Aortic Stenosis

Hong Kong Core Cardiology Certificate Course (Module 3)

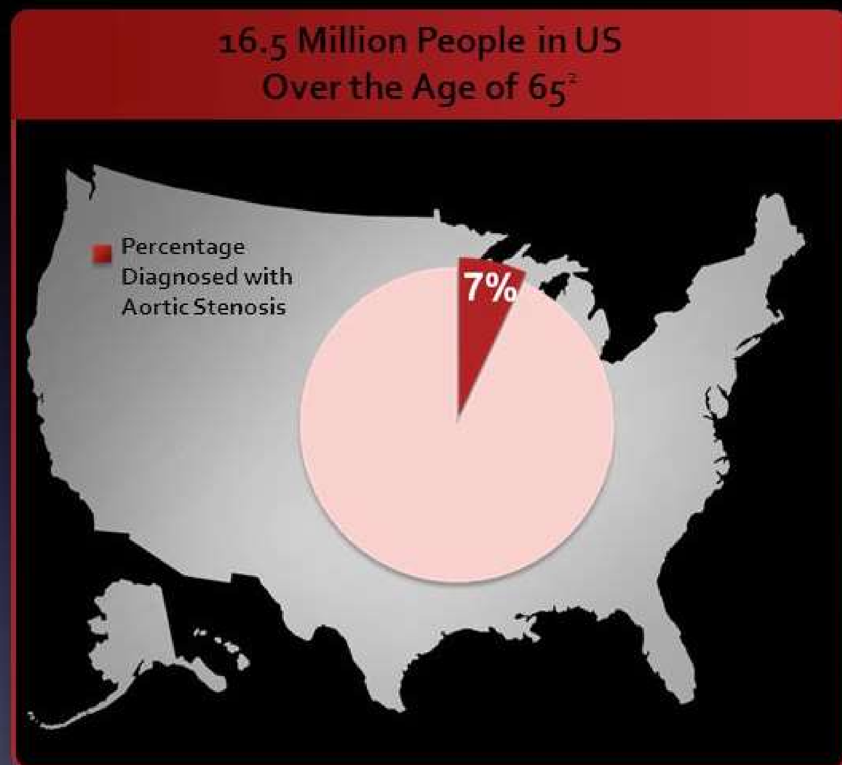
Dr Wong Chi Yuen Eric

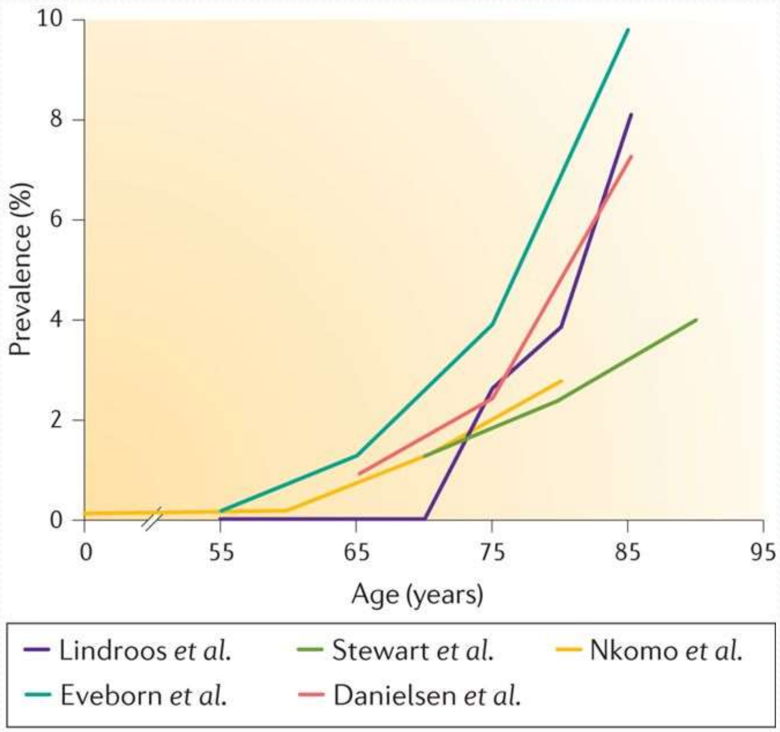
Associate Consultant
Division of Cardiology, Department of Medicine
Queen Elizabeth Hospital, Hong Kong

Prevalence

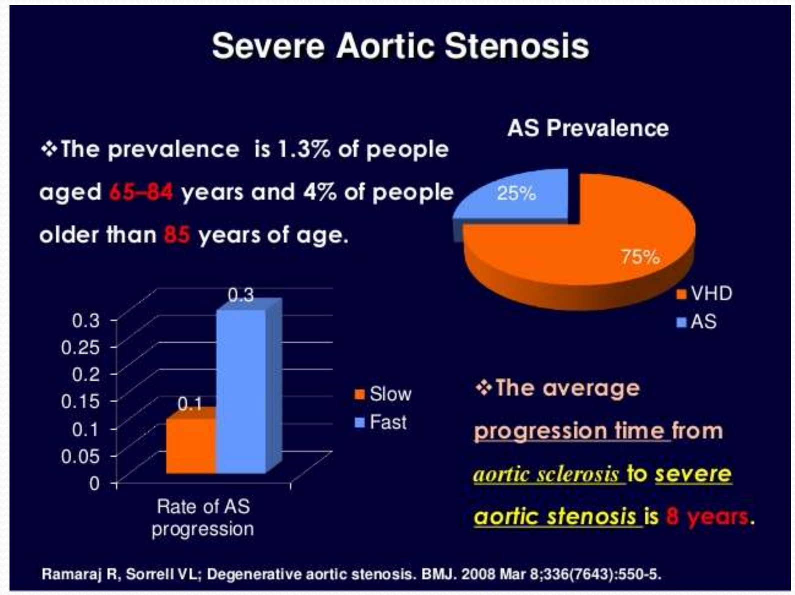
Aortic stenosis is estimated to be prevalent in up to 7% of the population over the age of 65[1]

It is more likely to affect men than women; 80% of adults with symptomatic aortic stenosis are male[3]



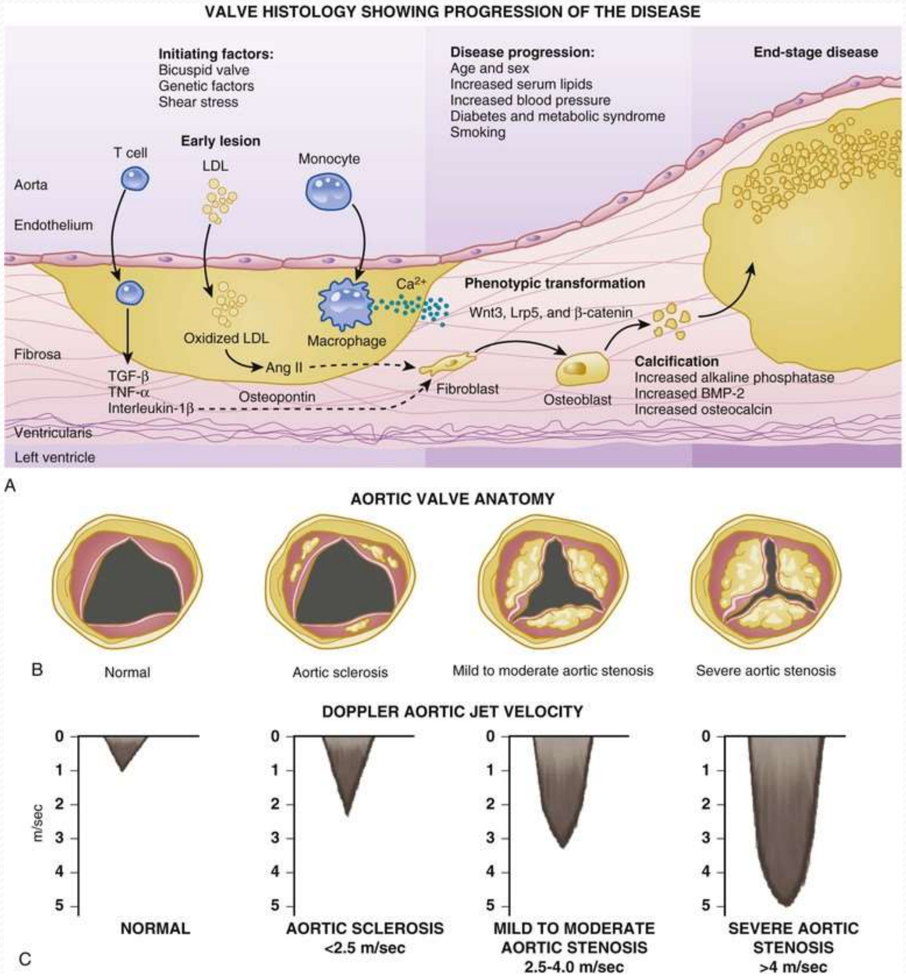


10
8
6
4
2
0
Prevalence (%)
0
55
65
75
85
95
Age (years)
Lindroos *et al.*
Stewart *et al.*
Nkomo *et al.*
Eveborn *et al.*
Danielsen *et al.*



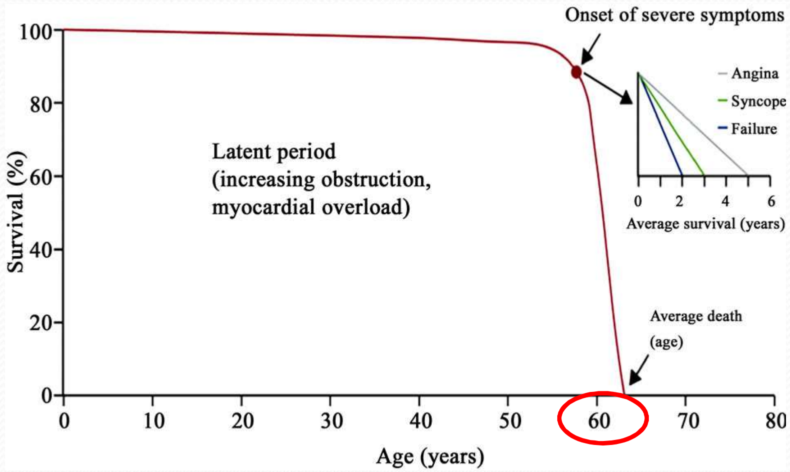
Severe Aortic Stenosis
❖The prevalence is 1.3% of people aged 65–84 years and 4% of people older than 85 years of age.
AS Prevalence
25%
75%
VHD
AS
0.3
0.1
0.3
0.25
0.2
0.15
0.1
0.05
0
Slow
Fast
Rate of AS progression
❖The average progression time from aortic sclerosis to severe aortic stenosis is 8 years.
Ramaraj R, Sorrell VL; Degenerative aortic stenosis. BMJ. 2008 Mar 8;336(7643):550-5.

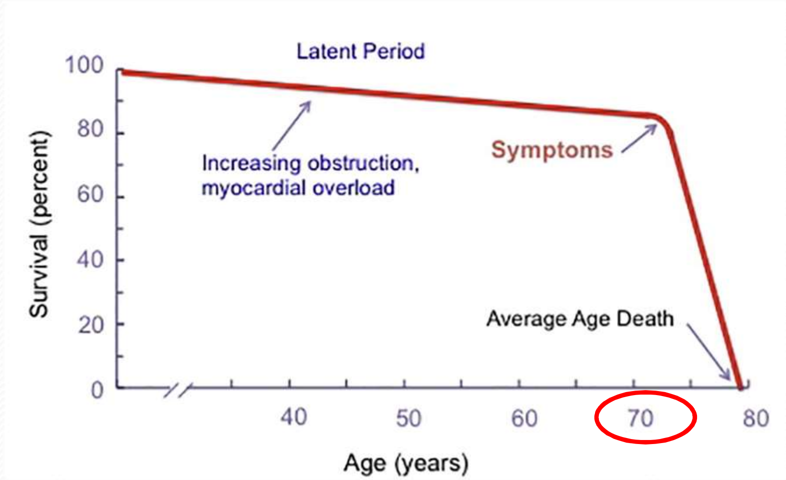
Pathophysiology



Natural History

- Asymptomatic for many years
- Symptoms develops with critically narrowed valve and LV dysfunction
  - Bicuspid – 5th-6th decade
  - Degenerative – 7th-8th decade
- Classical triad
  - Angina
  - Syncope
  - Heart failure
  - (Sudden death)





Aortic Stenosis - Causes

- Most common :-
  - Bicuspid aortic valve with calcification
  - Senile or Degenerative calcific AS
  - Rheumatic AS

Echo remains a standard tool for diagnosis and severity assessment

Make a correct diagnosis first before sending a patient for a advanced / ultra-major procedure

General Approach by Echo

- Morphology
- Etiology
- Colour Doppler
- Quantitative assessment
- Effect on chamber size and function

- **Put everything together and see if the parameters are concordant**

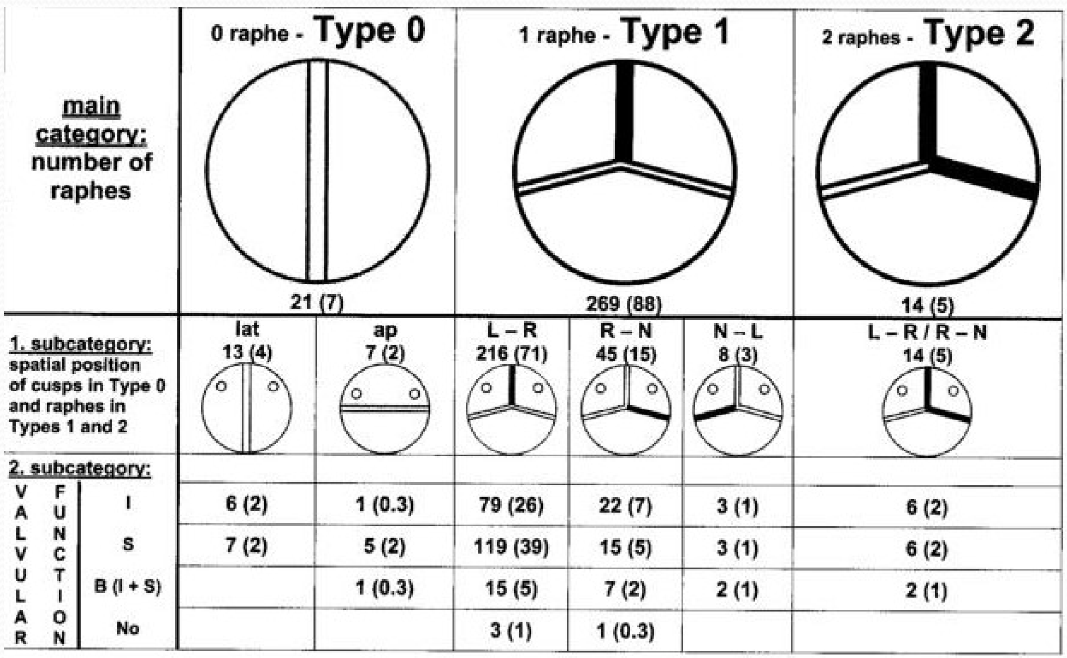
Anatomic Evaluation

- Combination of short and long axis images to identify
  - Number of leaflets
  - Describe leaf mobility, thickness, calcification

- Combination of imaging and Doppler allows the determination of the level of obstruction; sub-valvular, valvular, or supra-valvular.

