS



N Engl J Med 2000;343:611-7

Asymptomatic Severe AS



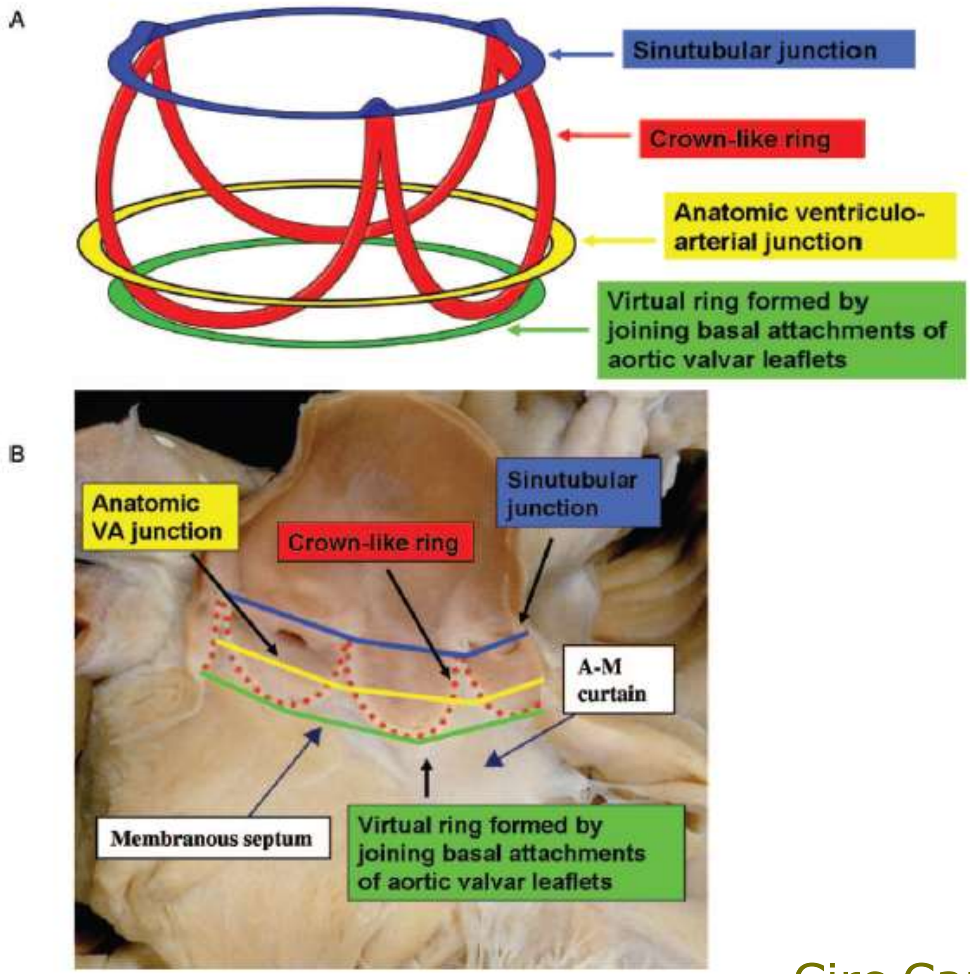
Moderate to severe calcification & Velocity increase > 0.3 m/s/year