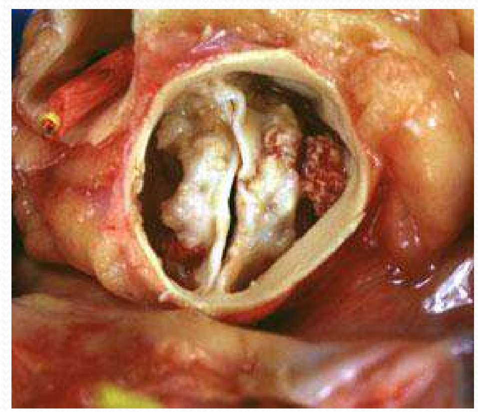
Bicuspid Aortic Valve

Commonest Congenital Abnormality
~ 2% in general population



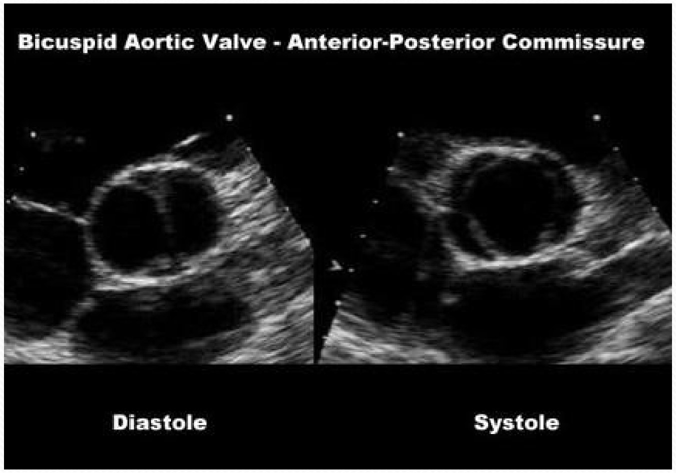
main category: number of raphes	0 raphe - Type 0		1 raphe - Type 1			2 raphes - Type 2
	21 (7)		269 (88)			14 (5)
1. subcategory: spatial position of cusps in Type 0 and raphes in Types 1 and 2	lat 13 (4)	ap 7 (2)	L – R 216 (71)	R – N 45 (15)	N – L 8 (3)	L – R / R – N 14 (5)
2. subcategory: VALVULAR FUNCTION						
I	6 (2)	1 (0.3)	79 (26)	22 (7)	3 (1)	6 (2)
S	7 (2)	5 (2)	119 (39)	15 (5)	3 (1)	6 (2)
B (I + S)		1 (0.3)	15 (5)	7 (2)	2 (1)	2 (1)
No			3 (1)	1 (0.3)		

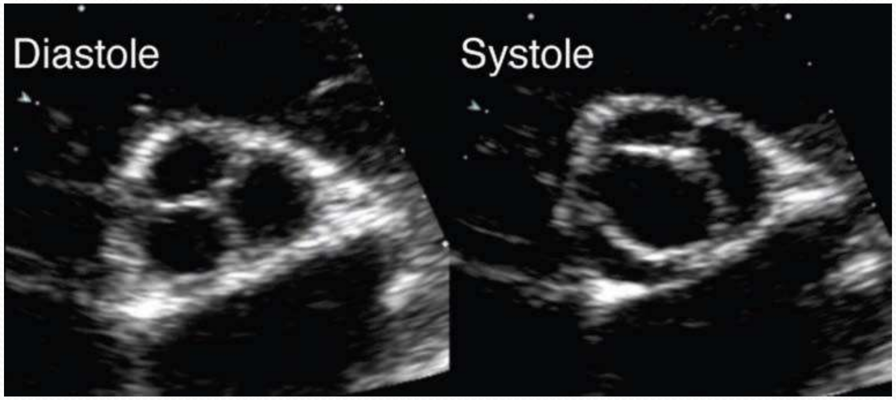
- Type 1 most common
  - Fusion of the right and left coronary cusps (80%)
  - Fusion of the right and non-coronary cusps(15%)



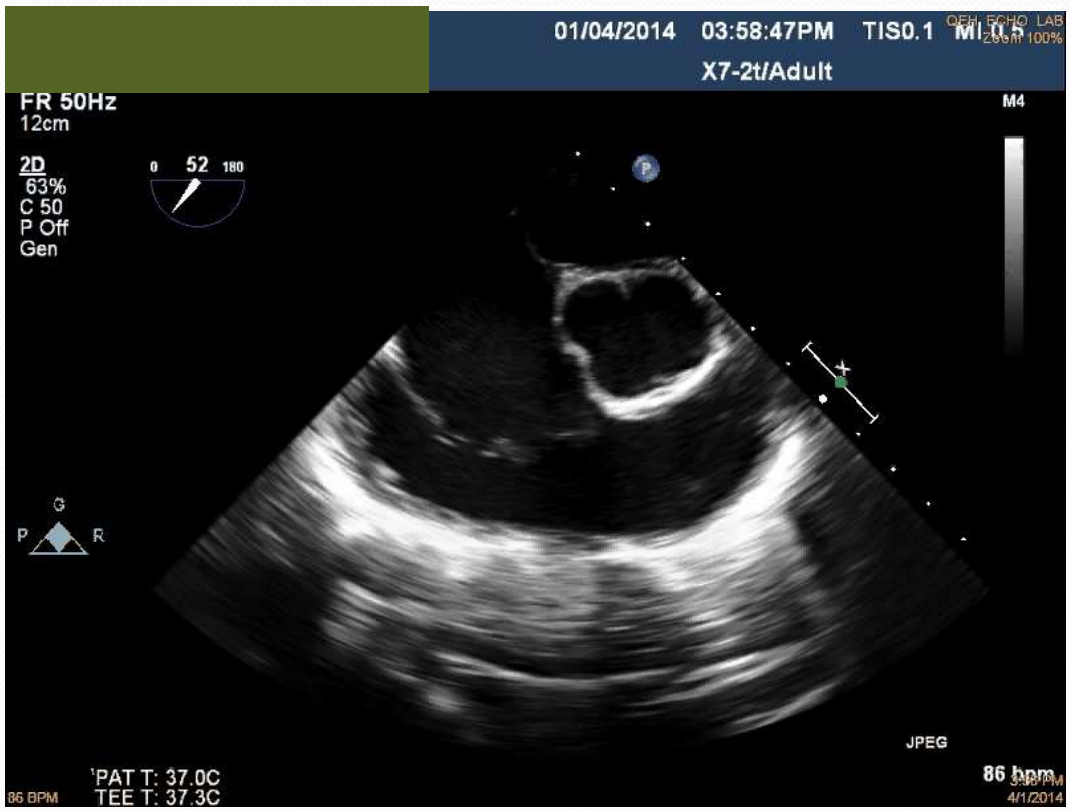
Bicuspid Aortic Valve (Pitfall 1)

- Two cusps are seen in systole with only two commissures framing an elliptical systolic orifice(the fish mouth appearance).
- Diastolic images may mimic a tricuspid valve when a raphe is present.



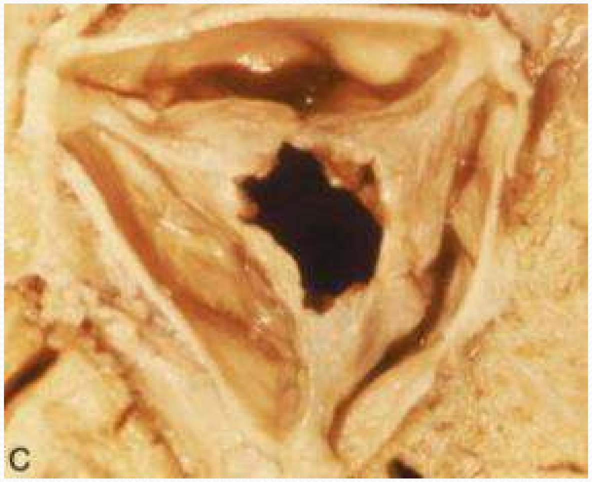


Bicuspid Aortic Valve Type 0



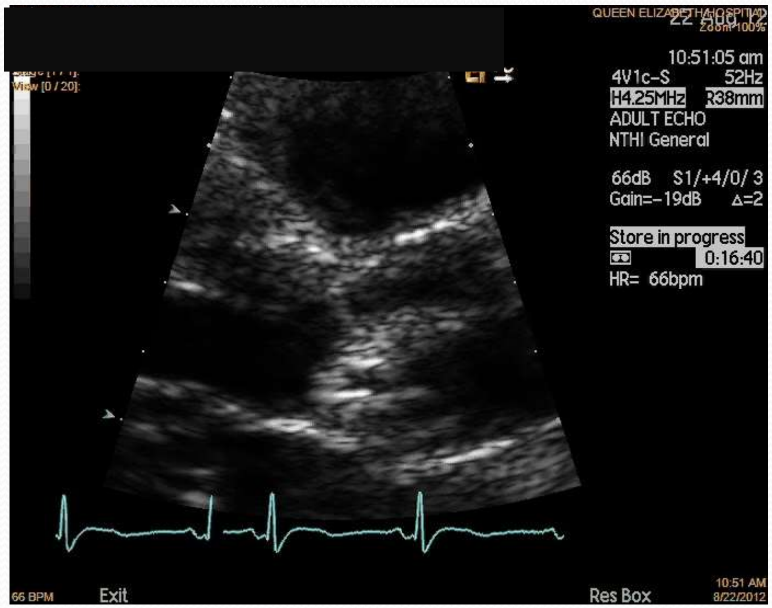
Calcific vs. Rheumatic Aortic Stenosis

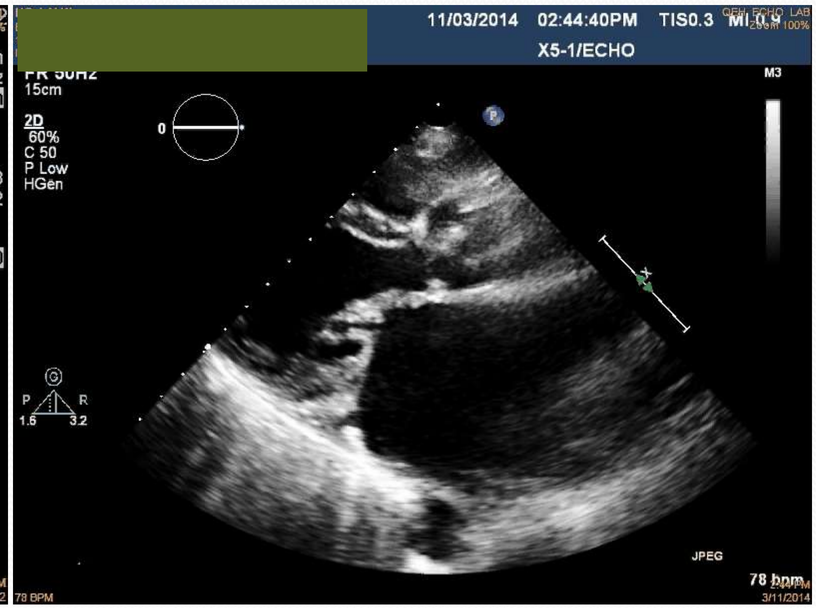
- Nodular calcific masses on aortic side of cusps
- No commissural fusion
- Free edges of cusps are not involved
- Stellate-shaped systolic orifice



- Commissural fusion
- Triangular systolic orifice
- Thickening +/- calcification
- Accompanied by rheumatic mitral valve changes

Calcific vs. Rheumatic Aortic Stenosis (Pitfall 2)





Doppler Assessment of AS

- The primary haemodynamic parameters recommended
  - Peak transvalvular velocity
  - Mean transvalvular gradient
  - Valve area by continuity equation

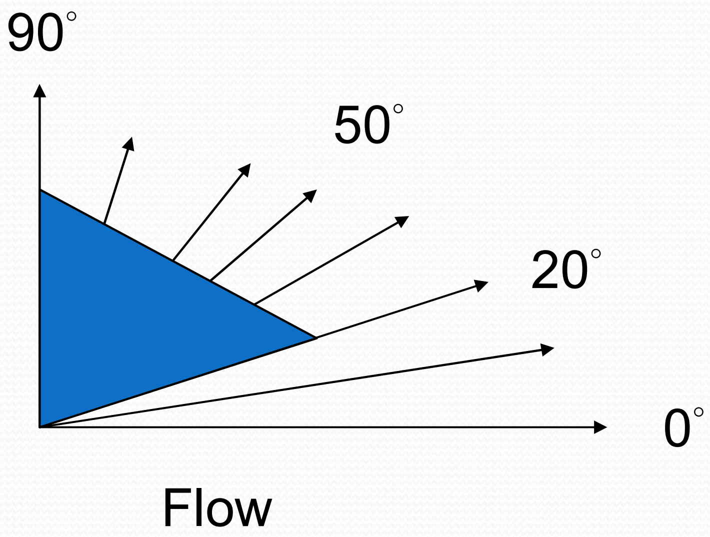
Peak Transvalvular Velocity Peak/Mean Gradient

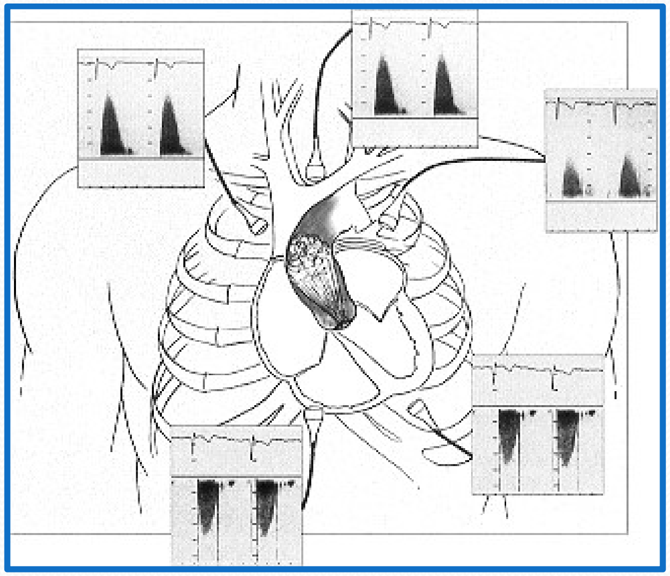
- Continuous-wave Doppler ultrasound
- Multiple acoustic windows
  - Apical and suprasternal or right parasternal most frequently yield the highest velocity
  - rarely subcostal or supraclavicular windows may be required
- The peak gradient is calculated from maximum velocity by Bernoulli equation
  - $\Delta P\ max = 4v^2\ max$
- The mean gradient is calculated by averaging the instantaneous gradients over the ejection period

Doppler Angle (Pitfall 3)

GOAL: Parallel to flow

As angle increases, velocity underestimated



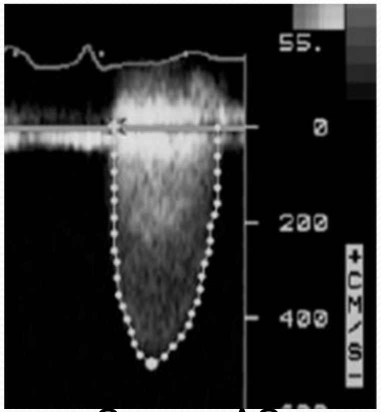


~20% cases peak velocity are not obtained from usual apical windows

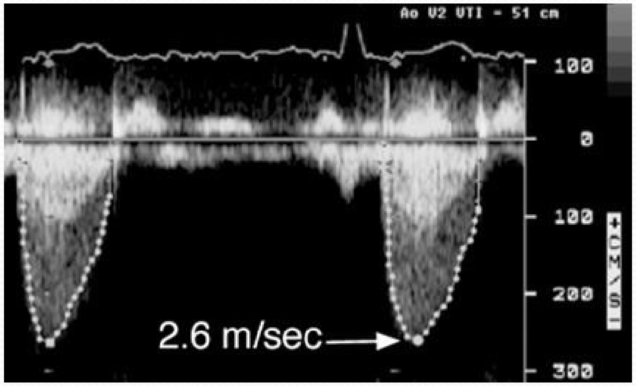
Non-imaging probe (CW only)

Shape of CW Doppler envelope

- Helpful in distinguishing the level and severity of obstruction.
- With severe obstruction, maximum velocity occurs later in systole and the curve is more rounded in shape
- With mild obstruction, the peak is in early systole with a triangular shape of the velocity curve

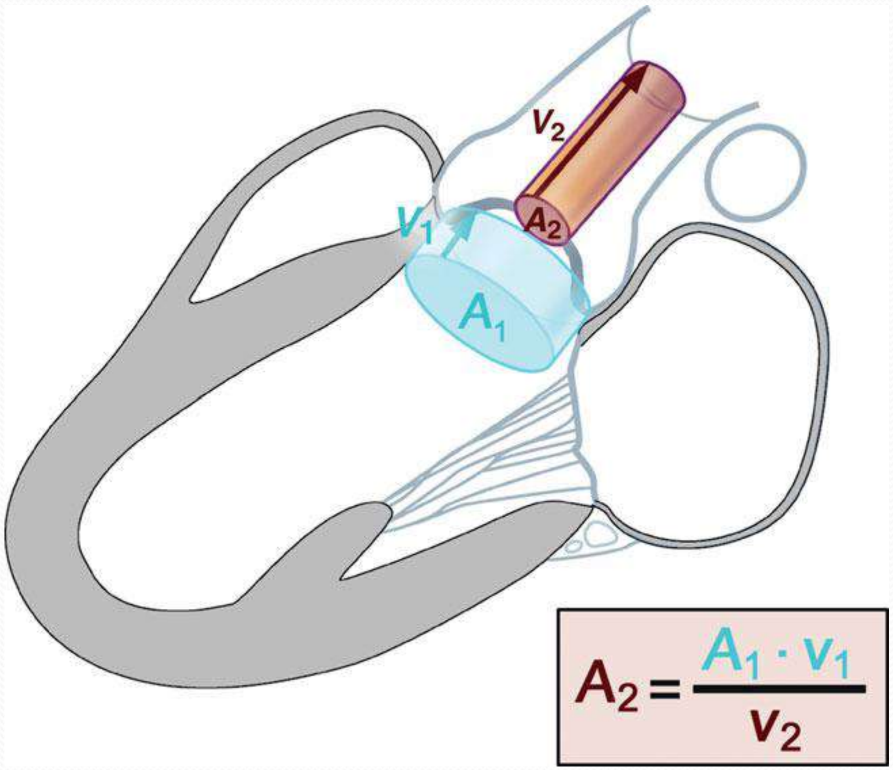


Severe AS



Non-severe AS

Aortic Valve Area
Continuity Equation

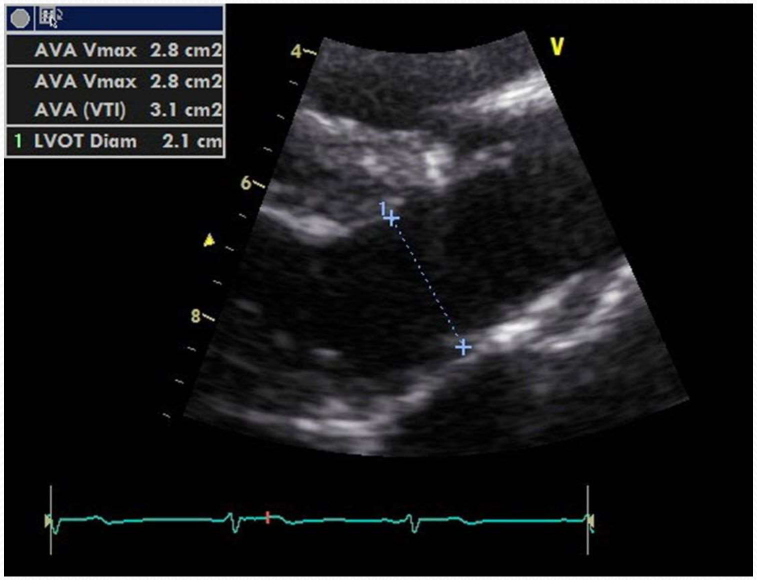


Aortic Valve Area

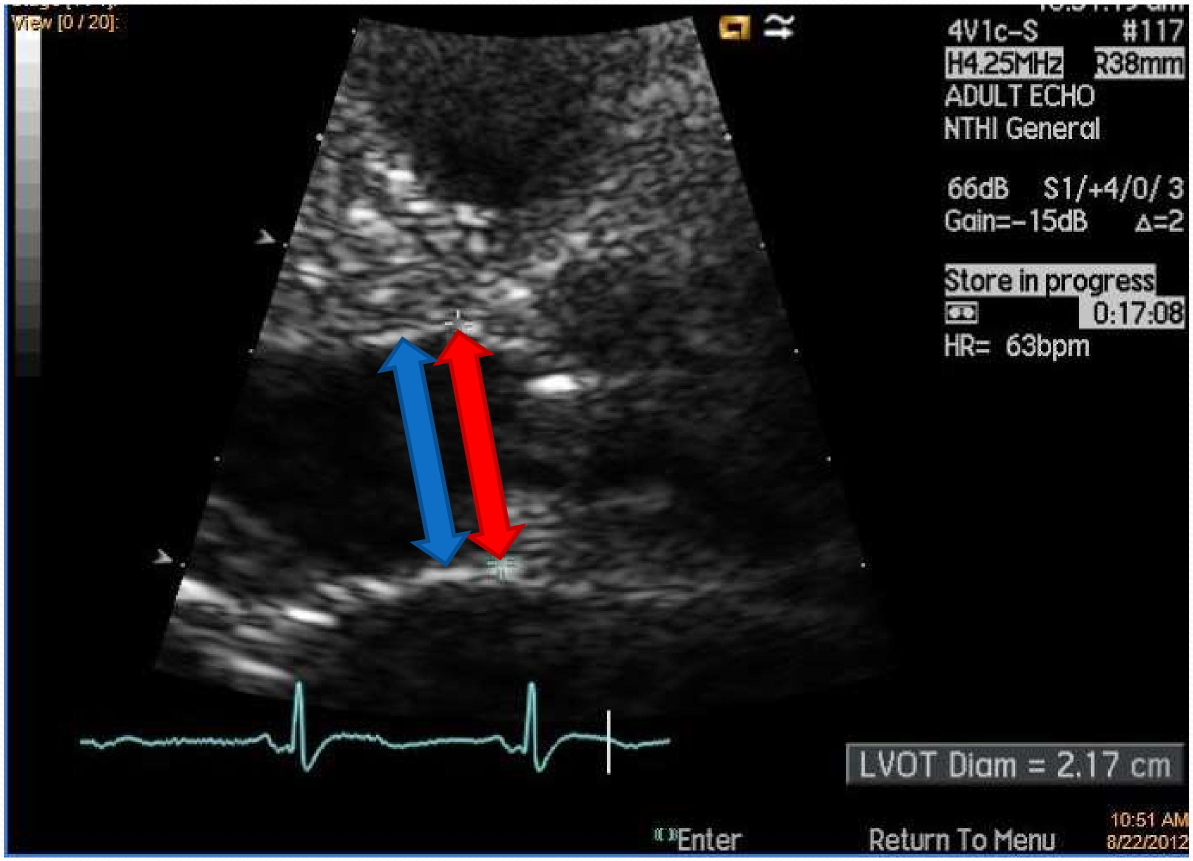
- Continuity equation concept that the stroke volume ejected through the LV outflow tract all passes through the stenotic orifice
- **$AVA = CSA_{LVOT} \times VTI_{LVOT} / VTI_{AV}$**
- Calculation of continuity-equation valve area requires three measurements
  - AS jet velocity time integral (VTI) by CWD
  - LVOT diameter for calculation of a circular CSA
  - LVOT VTI recorded with pulsed Doppler

LVOT diameter (Pitfall 4)

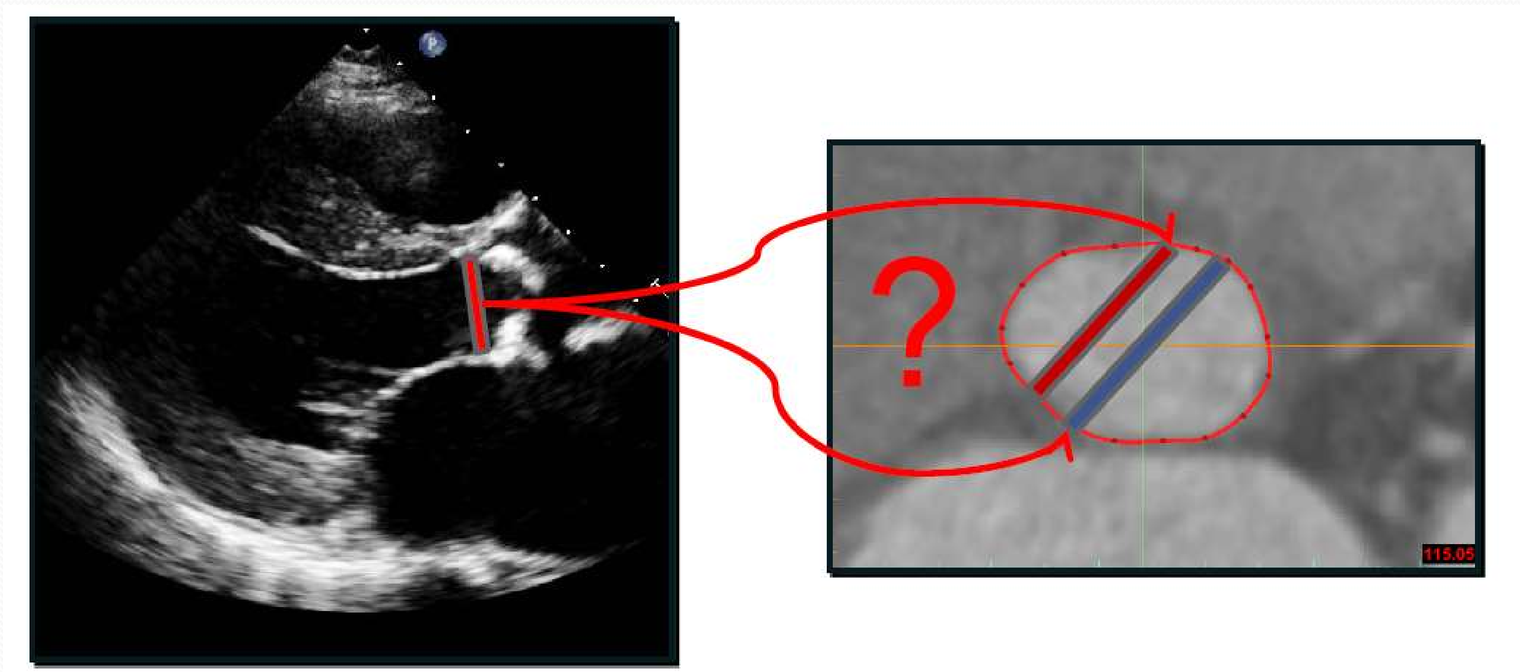
- LVOT diameter is measured from the inner edge to inner edge of the septal endocardium, and the anterior mitral leaflet in mid-systole
- ZOOM-IN, multiple measurement
- Largest source of error in AVA calculation (error would be squared)



Where to measure LVOT?