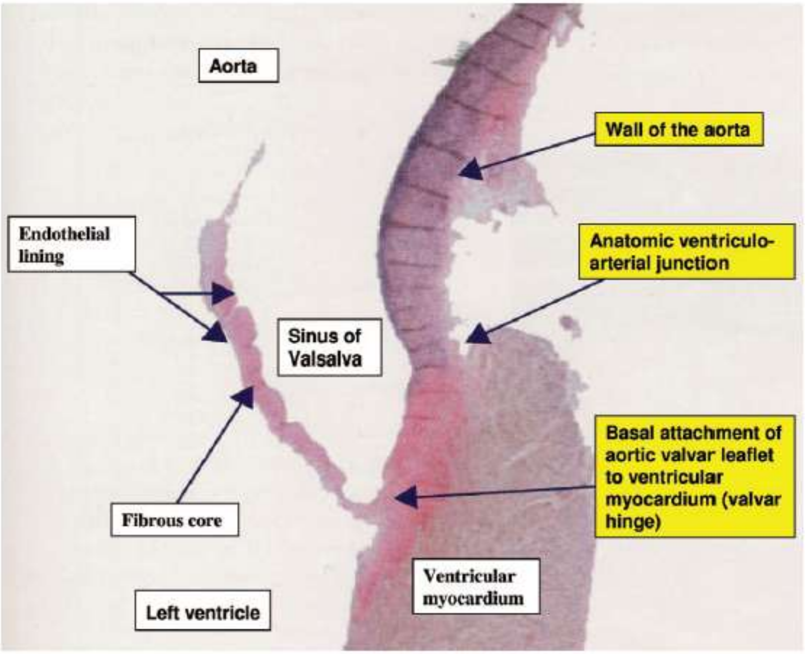
No. of Patients at Risk

34	12	7	5

N Engl J Med 2000;343:611-7

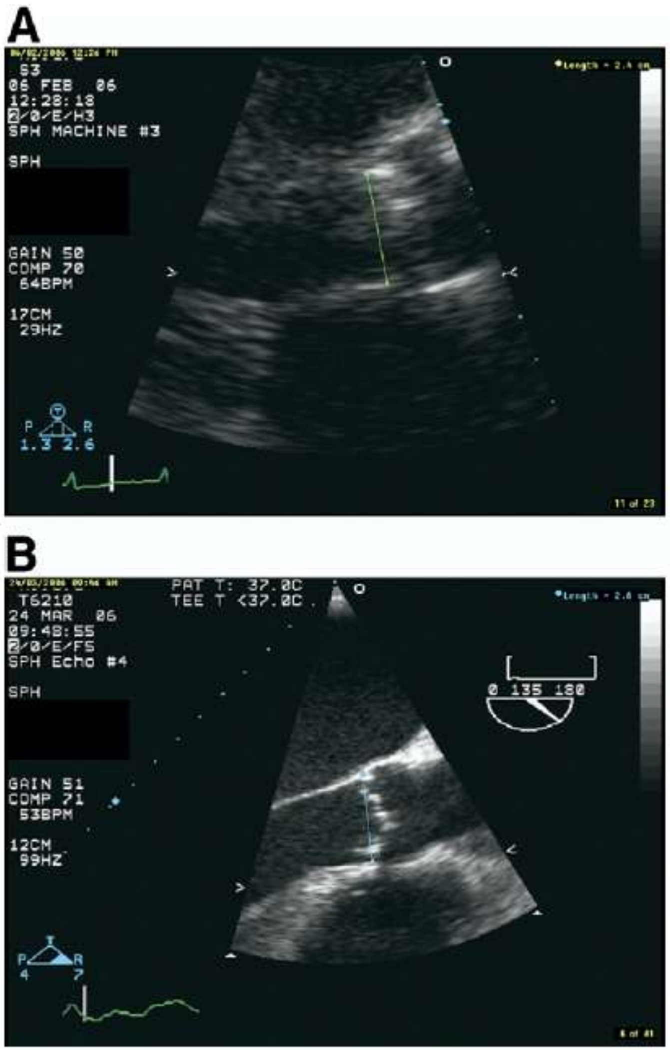
Aortic Valve Annulus

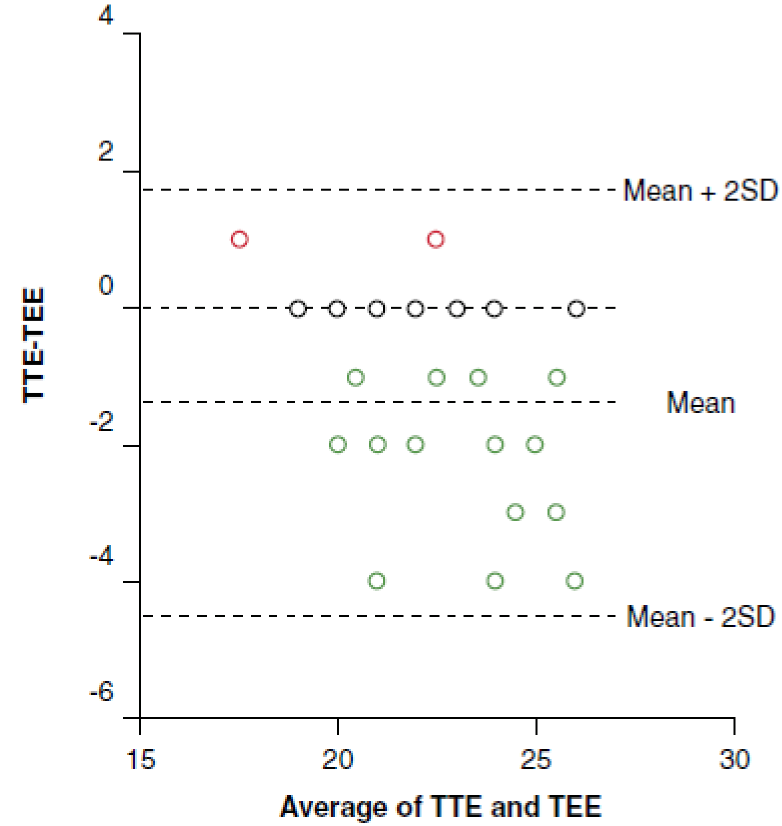




Circ Cardiovasc Intervent. 2008;1:74-81

Measurement of Aortic Annulus Size

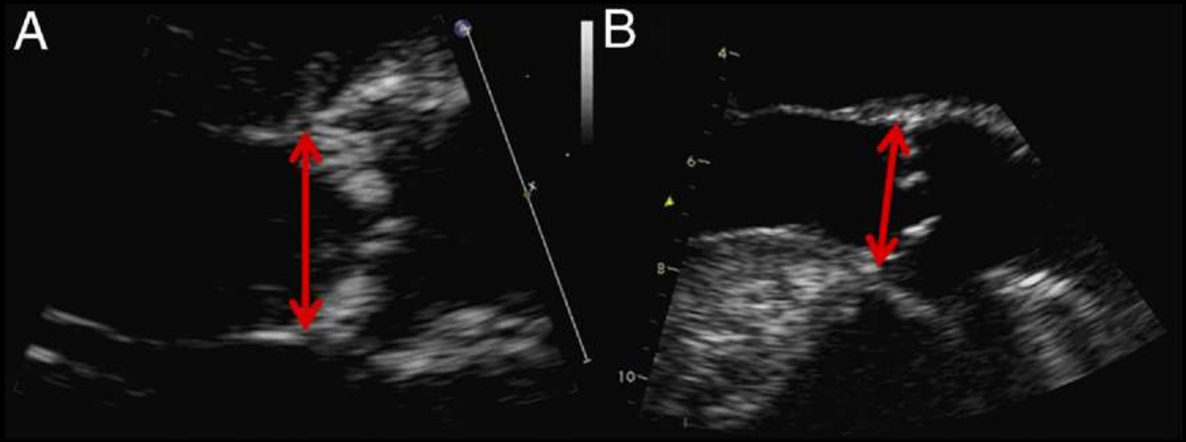


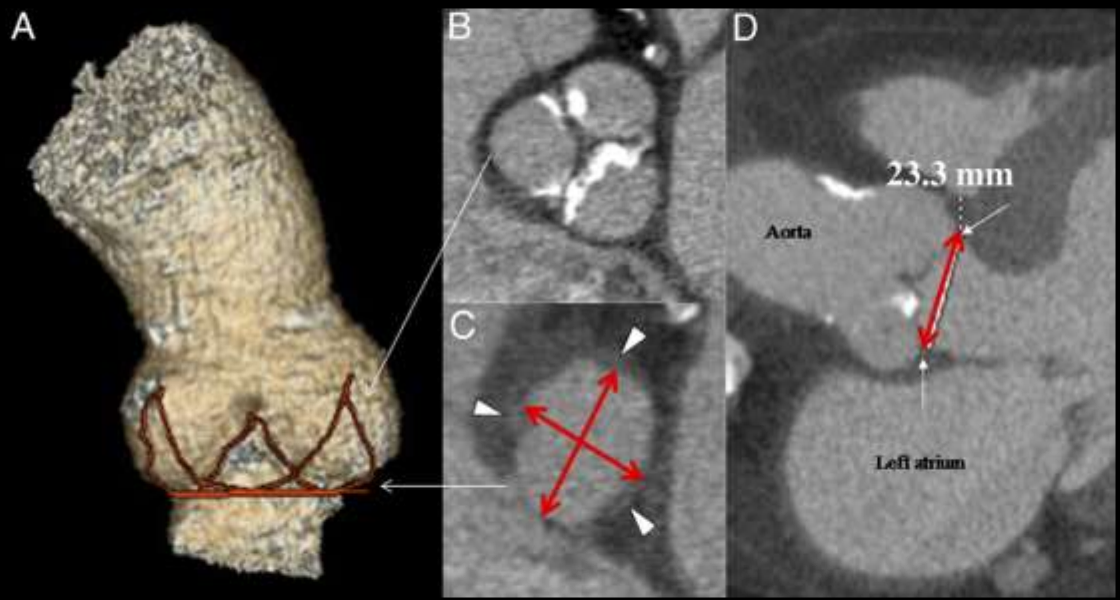


The mean difference (TTE-TEE) is -1.36 mm (2 SD -4.48 to +1.75 mm).