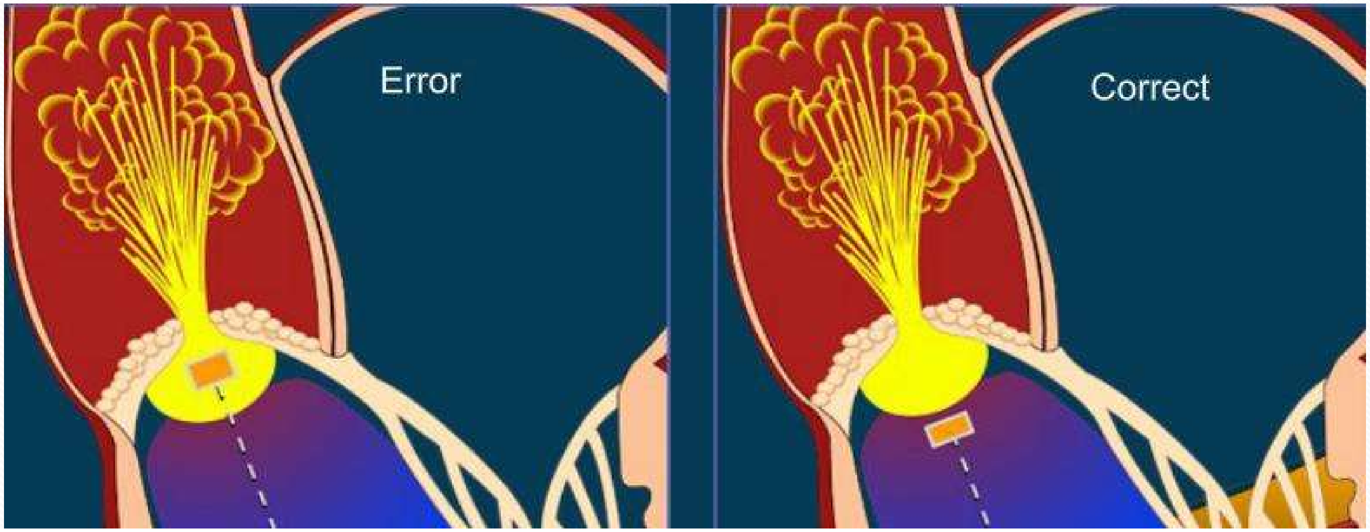


2D Echo LVOT measurement- Limitation



LVOT TVI measurement (Pitfall 5)

- When the PW sample volume is optimally positioned, the recording shows a smooth velocity curve with a well-defined peak.
- Measuring in flow acceleration zone would “overestimate” AVA

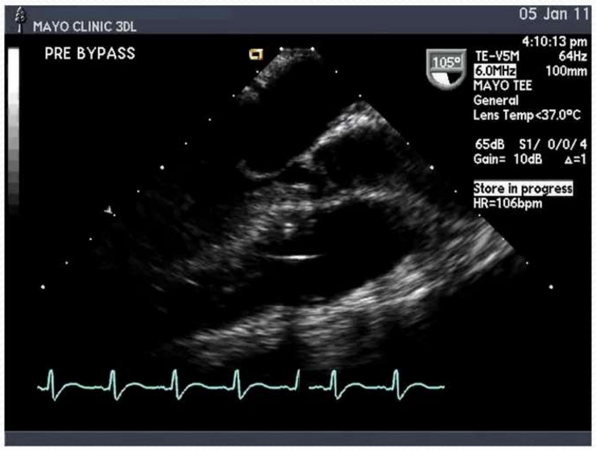


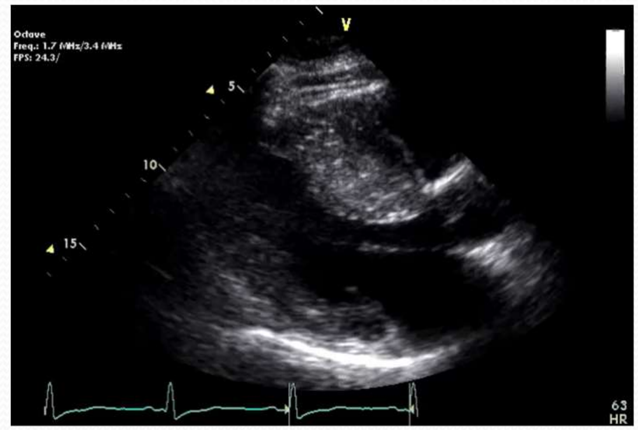
Conditions affecting flow (thus gradient) (Pitfall 6)

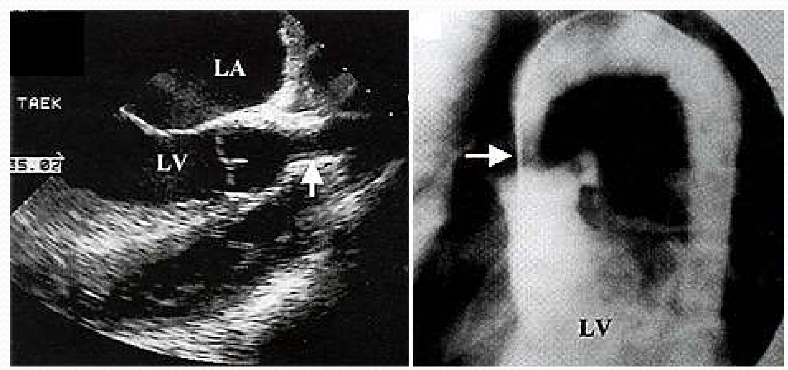
- Increase flow
  - Anaemia
  - Thyrotoxicosis
  - Fever
  - Severe AR
- Decrease flow
  - Poor LV
  - Severe MR
  - Severe MS
  - Severe TR

Check for proportionate change of LVOT TVI
Do not just report gradient without calculating AVA

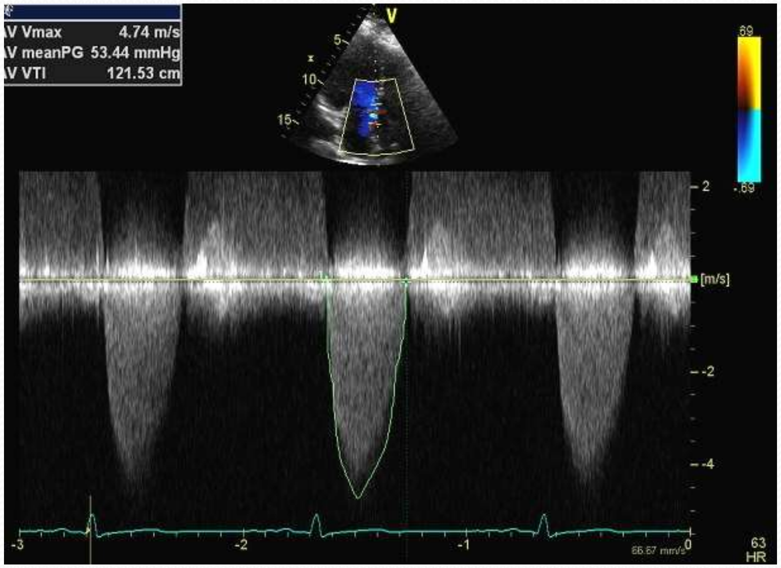
Failure to identify non-valvular stenotic lesions (Pitfall 7)

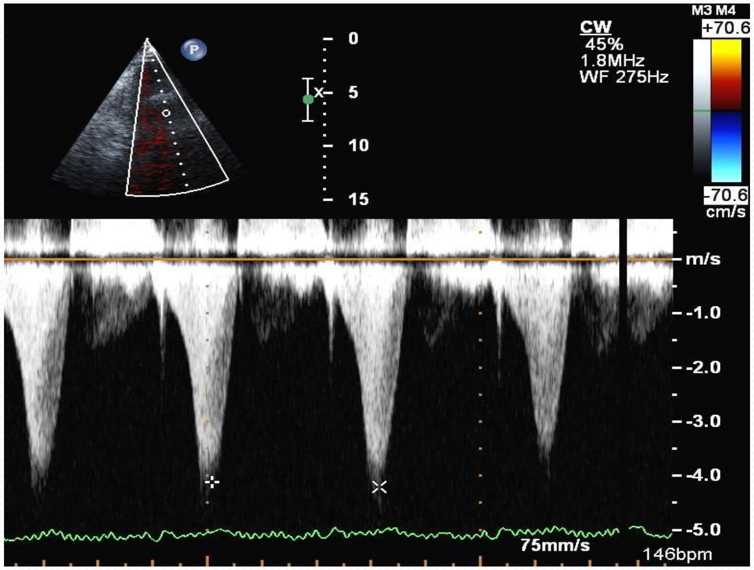






Fixed vs Dynamic Obstruction (Pitfall 8)

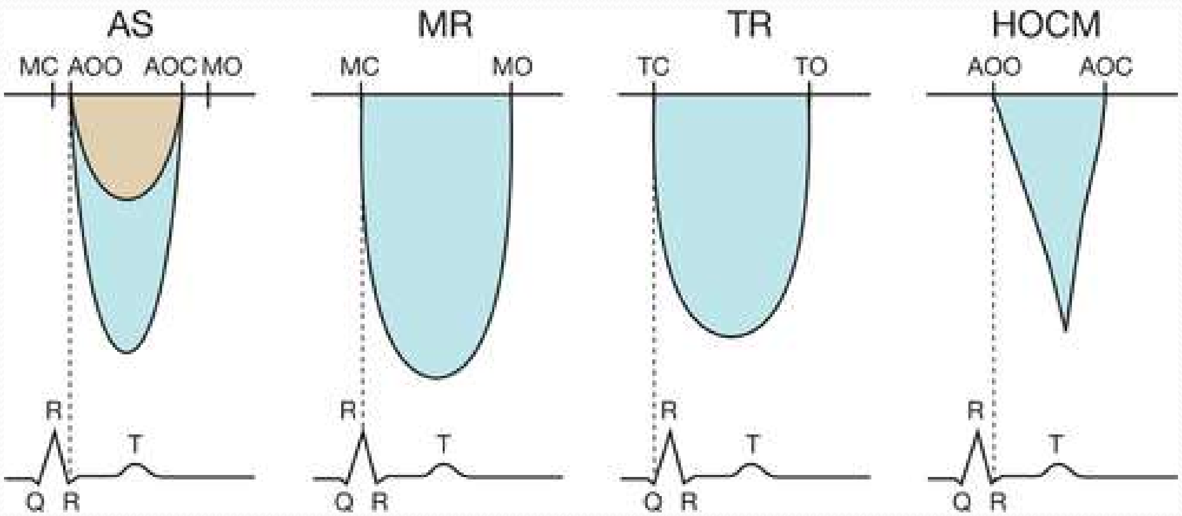




Parabolic

Late peaking

Mixing up AS and MR jet (Pitfall 9)



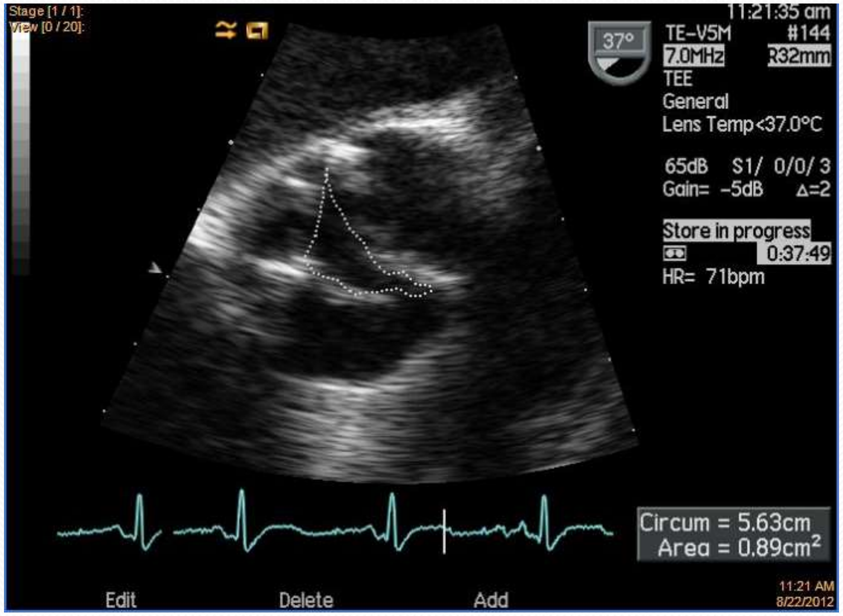
- AS jet narrower (excluded IVCT and IVRT)
- MR velocity always higher than AS
- Superimposed LVOT TVI signal

LVOT/AV TVI ratio

- Dimensionless index
- Error of LVOT diameter measurement “ignored”
- Suboptimal CW or PW beam angle “ignored”
- Effect of high flow “ignored”
- Provide an alternative if AVA difficult to assess
- < 0.25 – severe aortic stenosis

Aortic valve area – Planimetry

- Planimetry may be an acceptable alternative when Doppler estimation of flow velocities is unreliable
- Planimetry may be inaccurate when valve calcification causes shadows or reverberations limiting identification of the orifice



How to (appear to) be smart when reading the Echo report without looking at the images?

Case 1

- M/70, mildly thickened aortic valve with good mobility
  - LVEF 70%
  - AV mean gradient 5 mmHg
  - LVOT TVI : 25.8 cm
  - AV TVI : 23.6 cm
  - LVOT diameter : 2 cm
  - AVA 3.43 cm2 (by continuity equation)

Case 2

- M/80 s/p TAVI, FU at discharge and at 1 month
  - LVEF 60%, trivial PVL

Aortic Valve

LVOT VTI :	35.23 cm
AV VTI :	44.58 cm
VTI ratio :	0.79
AV peak systolic Gr. :	mmH
AV mean systolic Gr. :	16.16 mmH
AR vena contracta :	cm
AR pressure half time :	mse
Des Thor Ao Reversal :	cm
LVOT diameter :	2.2 cm

AVA 3 cm2

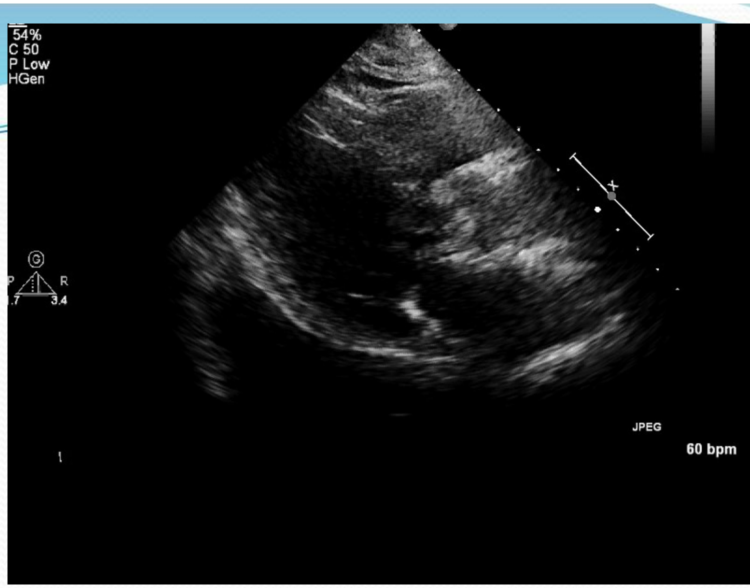
Aortic Valve

LVOT VTI :	22.3 cn
AV VTI :	51.7 cn
VTI ratio :	0.43
AV peak systolic Gr. :	35 mı
AV mean systolic Gr. :	16 mı
AR vena contracta :	cn
AR pressure half time :	ms
Des Thor Ao Reversal :	cn
LVOT diameter :	2.15 cn