Moss, JACC Img 2008;1:15–24

TTE, TEE & CT





JACC 2010;55:186-94

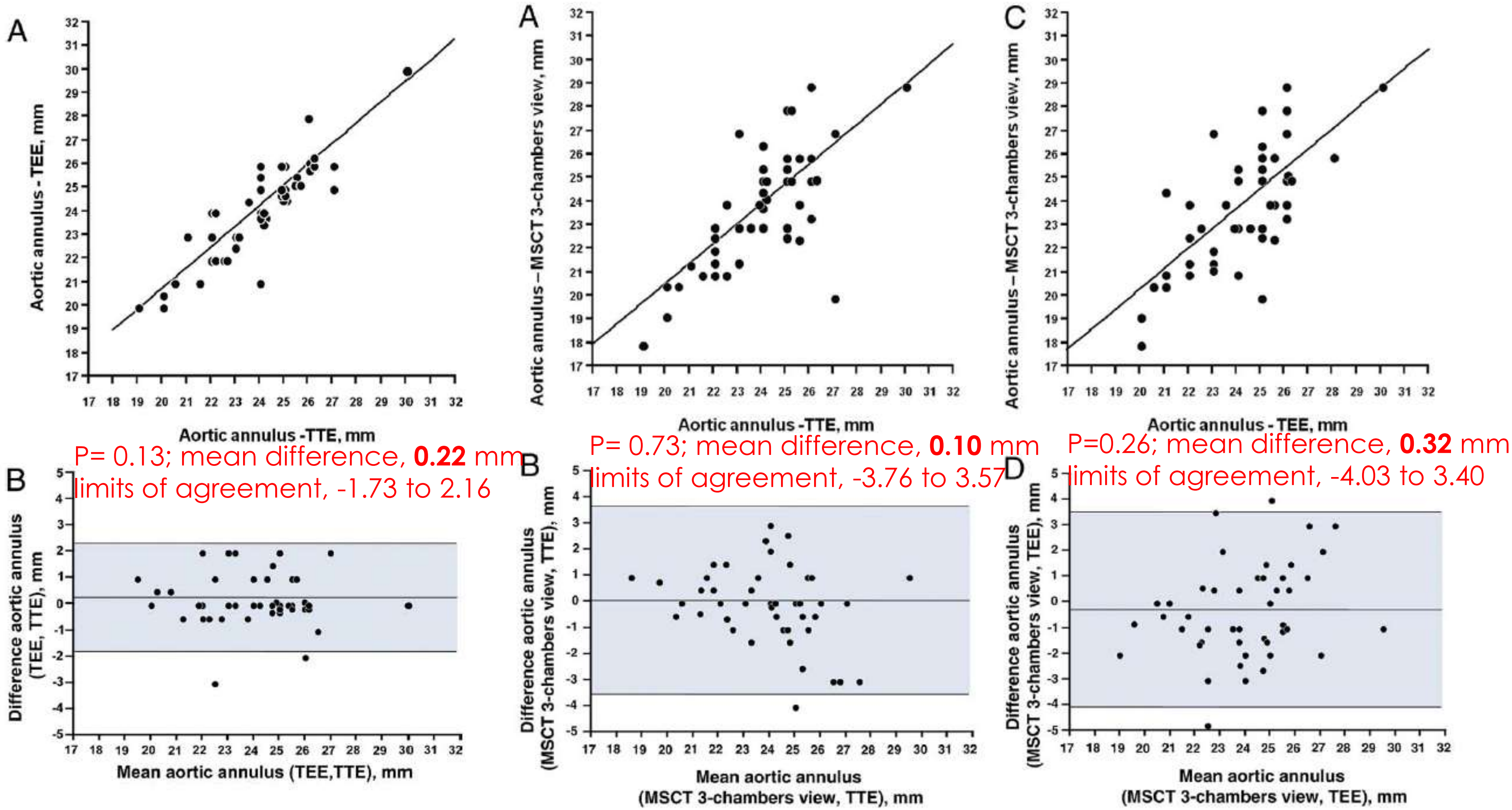
TTE, TEE & CT

Table 1	Comparison Between Echocardiographic and MSCT Measurements						
	Mean Annulus Diameter (mm)	Median	Range	p Value vs. TTE	R vs. TTE	p Value vs. TEE	R vs. TEE
Echocardiographic measurements							
TTE	23.9 ± 2.1	24	19–30	—	—	0.13	0.89
TEE	24.1 ± 2.1	24.5	20–30	0.13	0.89	—	—
MSCT measurements							
Virtual basal ring							
Long-axis	27.5 ± 3.1	27	22–34	<0.0001	0.69	<0.0001	0.67
Short-axis	21.7 ± 2.3	22	17.5–28	<0.0001	0.73	<0.0001	0.69
Mean	24.6 ± 2.4	24	19.8–29.5	0.004	0.80	0.07	0.77
3-chamber view	23.8 ± 2.6	24	18–29	0.73	0.71	0.26	0.70

Data presented are mean ± SD. R is coefficient of correlation.
MSCT = multislice computed tomography; TEE = transesophageal echocardiography; TTE = transthoracic echocardiography.

JACC 2010;55:186-94

TTE, TEE & CT



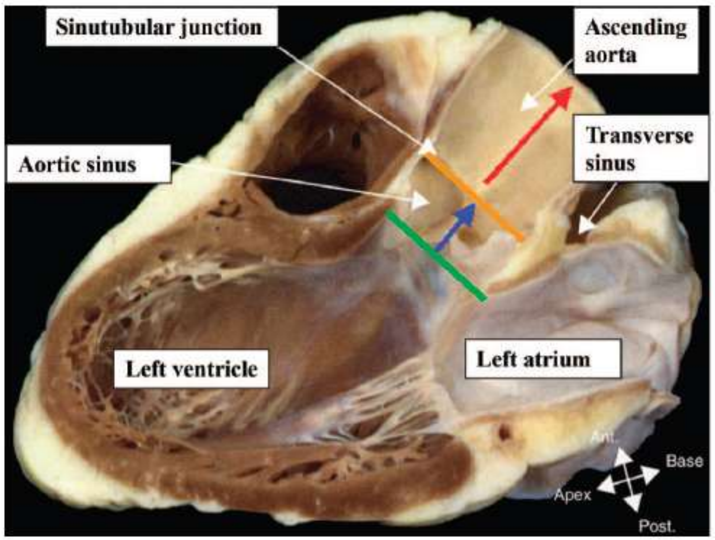
P= 0.13; mean difference, **0.22** mm
limits of agreement, -1.73 to 2.16

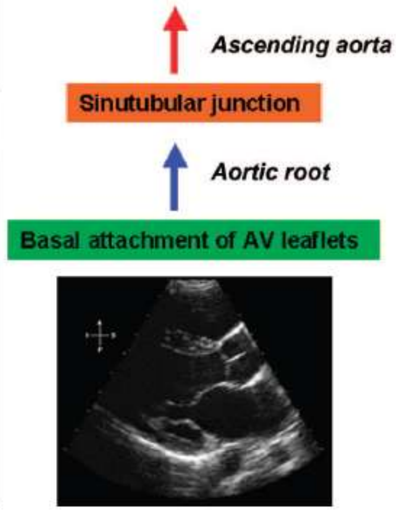
P= 0.73; mean difference, **0.10** mm
limits of agreement, -3.76 to 3.57

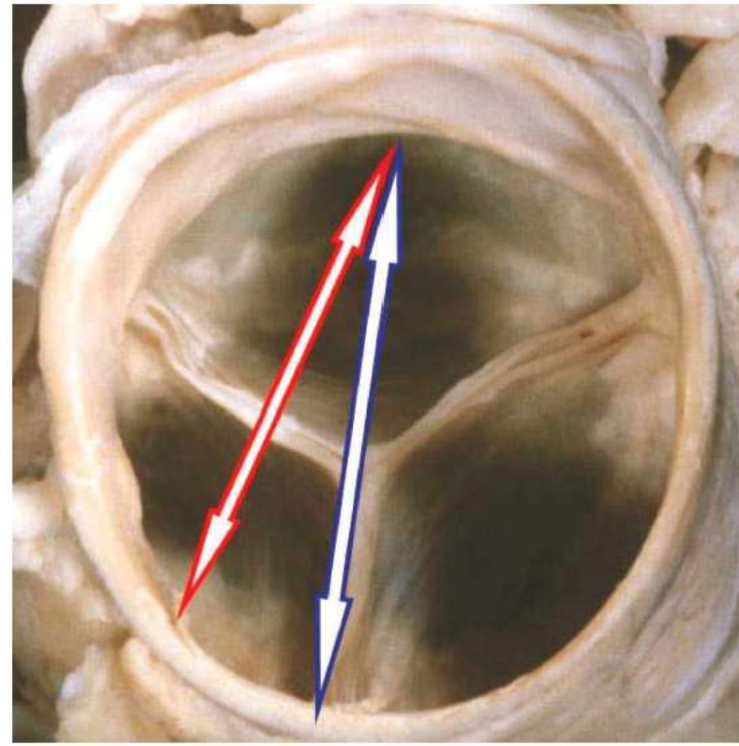
P=0.26; mean difference, **0.32** mm
limits of agreement, -4.03 to 3.40

JACC 2010;55:186-94

Measurement of Aortic Valve Annulus

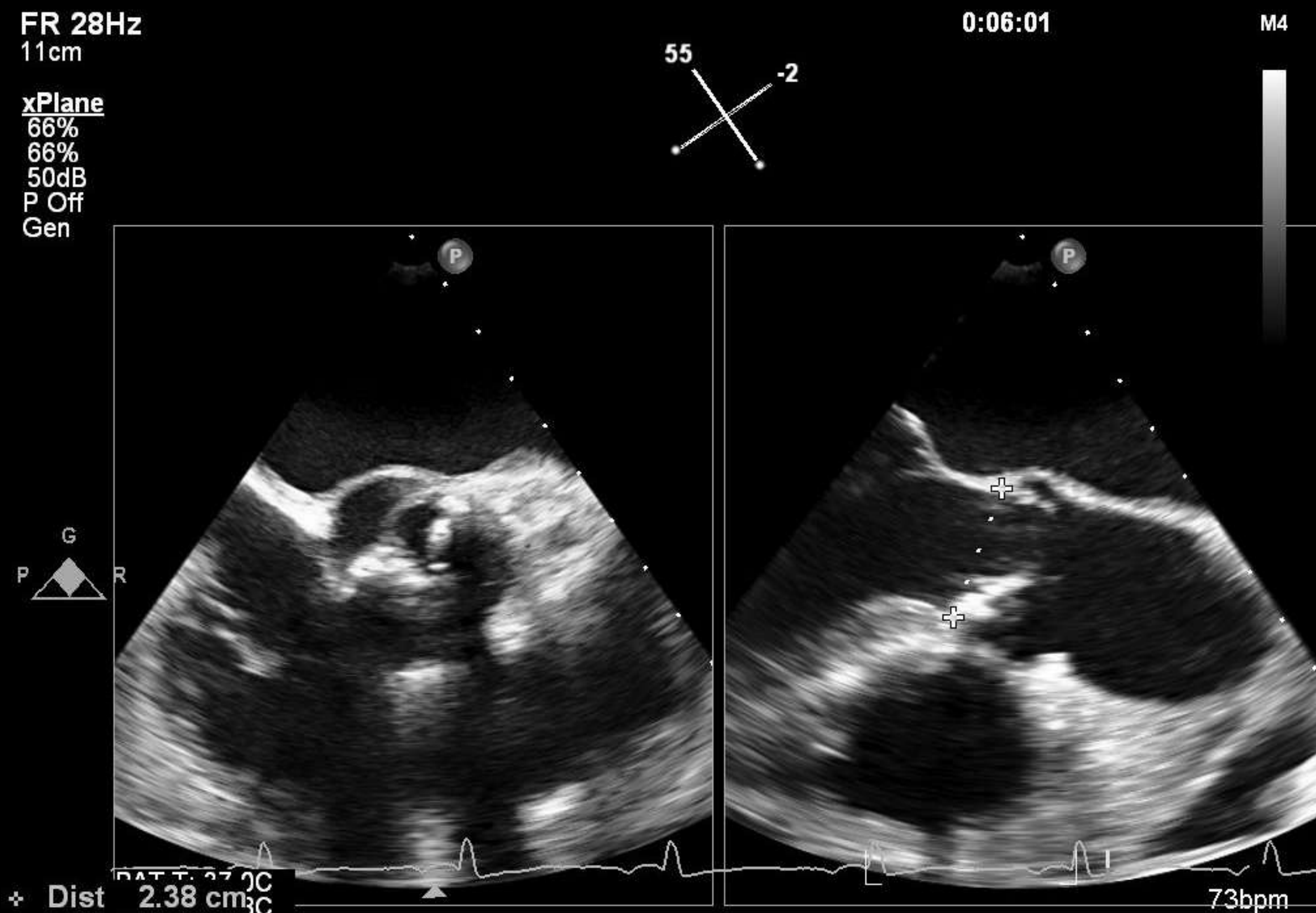






Circ Cardiovasc Intervent. 2008;1:74-81

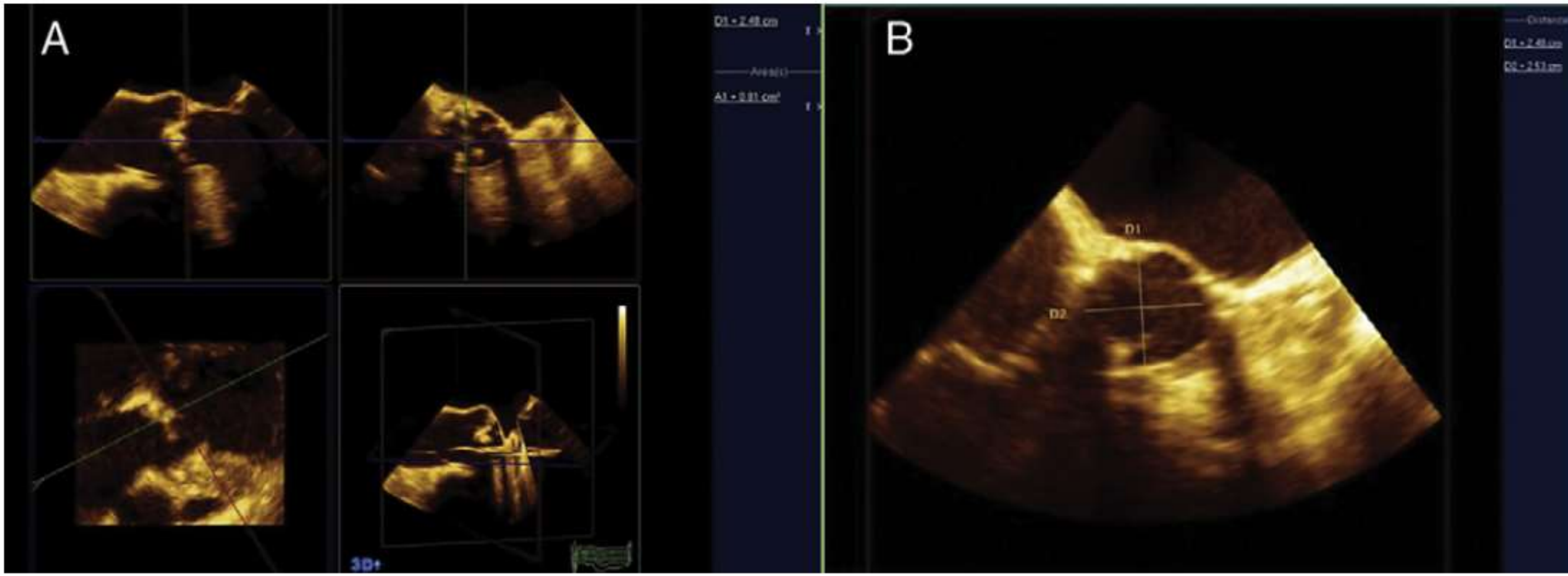
Biplane Image



AV on 3D TEE

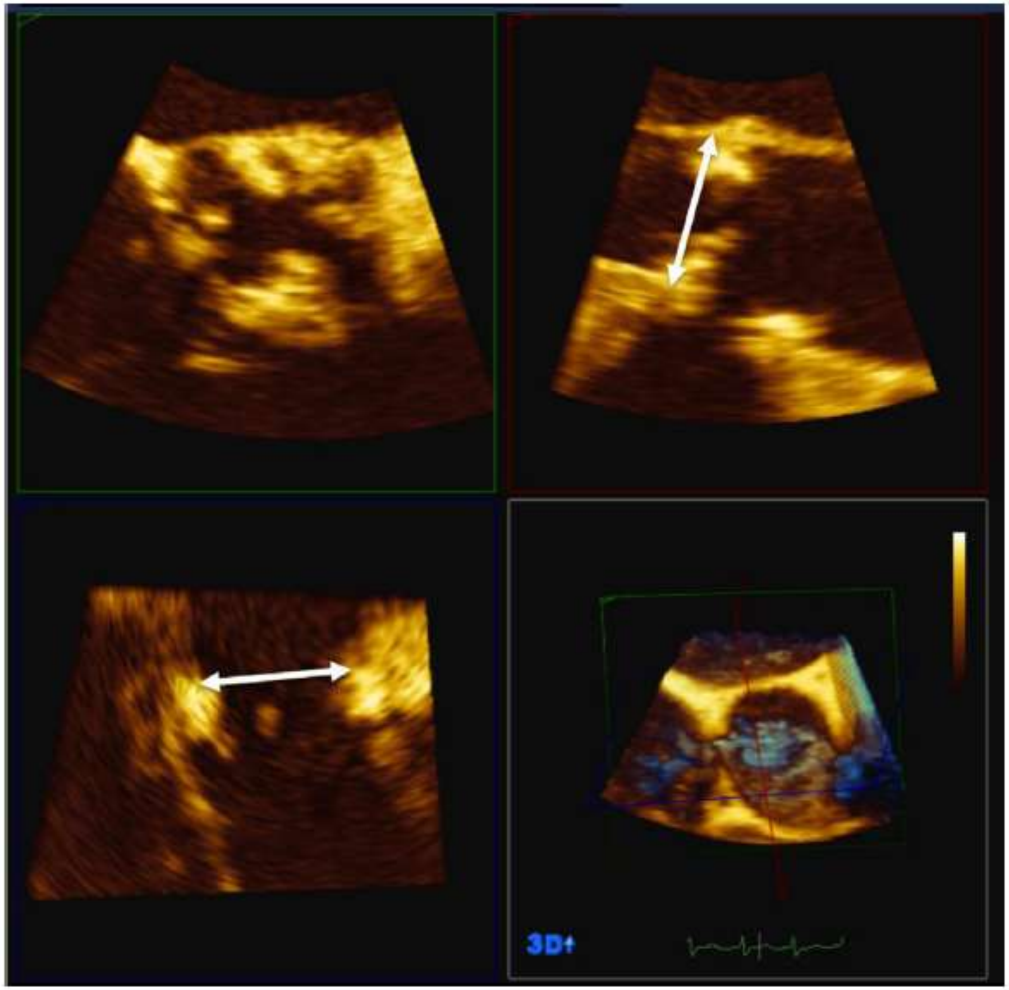

FR 28Hz
11cm
Live 3D
3D 42%
3D 40dB
Gen
0 35 180
M4
JPEG
50 bpm
PAT T: 37.0C
TEE T: 39.1C