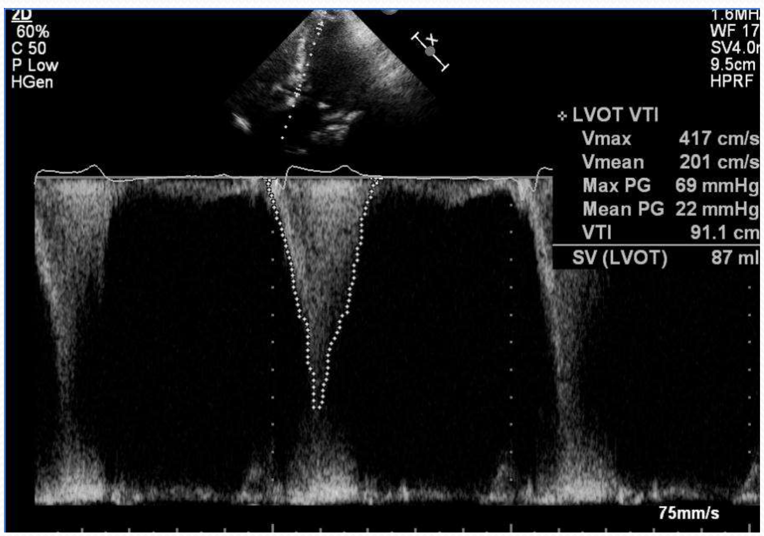
AVA 1.56 cm2

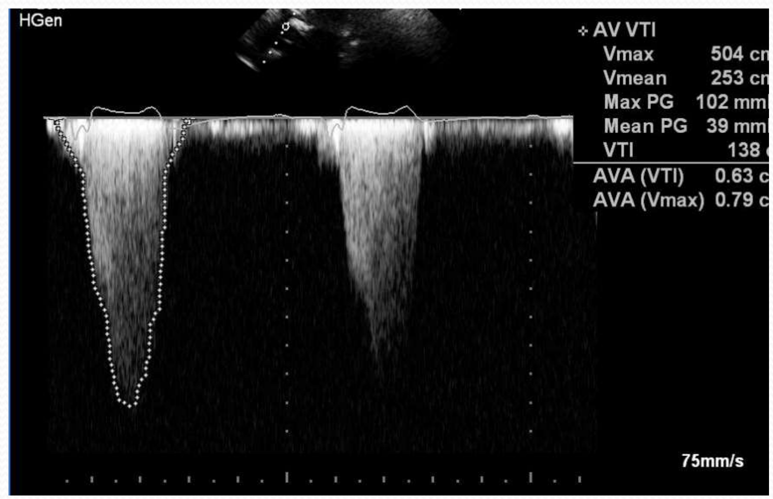
Case 3

- F/90 referred for ?TAVI for severe AS
  - LVEF : 60%
  - AV mean gradient : 39 mmHg
  - LVOT TVI : 91 cm
  - AV TVI : 138 cm
  - LVOT diameter : 1.1 cm
  - AVA : 0.63 cm2 (by continuity equation)


54%
C 50
P Low
HGen
JPEG
60 bpm


2D
71%
C 50
P Low
HGen
LVOT Diam 1.1 cm
LVOT Area 0.950 cm²


2D
60%
C 50
P Low
HGen
LVOT VTI
Vmax 417 cm/s
Vmean 201 cm/s
Max PG 69 mmHg
Mean PG 22 mmHg
VTI 91.1 cm
SV (LVOT) 87 ml
75mm/s


HGen
AV VTI
Vmax 504 cm
Vmean 253 cm
Max PG 102 mm
Mean PG 39 mm
VTI 138
AVA (VTI) 0.63 c
AVA (Vmax) 0.79 c
75mm/s

Valve Stenoses
Gorlin Formula Derivation

$$A = \frac{\text{Flow}}{C \cdot 44.3 \sqrt{h}}$$

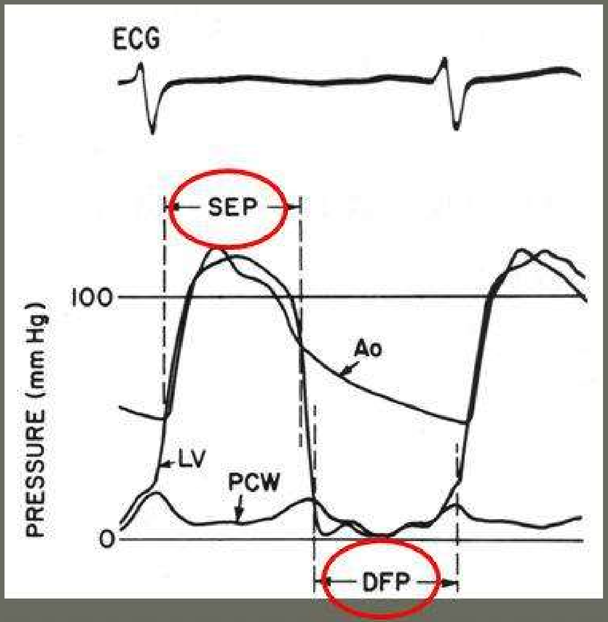
Flow has to be corrected for the time during which there is cardiac output across the valve.

Aortic, Pulmonic } Systolic Flow (SEP)

Tricuspid, Mitral } Diastolic Flow (DFP)

Gorlin Formula:

$$A = \frac{CO / (DFP \text{ or } SEP) \cdot HR}{C \cdot 44.3 \sqrt{\Delta P}}$$



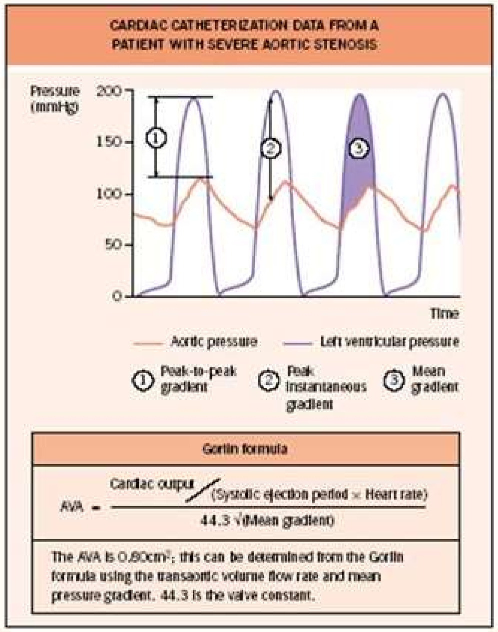
Constant:

Aortic, Tricuspid, Pulmonic: C = 1.0

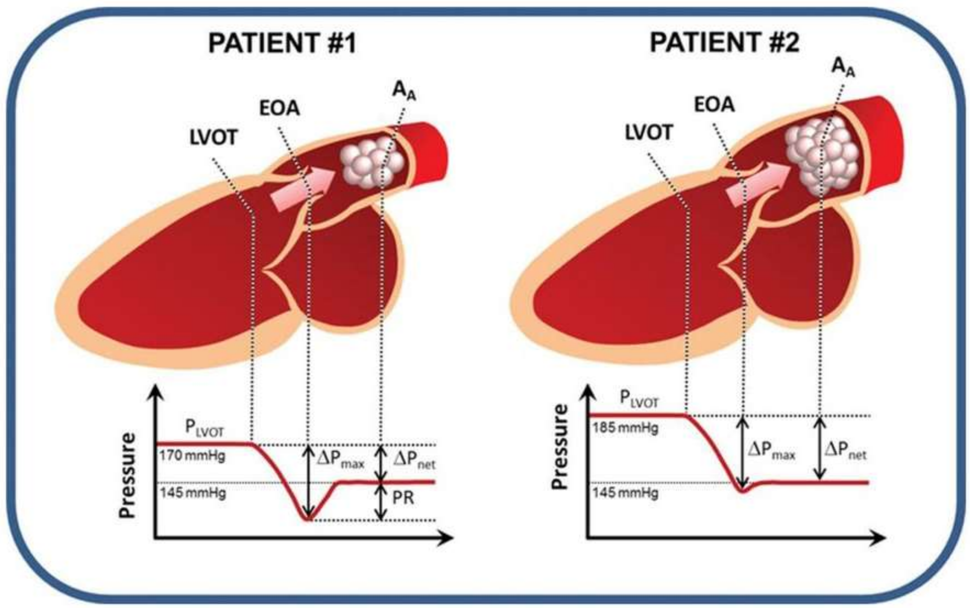
Mitral: C = 0.85

Cath vs. Echo gradient

- The **peak-to-peak gradient** is the difference between the peak left ventricular pressure and the peak aortic pressure.
- The **peak instantaneous gradient** corresponds to the maximum gradient measured by Doppler echocardiographic methods.
- The **mean gradient** is average transaortic gradient during the systolic ejection period



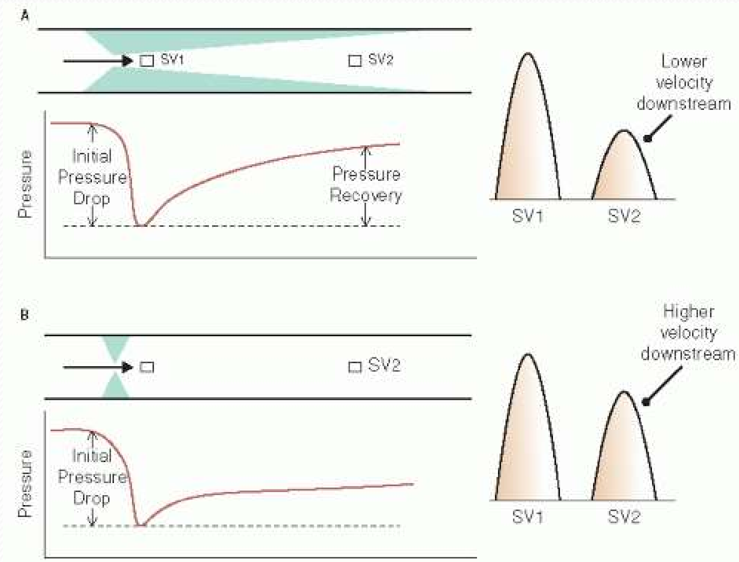
Pressure recovery phenomenon



Philippe Pibarot et al. Circulation. 2013;127:1101-1104

- Kinetic energy -> Potential or static energy in ascending aorta after passing through the stenosis
- Usually negligible in large aorta

Pressure recovery phenomenon (Pitfall 10)



- Smaller sinotubular junction or aorta (< 3cm), greater pressure recovery, higher pressure at AsAo
- Greater discrepancy between Cath vs. Echo net gradient (Cath < Echo)

Classification of progression of Valvular Heart Diseases

Table 3. Stages of Progression of VHD

Stage	Definition	Description
A	At risk	Patients with risk factors for development of VHD
B	Progressive	Patients with progressive VHD (mild-to-moderate severity and asymptomatic)
C	Asymptomatic severe	Asymptomatic patients who have the criteria for severe VHD: C1: Asymptomatic patients with severe VHD in whom the left or right ventricle remains compensated C2: Asymptomatic patients with severe VHD, with decompensation of the left or right ventricle
D	Symptomatic severe	Patients who have developed symptoms as a result of VHD

VHD indicates valvular heart disease.

J Am Coll Cardiol. March 2014

Stages of Aortic Stenosis

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

Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
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 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 is ≤1 cm^2 (or AVAi ≤0.6 cm^2/m^2)	• LVEF <50%	• None

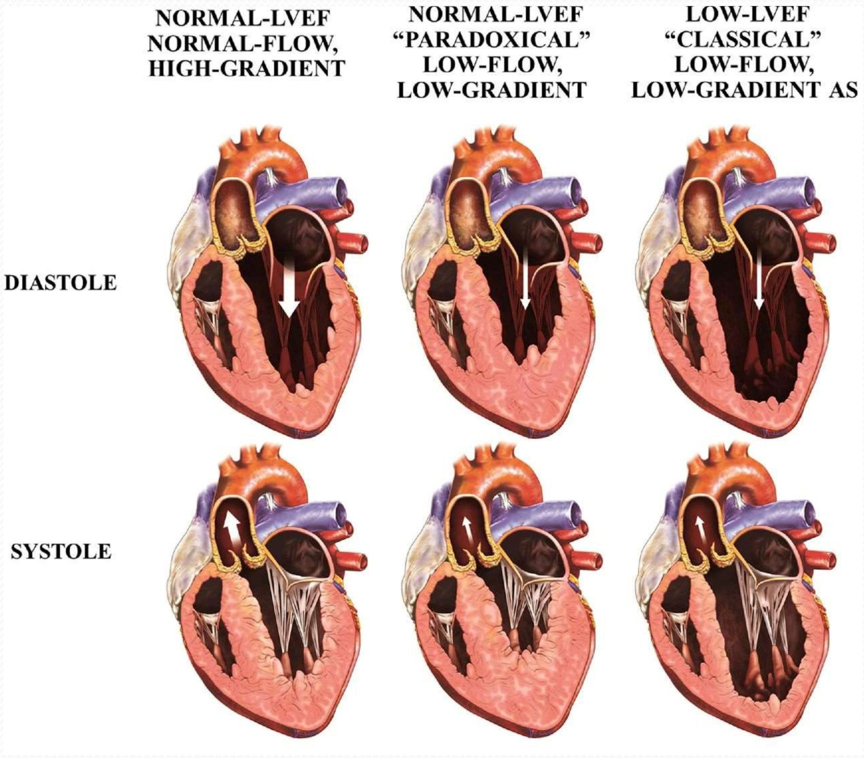
Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
D - Symptomatic severe AS					
D1	**Symptomatic severe high-gradient AS**	• Severe leaflet calcification or congenital stenosis with severely reduced leaflet opening	• Aortic V_{max} ≥4 m/s, or mean ΔP ≥40 mm Hg • AVA typically is ≤1 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 cm^2 with resting aortic V_{max} <4 m/s or mean ΔP <40 mm Hg • Dobutamine stress echo shows AVA ≤1 cm^2 with V_{max} ≥4 m/s at any flow rate	• LV diastolic dysfunction • LV hypertrophy • LVEF <50%	• HF, • Angina, • Syncope or presyncope

Stage	Definition	Valve Anatomy	Valve Hemodynamics	Hemodynamic Consequences	Symptoms
D - Symptomatic severe AS					
D3	**Symptomatic severe low-gradient AS with normal LVEF or paradoxical low-flow severe AS**	• Severe leaflet calcification with severely reduced leaflet motion	• AVA ≤1 cm^2 with aortic V_{max} <4 m/s, or mean ΔP <40 mm Hg • Indexed AVA ≤0.6 cm^2/m^2 and • Stroke volume index <35 mL/m^2 • Measured when the patient is normotensive (systolic BP <140 mm Hg)	• Increased LV relative wall thickness • Small LV chamber with low-stroke volume. • Restrictive diastolic filling • LVEF ≥50%	• HF, • Angina, • Syncope or presyncope

- The diagnosis of “severe aortic stenosis” can be confidently established when the data are congruent with each other
  - Normal flow, Normal EF, High gradient

- What if there are mismatch of information??
  - esp “severe AS by AVA” but low gradient, low EF
  - Could be due to “burning out of pure AS” or “concomitant obstructive CAD”