Annulus Measurement by 3D TEE



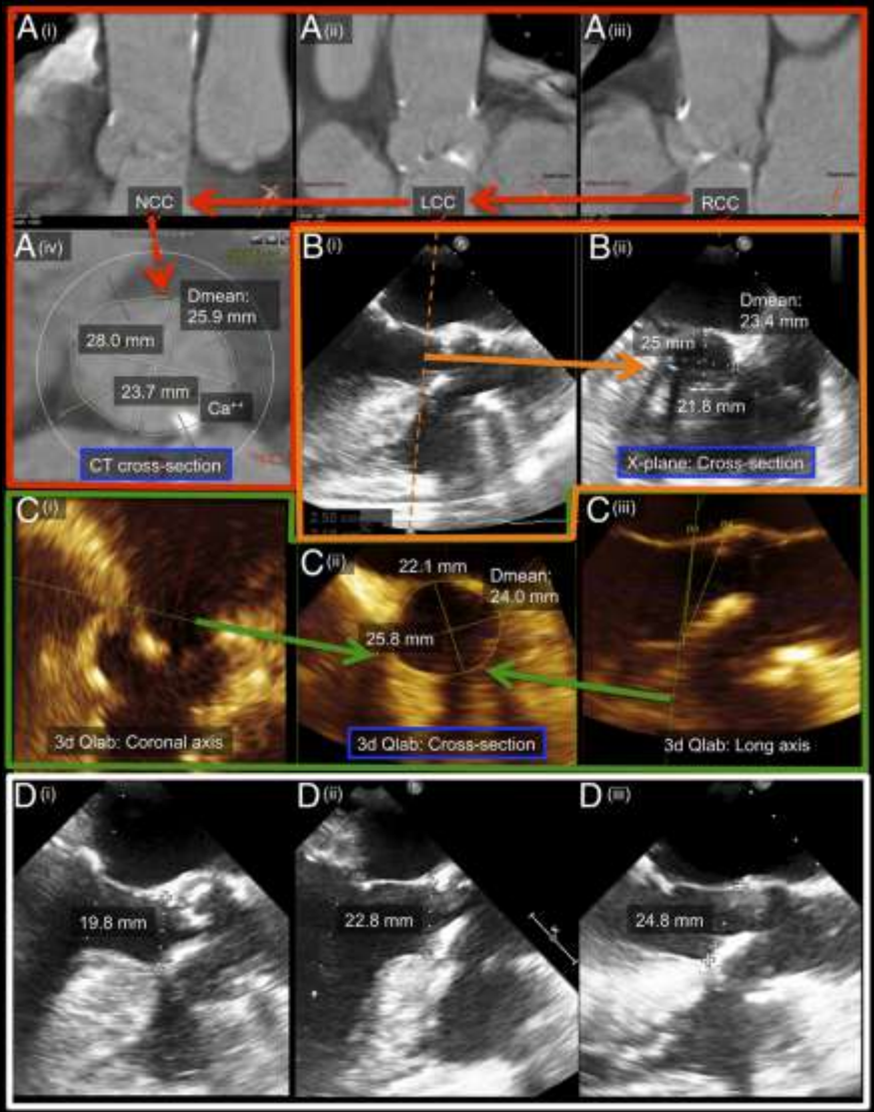
JASE 2011;24:937-65

Annulus Measurement by 3D TEE



JASE 2013;26:359-69

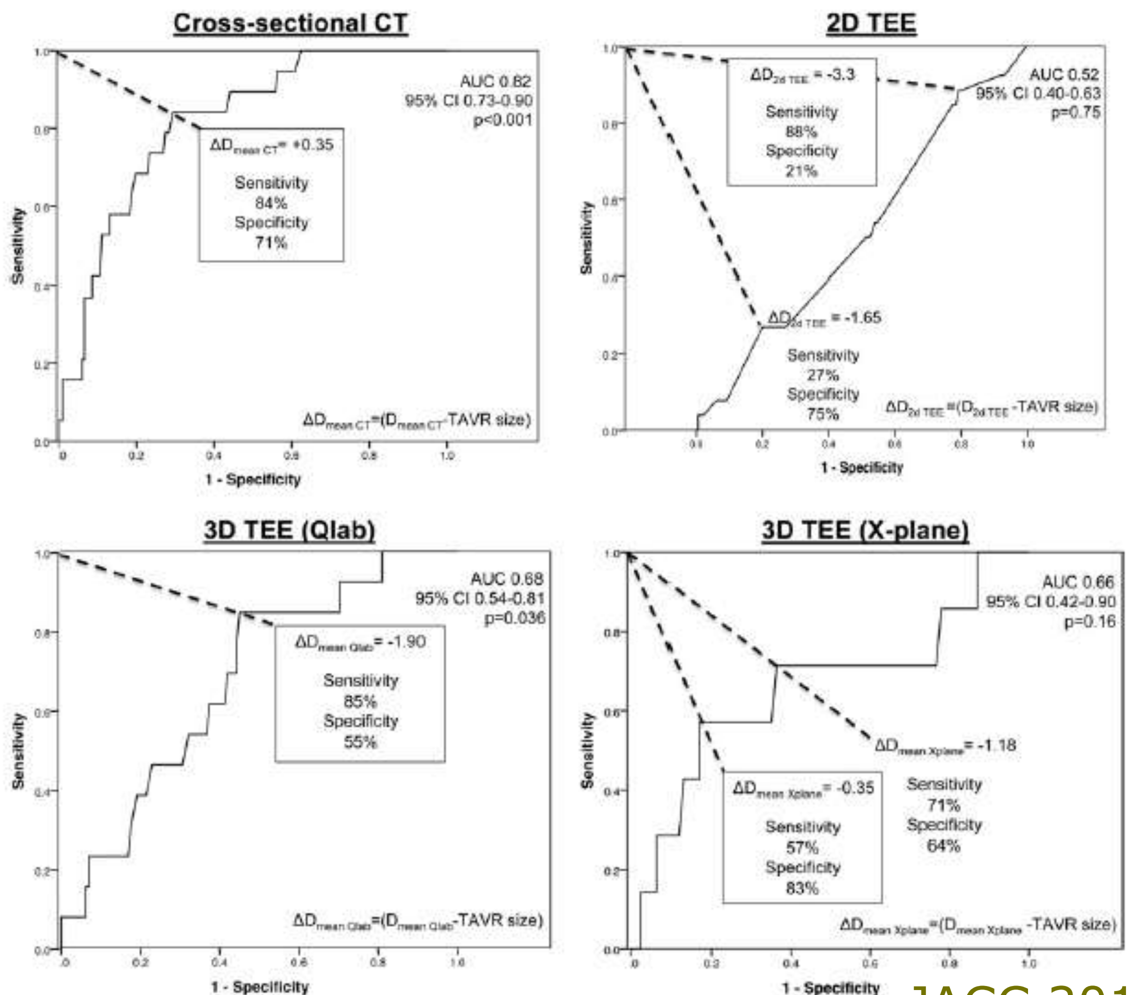
CT & 2D-/3D-TEE



JACC 2013;61:908–16

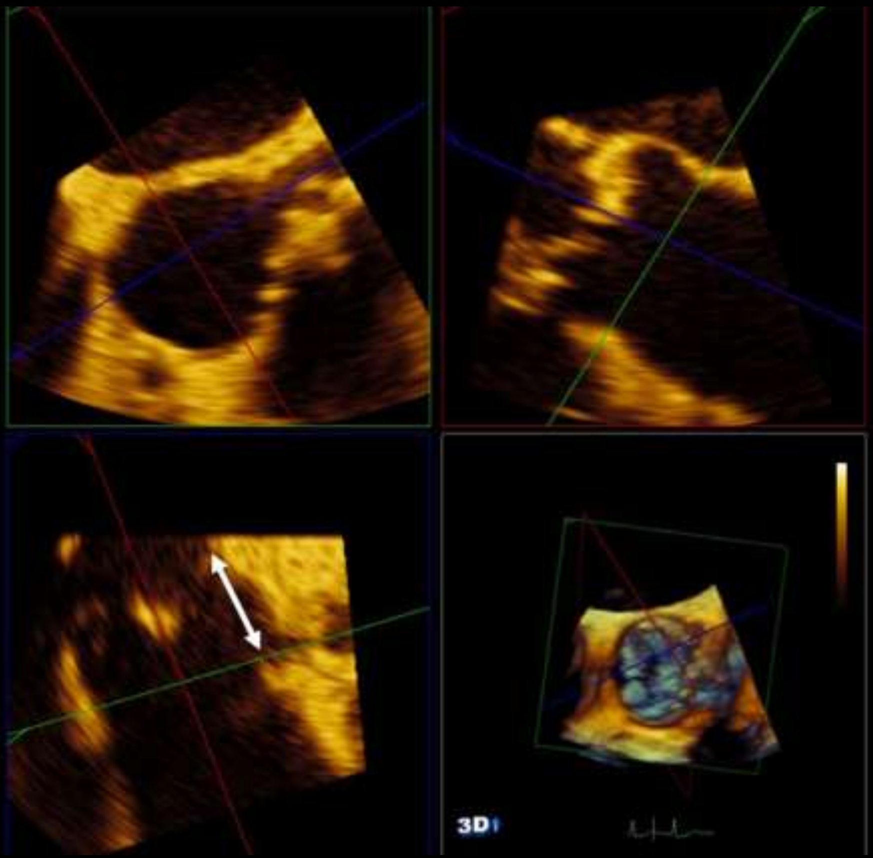
CT & 2D-/3D-TEE

For predicting significant paravalvular AR



JACC 2013;61:908–16

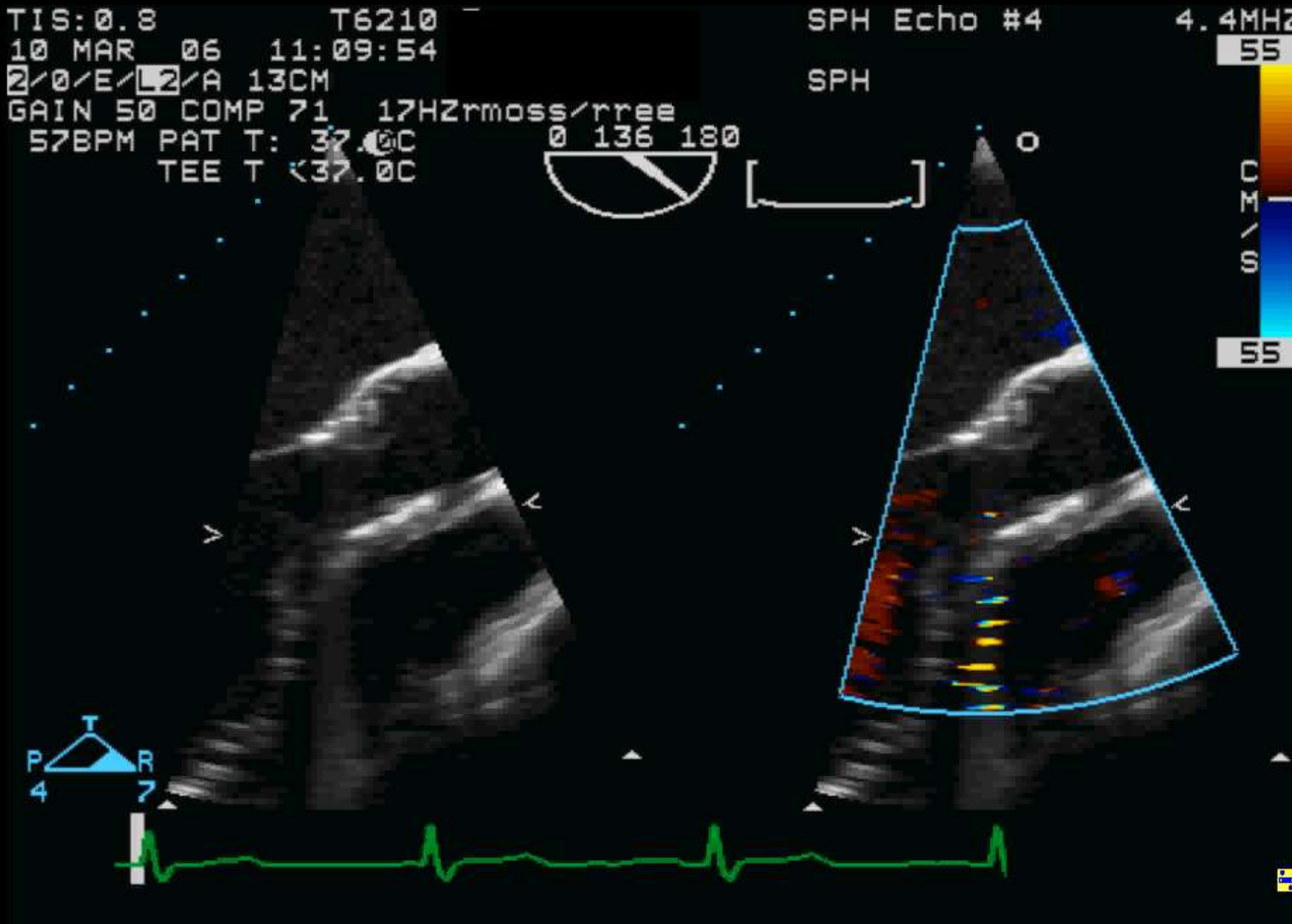
Localization of LCA by 3D TEE



In general, a distance of >**10 mm** is desirable for the 23 mm balloon-expandable valve and a distance of >**11 mm** is desirable for the 26 mm valve.