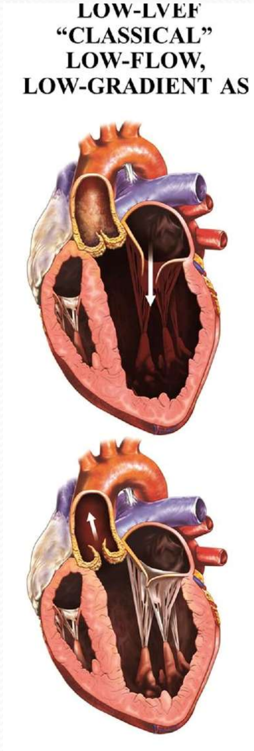
Low-Flow Low-Gradient (LFLG) AS



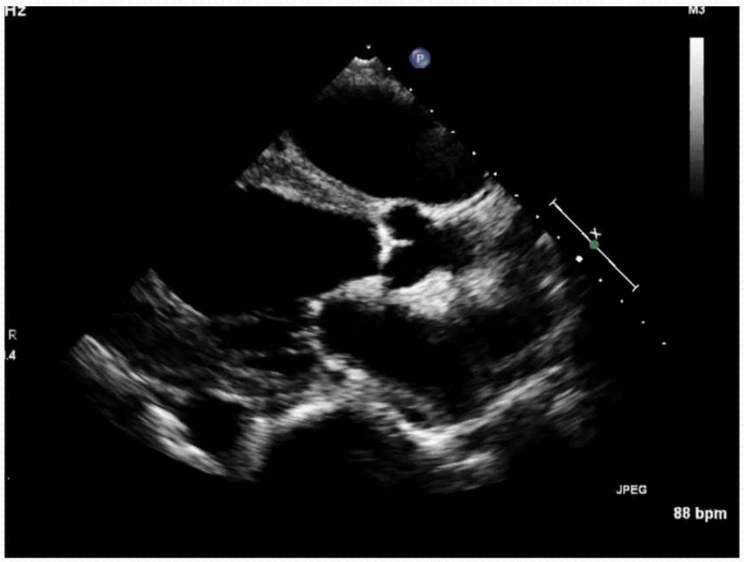
- Low flow Low gradient AS with Low EF (Paradoxical)
- Low flow Low gradient AS with Normal EF (Classical)
- Normal-Flow, Low-Gradient AS (?Measurement error)

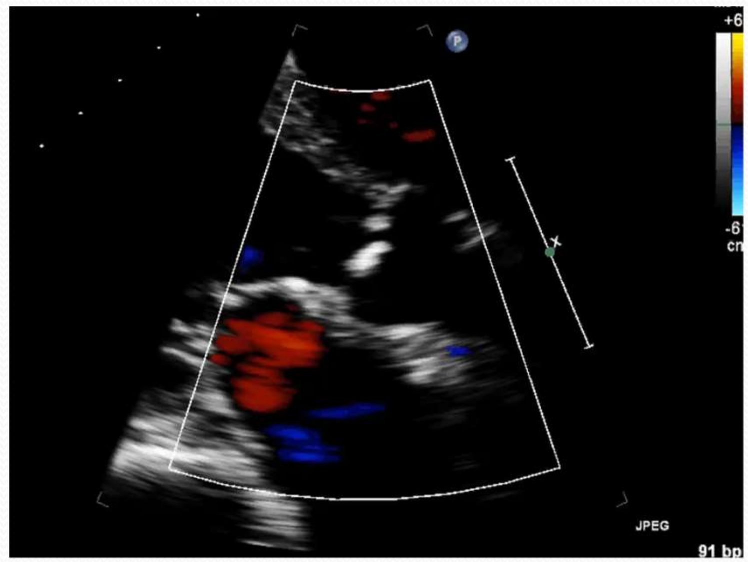
Classical LFLG AS

- Low Flow secondary to Low EF due to myocardial dysfunction
  - secondary to AS
  - secondary to other causes
  - primary myocardial disease
- “Psedo-severe” AS with impaired LVEF
  - DCMP(Primary Myocardial Dysfunction)
  - Ischemic Heart Disease
  - HT Heart Disease (After load mismatch)

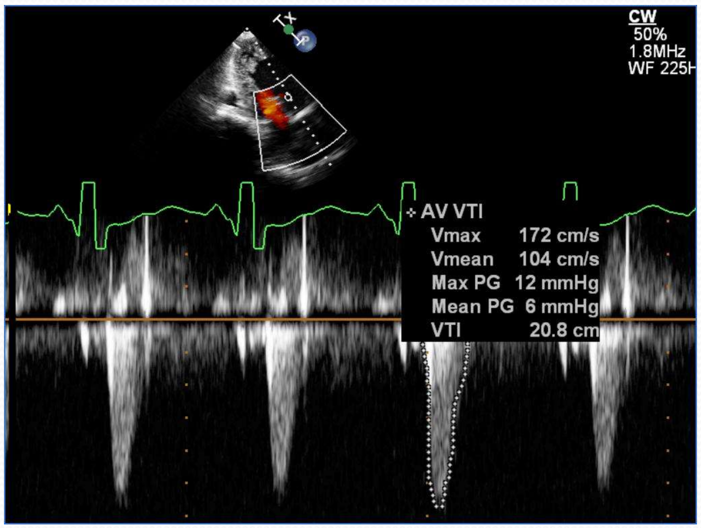


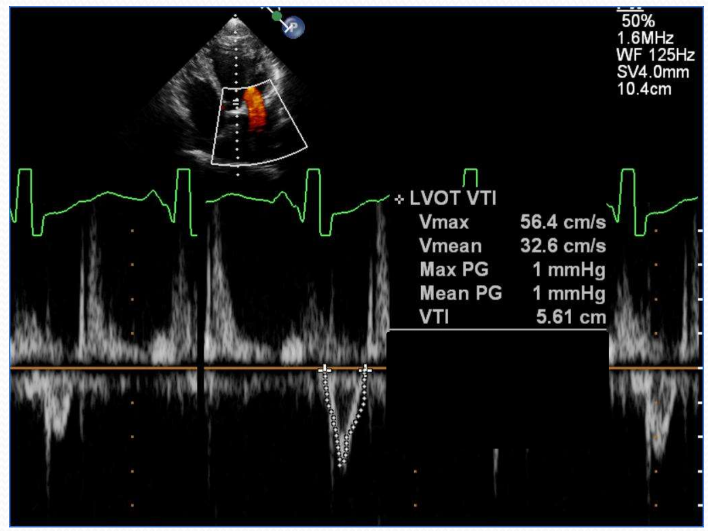
Referred for TAVI



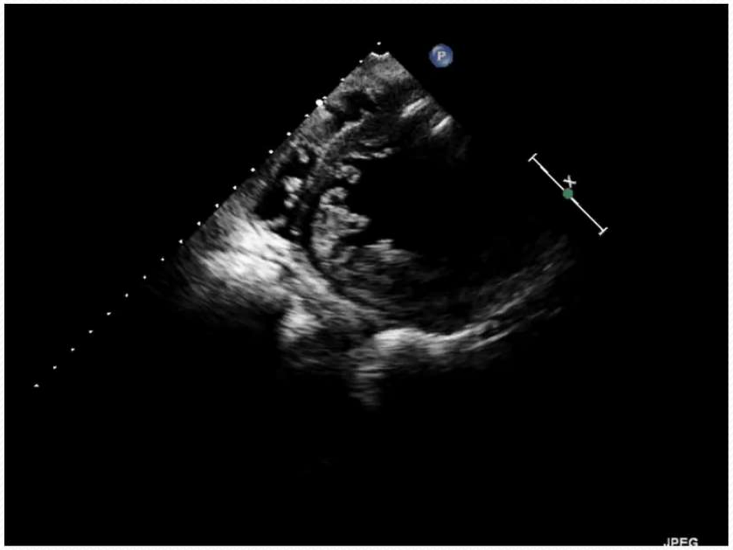


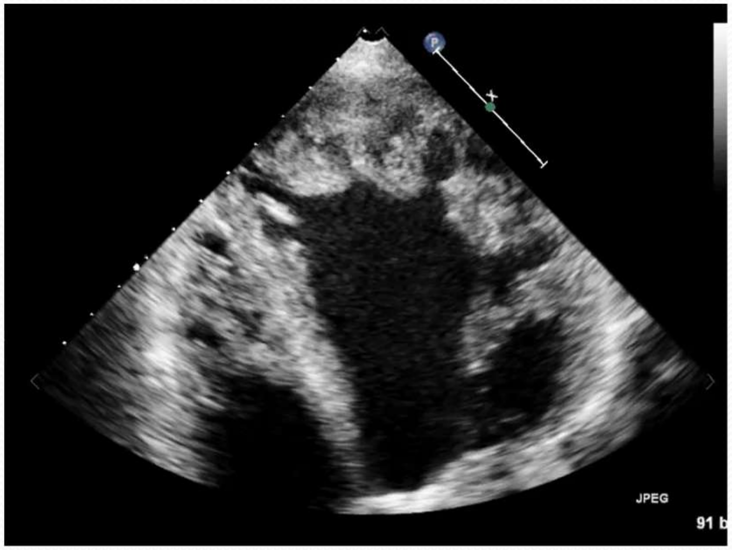
AV mean grad. 6mmHg, LVOT dia. 2.05 cm
Calculated AVA 0.96 cm2





LV non-compaction, EF 10%



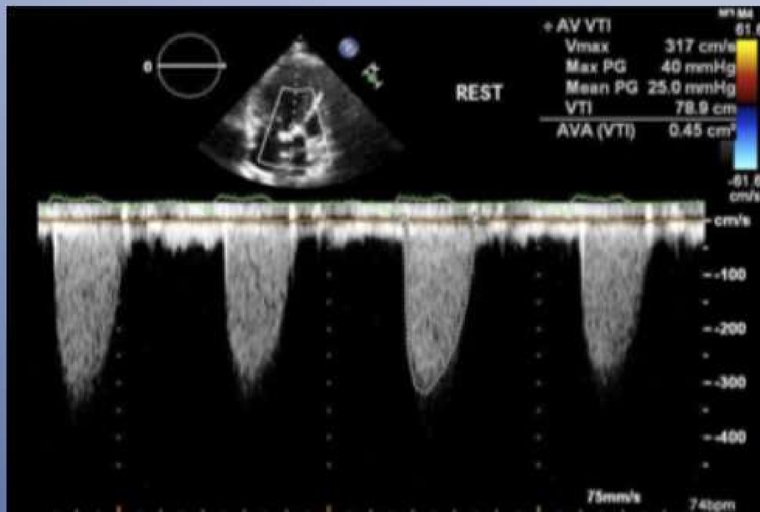


Dobutamine Stress Echo (DSE)

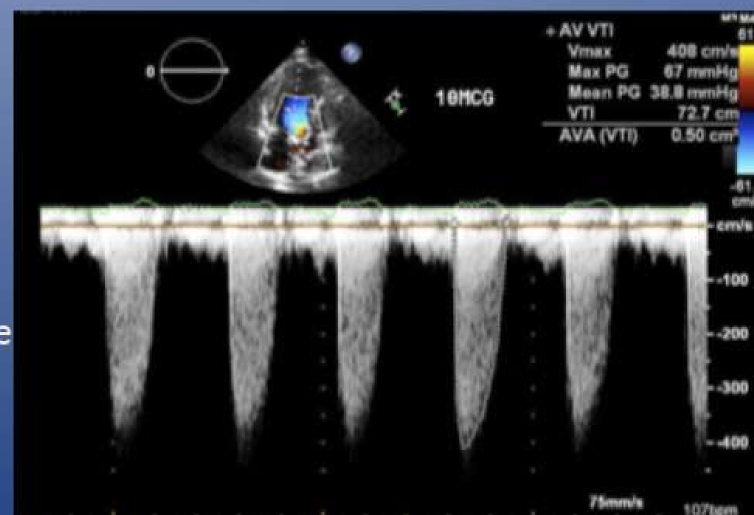
- Measure of the contractile response to dobutamine
- Assess for flow reserve, change in EOA and change in Gradient and velocity
- Low dose protocol up to 20 μg/kg/min

- Stress findings of true severe stenosis
  - AVA<1cm^2
  - Jet velocity>4m/s
  - Mean gradient>40mm of Hg
    - ***Nishimura RA et al. Circulation 2002;106:809-13.***
- Lack of contractile reserve-
  - Failure of LVEF to ↑ by 20% is a poor prognostic sign
    - ***Monin JL et al. Circulation 2003;108:319-24.***

Dobutamine stress ECHO in patient with LGSAS

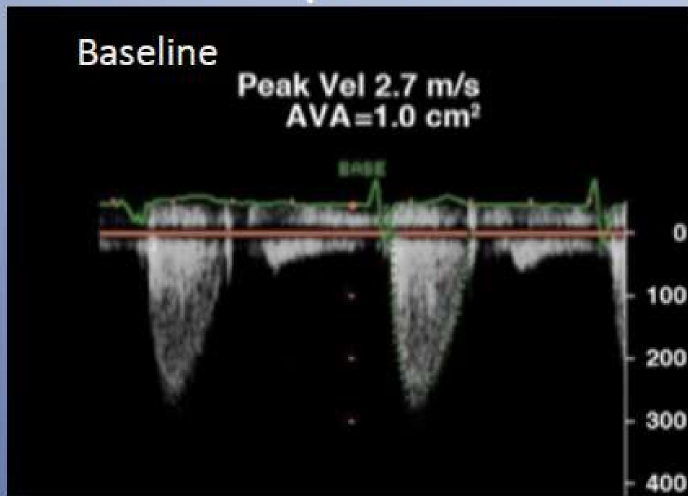


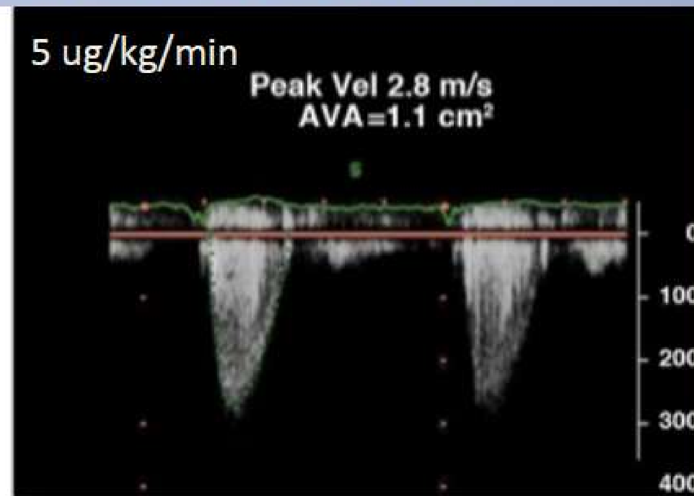
Baseline CW tracing:
Peak velocity 3.2 m/s
Mean grad 25 mmHg
AVA 0.45 cm^2