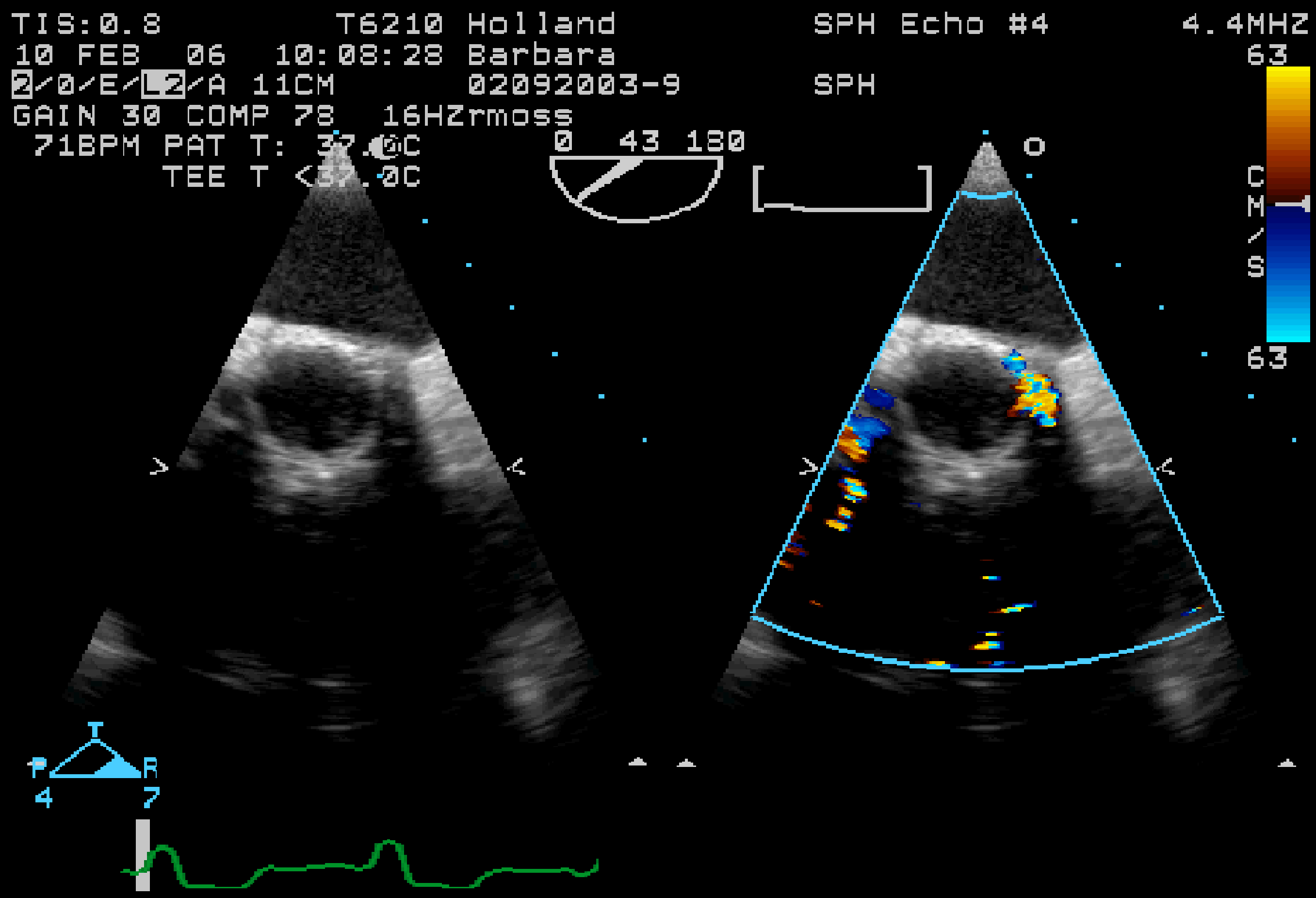
JASE 2013;26:359-69

Post-Implantation



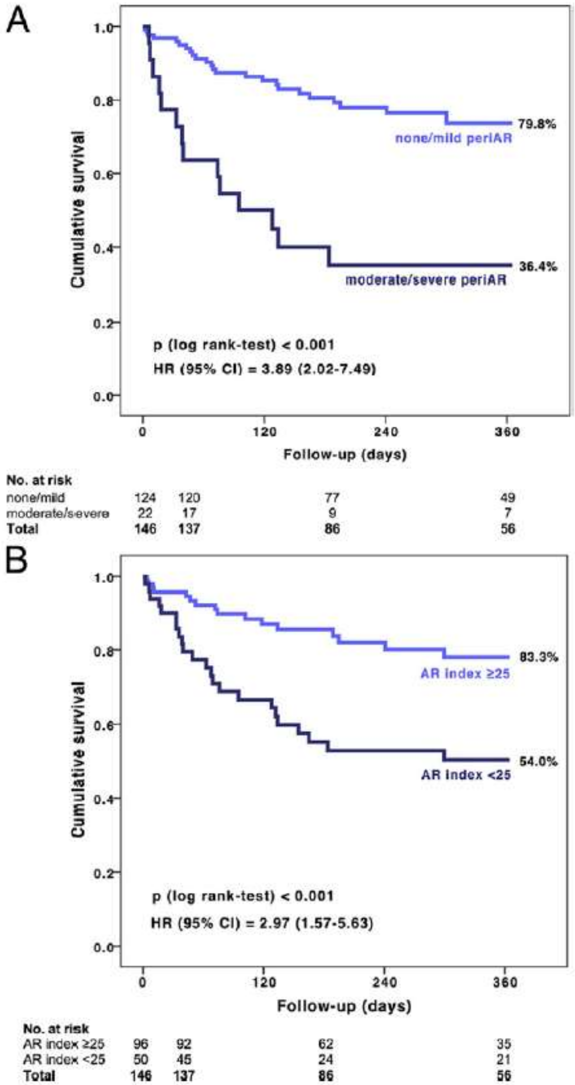
Moss, JACC Img 2008;1:15–24

Paravalvular AR After Implantation



Moss, JACC Img 2008;1:15–24

AR index & Prognosis



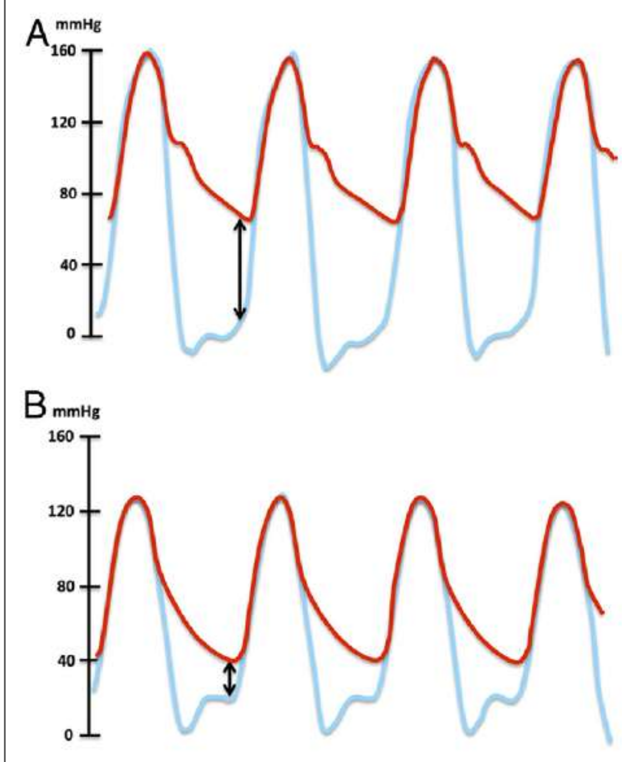


Figure 1 Calculation of the AR Index

Simultaneous determination of left ventricular end-diastolic pressure (LVEDP) **(blue line)** and diastolic blood pressure (DBP) in the aorta **(red line)** in a patient without peri-prosthetic aortic regurgitation (periAR) **(A)** and in a patient with moderate periAR **(B)** for the calculation of the aortic regurgitation (AR) index: ([DBP − LVEDP]/SBP) × 100. **(A)** AR index = ([65 − 10]/160) × 100 = 34.4. **(B)** AR index = ([40 − 20]/130) × 100 = 15.4.

JACC 2012;59:1134–41

Severity of AR

Table 10 Prosthetic Valve Dysfunction

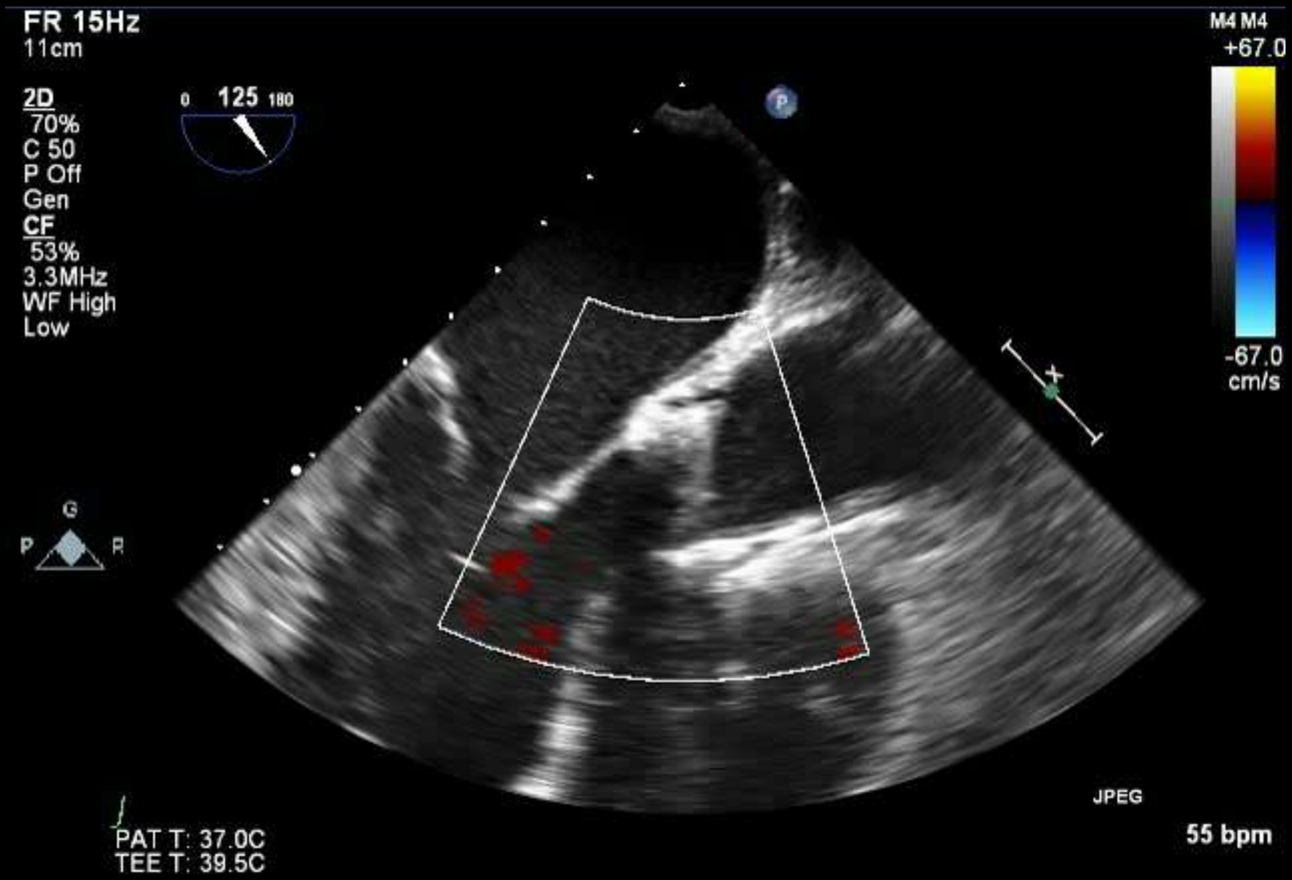
	Prosthetic Aortic Valve Stenosis[a]		
	Normal	Mild Stenosis	Moderate/Severe Stenosis
Quantitative parameters (flow-dependent)†			
Peak velocity (m/s)	<3 m/s	3–4 m/s	>4 m/s
Mean gradient (mmHg)	<20 mm Hg	20–40 mm Hg	>40 mm Hg
Quantitative parameters (flow-independent)			
Doppler velocity index‡	>0.35	0.35–0.25	<0.25
Effective orifice aread§	>1.1 cm^2	1.1–0.8 cm^2	<0.8 cm^2
Effective orifice area‖	>0.9 cm^2	0.9–0.6 cm^2	<0.6 cm^2
	Prosthesis-Patient Mismatch (PPM)		
	Insignificant	Moderate	Severe
Indexed effective orifice area¶ (cm^2/m^2)	>0.85 cm^2/m^2	0.85–0.65 cm^2/m^2	<0.65 cm^2/m^2
Indexed effective orifice area# (cm^2/m^2)	>0.70 cm^2/m^2	0.90–0.60 cm^2/m^2	<0.60 cm^2/m^2
	Prosthetic Aortic Valve Regurgitation		
	Mild	Moderate	Severe
Semi-quantitative parameters			
Diastolic flow reversal in the descending aorta—PW	Absent or brief early diastolic	Intermediate	Prominent, holodiastolic
Circumferential extent of prosthetic valve paravalvular regurgitation (%)**	<10%	10–29%	≥30%
Quantitative parameters‡			
Regurgitant volume (mL/beat)	<30 ml	30–59 ml	≥60 ml
Regurgitant fraction (%)	<30%	30–49%	≥50%
EROA (cm^2)	0.10 cm^2	0.10–0.29 cm^2	≥0.30 cm^2

*In conditions of normal or near normal stroke volume (50–70 ml). †These parameters are more affected by flow, including concomitant aortic regurgitation. ‡For LVOT >2.5 cm, significant stenosis criteria is <0.20. §Use in setting of BSA ≥1.6 cm^2 (note: dependent on the size of the valve and the size of the native annulus). ‖Use in setting of BSA <1.6 cm^2. ¶Use in setting of BMI <30 kg/cm^2. #Use in setting of BMI ≥30 kg/cm^2. **Not well-validated and may overestimate the severity compared with the quantitative Doppler.

EROA = effective regurgitant orifice area; PW = pulsed wave.

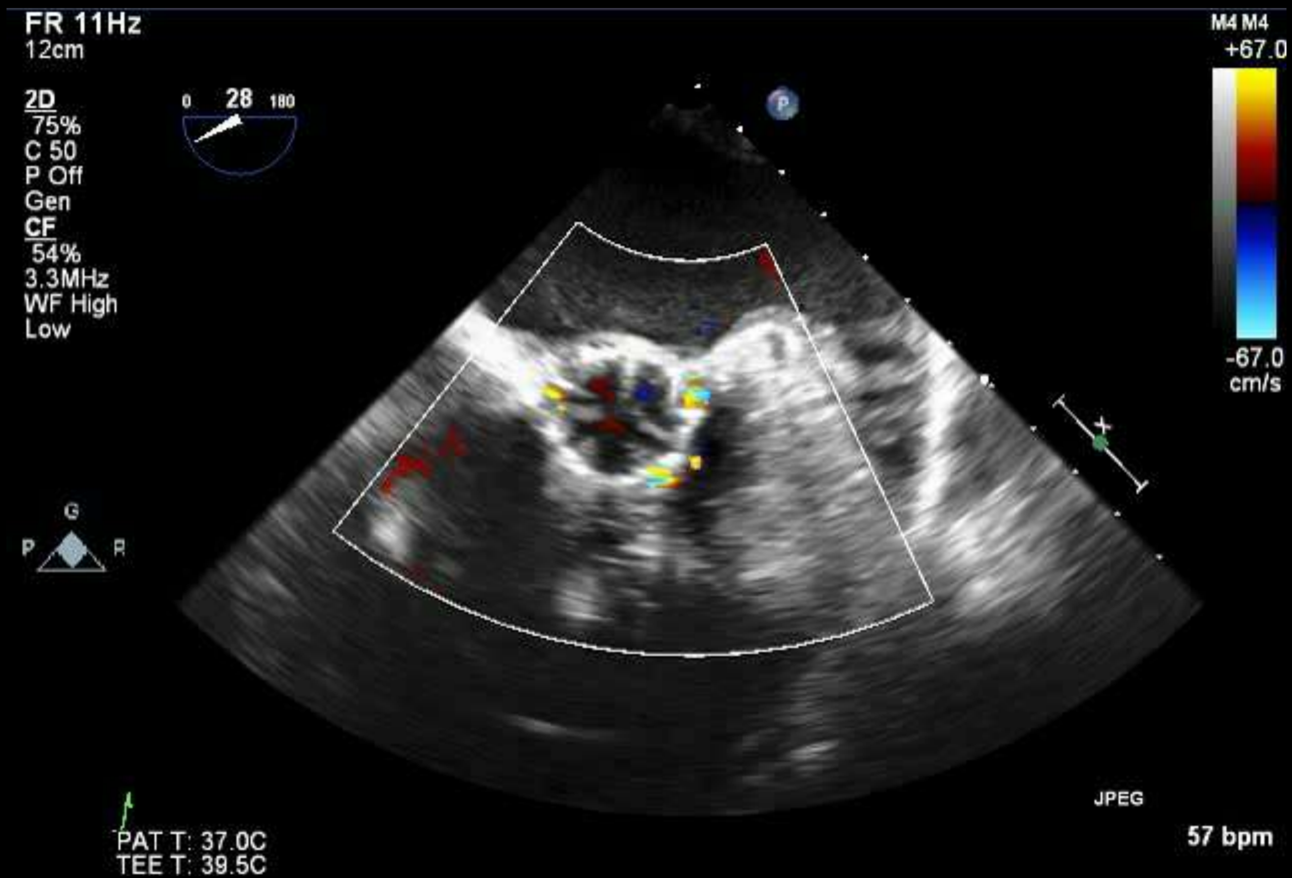
JACC 2012;60:1438–54

Evaluation after TAVI



Mild Paravalvular Leakage

Severe Paravalular Leakage




Thank you for your attention.