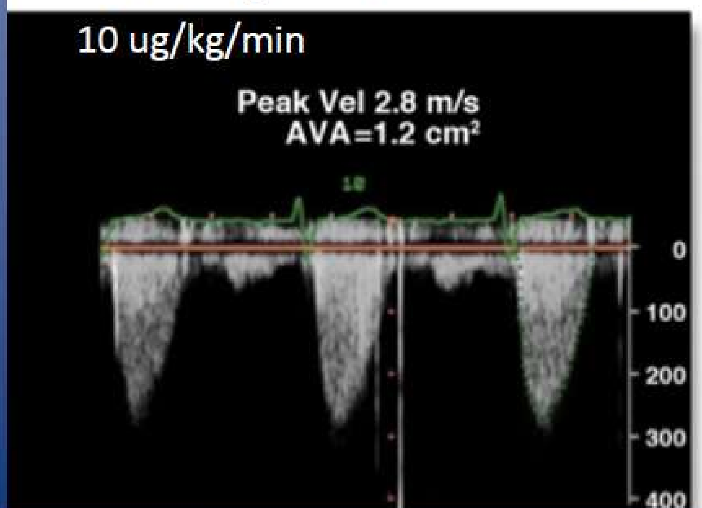
CW 10ug/kg/min dobutamine
Peak velocity 4.1 m/s
Mean grad 39 mmHg
AVA 0.5 cm^2

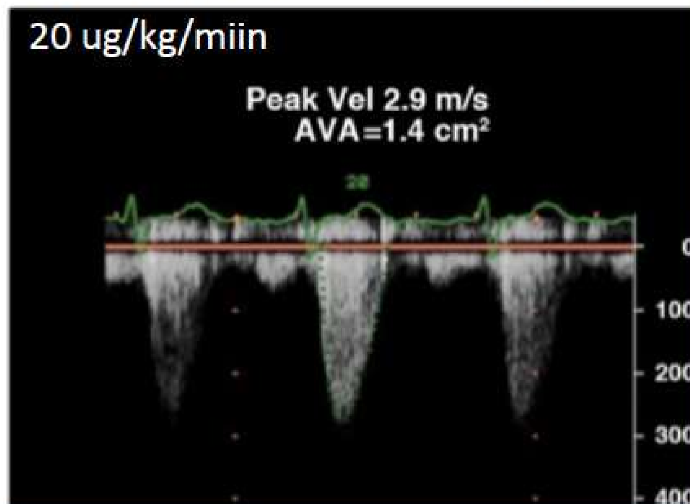
DSE in a patient with Pseudo-severe AS





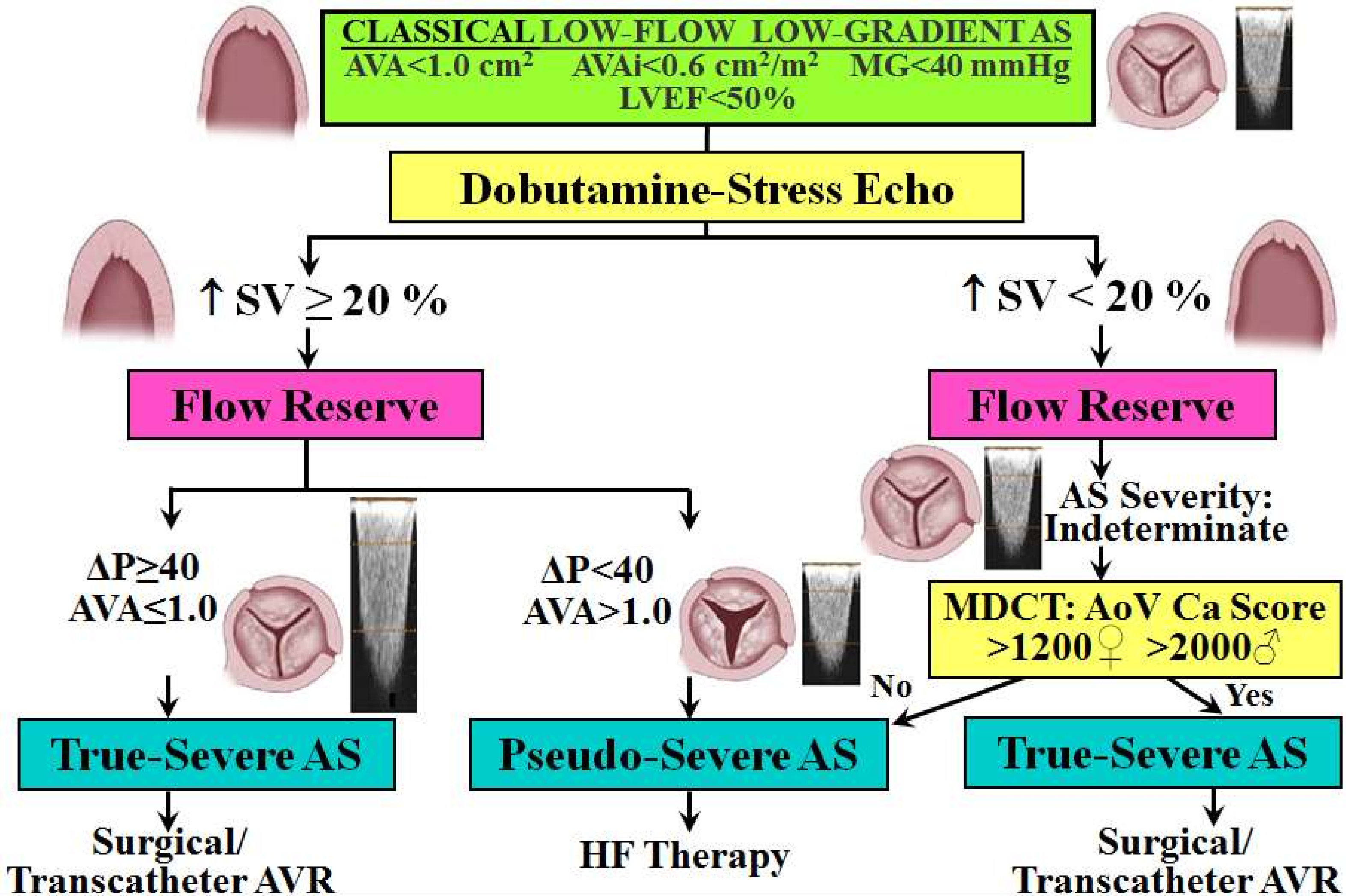
Peak velocity stable, AVA increased, contractile reserve +, absence of severe AS





Lack of Contractile Reserve

- Defined by increase in SV <20% during DSE or catheterization
- Higher operative mortality (22% to 33%) than those with flow reserve (5% to 8%).
- Higher prevalence of multivessel CAD
- Yet, should NOT preclude consideration of AV surgery in symptomatic subjects with severe AS



CLASSICAL LOW-FLOW LOW-GRADIENT AS
AVA<1.0 cm² AVAi<0.6 cm²/m² MG<40 mmHg
LVEF<50%
Dobutamine-Stress Echo
↑ SV ≥ 20 %
↑ SV < 20 %
Flow Reserve
Flow Reserve
AS Severity:
Indeterminate
ΔP≥40
AVA≤1.0
ΔP<40
AVA>1.0
MDCT: AoV Ca Score
>1200♀ >2000♂
No
Yes
True-Severe AS
Pseudo-Severe AS
True-Severe AS
Surgical/
Transcatheter AVR
HF Therapy
Surgical/
Transcatheter AVR

Valvular Heart Disease

Projected Valve Area at Normal Flow Rate Improves the Assessment of Stenosis Severity in Patients With Low-Flow, Low-Gradient Aortic Stenosis

The Multicenter TOPAS (Truly or Pseudo-Severe Aortic Stenosis) Study

Claudia Blais, MSc; Ian G. Burwash, MD; Gerald Mundigler, MD; Jean G. Dumesnil, MD; Nicole Loho, MD; Florian Rader, MD; Helmut Baumgartner, MD; Rob S. Beanlands, MD; Boris Chayer, Eng; Lyes Kadem, Eng, PhD; Damien Garcia, Eng, PhD; Louis-Gilles Durand, Eng, PhD; Philippe Pibarot, DVM, PhD

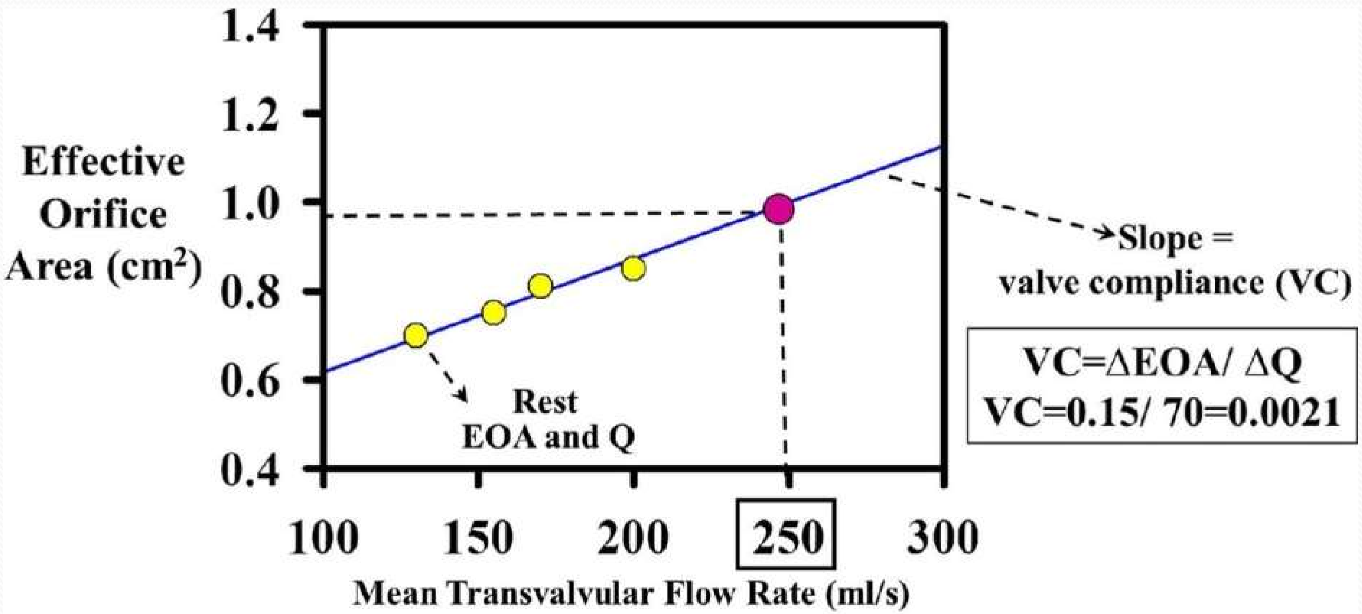
Background—We sought to investigate the use of a new parameter, the projected effective orifice area (EOA_{proj}) at normal transvalvular flow rate (250 mL/s), to better differentiate between truly severe (TS) and pseudo-severe (PS) aortic stenosis (AS) during dobutamine stress echocardiography (DSE). Changes in various parameters of stenosis severity have been used to differentiate between TS and PS AS during DSE. However, the magnitude of these changes lacks standardization because they are dependent on the variable magnitude of the transvalvular flow change occurring during DSE.

Methods and Results—The use of EOA_{proj} to differentiate TS from PS AS was investigated in an in vitro model and in 23 patients with low-flow AS (indexed EOA <0.6 cm^2/m^2, left ventricular ejection fraction $\leq 40\%$) undergoing DSE and subsequent aortic valve replacement. For an individual valve, EOA was plotted against transvalvular flow (Q) at each dobutamine stage, and valve compliance (VC) was derived as the slope of the regression line fitted to the EOA versus Q plot; EOA_{proj} was calculated as $EOA_{proj}=EOA_{rest}+VC\times(250-Q_{rest})$, where EOA_{rest} and Q_{rest} are the EOA and Q at rest. Classification between TS and PS was based on either response to flow increase (in vitro) or visual inspection at surgery (in vivo). EOA_{proj} was the most accurate parameter in differentiating between TS and PS both in vitro and in vivo. In vivo, 15 of 23 patients (65%) had TS and 8 of 23 (35%) had PS. The percentage of correct classification was 83% for EOA_{proj} and 91% for indexed EOA_{proj} compared with percentages of 61% to 74% for the other echocardiographic parameters usually used for this purpose.

Conclusions—EOA_{proj} provides a standardized evaluation of AS severity with DSE and improves the diagnostic accuracy for distinguishing TS and PS AS in patients with low-flow, low-gradient AS. (***Circulation*. 2006;113:711-721.**)

Key Words: aortic valve stenosis ■ echocardiography ■ hemodynamics ■ surgery ■ valves

Projected EOA

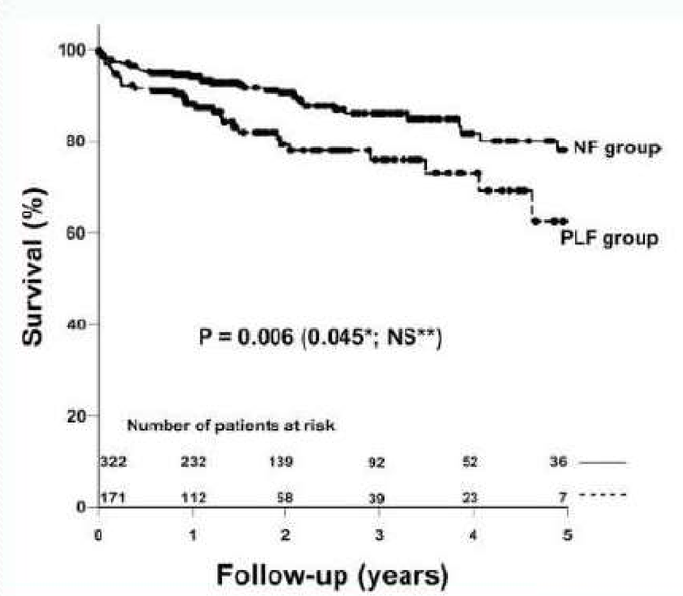


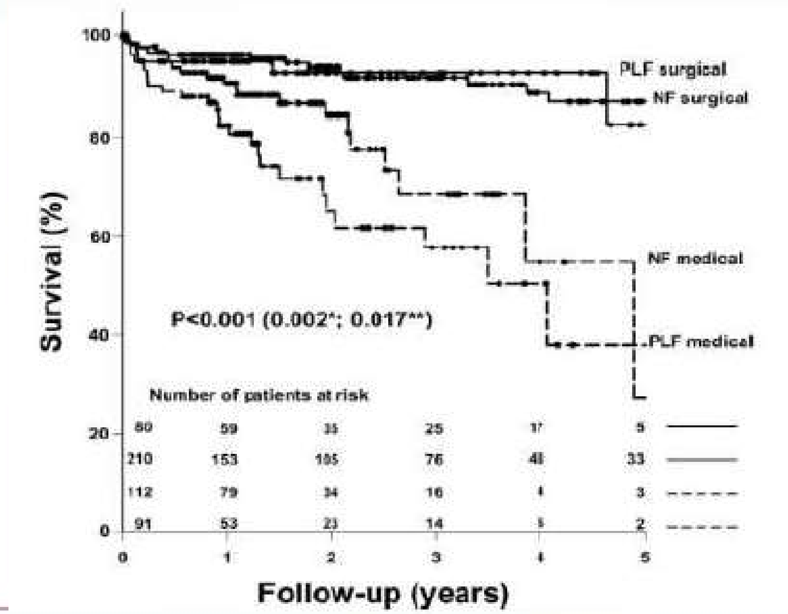
$$EOA_{Projected} = EOA_{Rest} + VC \times (250 - Q_{Rest})$$
$$= 0.70 + 0.0021 \times (250 - 130) = 0.97\ cm^2$$

Paradoxical LFLG AS - essentials

- (Would be another hour of talk!)
- Old, female, concomitant HT
- Pronounced LV concentric remodeling
- Small LV with restrictive filling
- Higher valvulo-arterial impedance (Zva)
- (Small body size – index AVA may be helpful but not for obese patient)

Worse prognosis than NF severe AS if treated medically

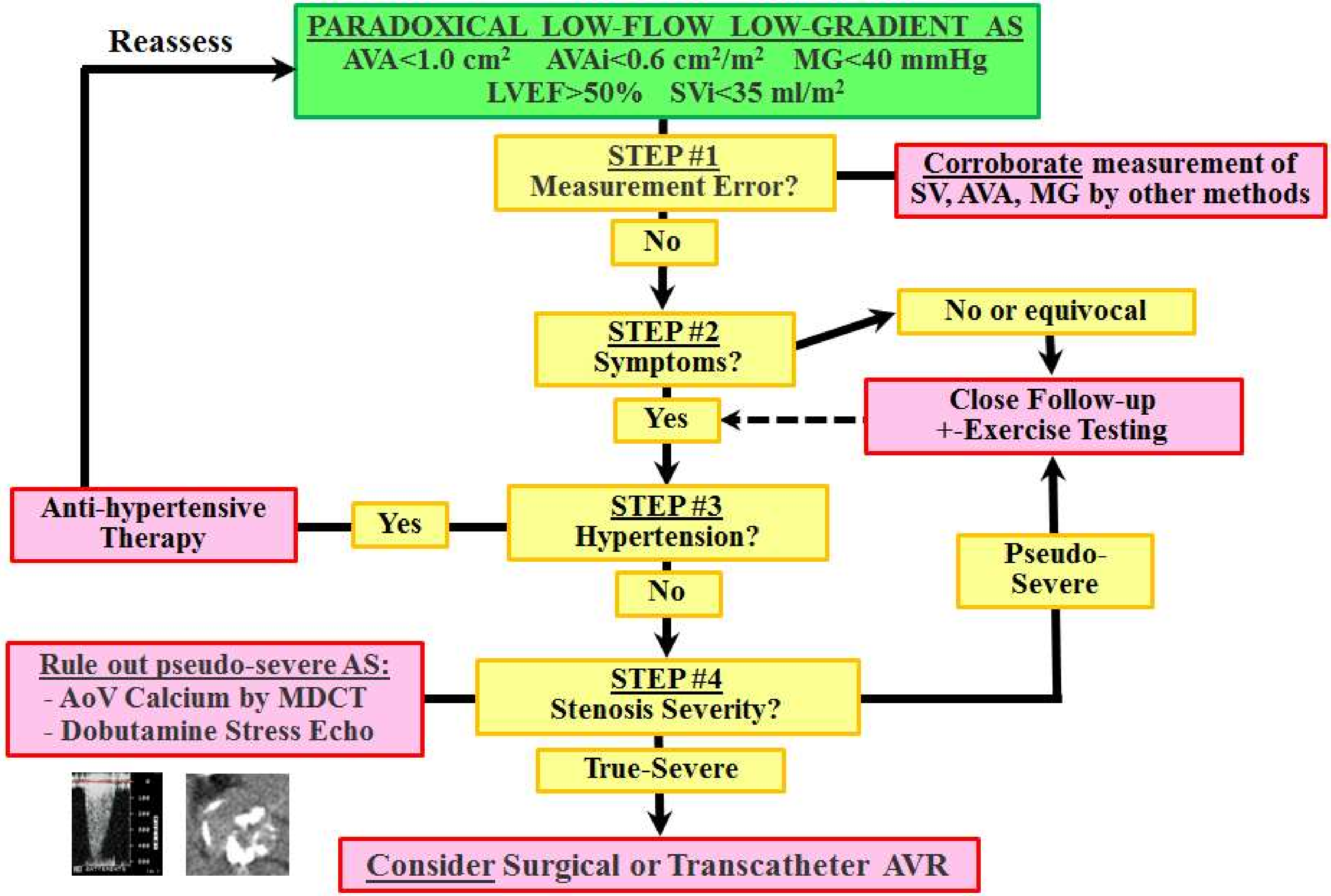


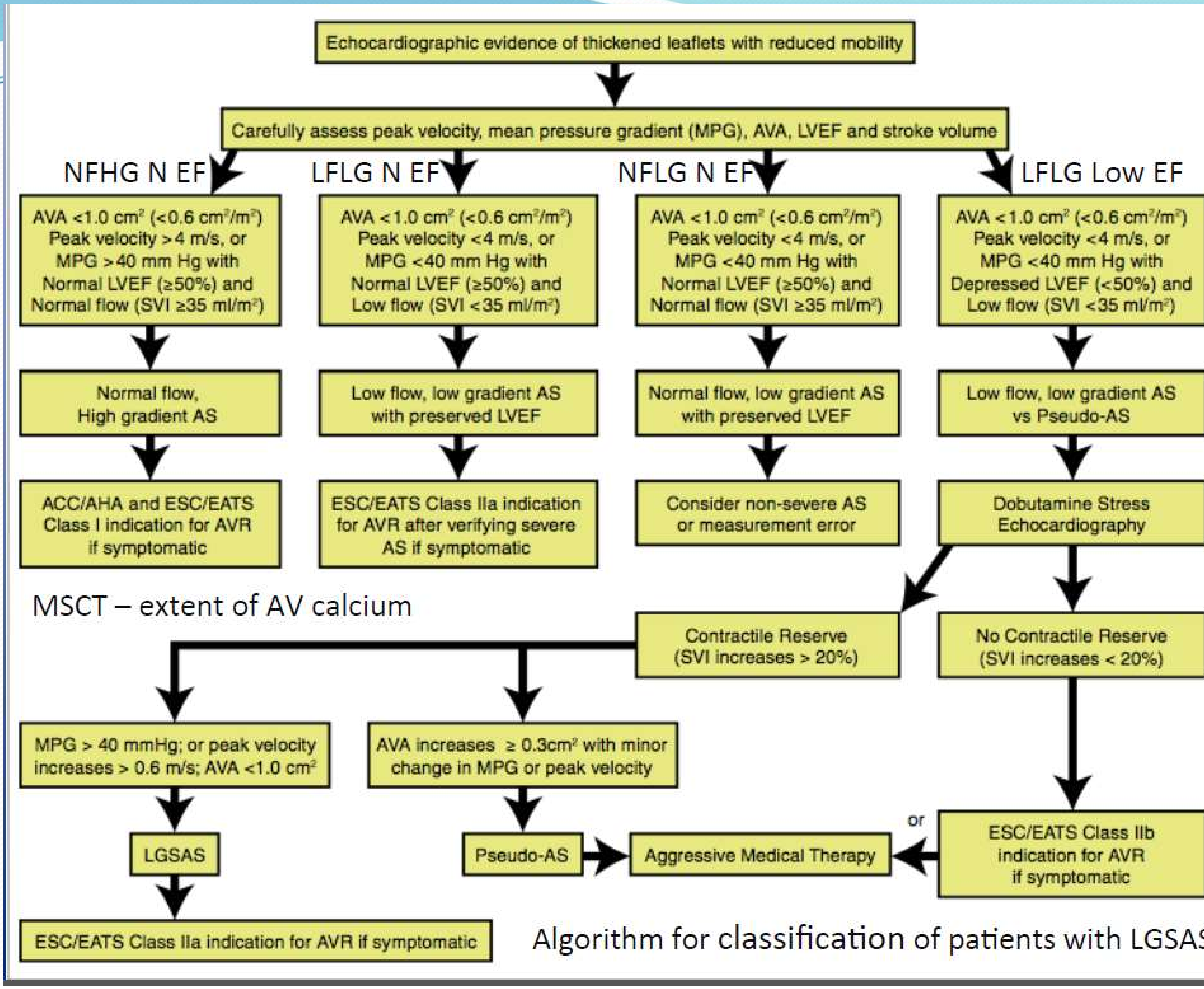


Hachicha et al. Circulation. 2007;115:2856 -64

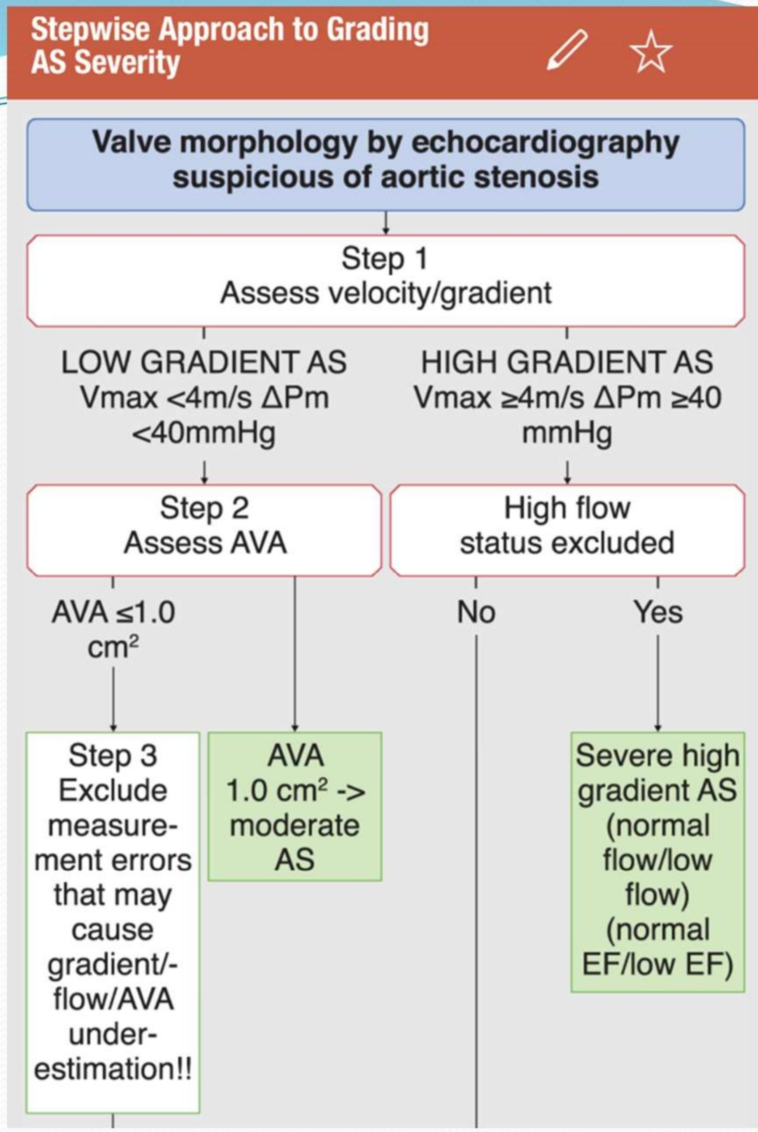
Prognosis

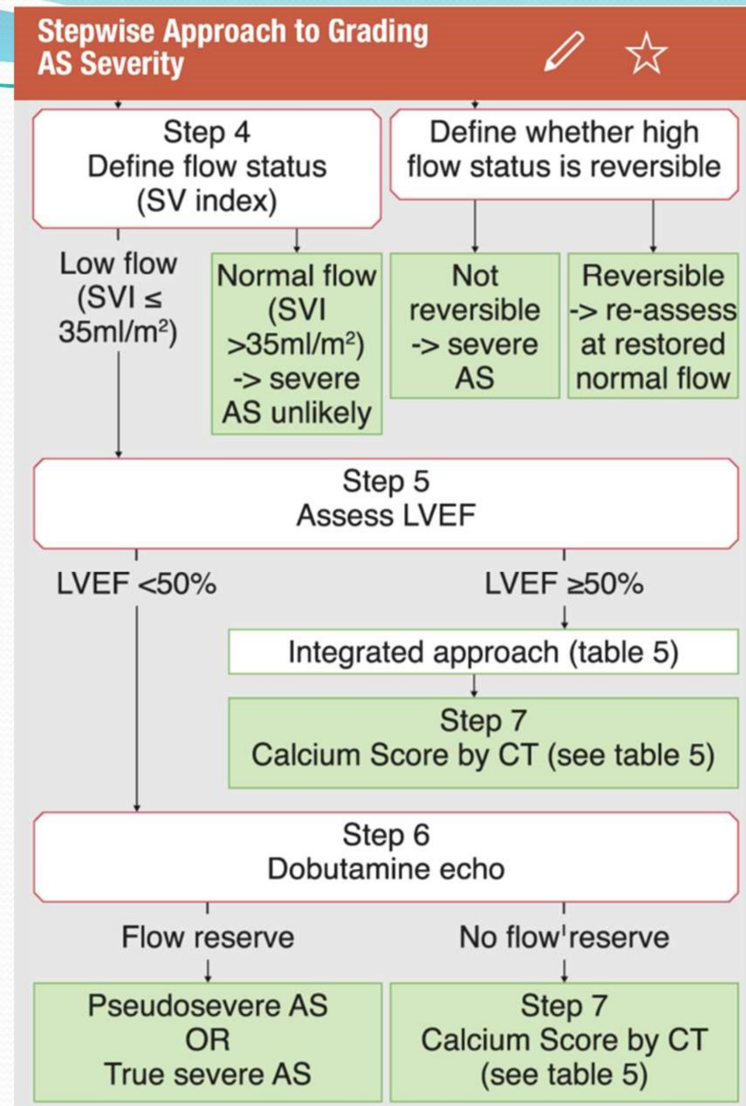
- Worse than moderate AS (albeit contradictory reports)
- Worse than severe AS with high gradient group
- Lower overall 3-year survival (76% versus 86%)
  - ($p < 0.006$ in 512 patients By Hacicha et al.)
- Two-fold increase in mortality and an almost **50% lower referral rate** (?undertreated) for AVR in the low gradient AS compared to the high gradient group (Barasch et al)


PARADOXICAL LOW-FLOW LOW-GRADIENT AS
AVA<1.0 cm² AVAi<0.6 cm²/m² MG<40 mmHg
LVEF>50% SVi<35 ml/m²
Reassess
STEP #1
Measurement Error?
Corroborate measurement of SV, AVA, MG by other methods
No
STEP #2
Symptoms?
No or equivocal
Close Follow-up
+-Exercise Testing
Yes
Anti-hypertensive Therapy
Yes
STEP #3
Hypertension?
No
Pseudo-Severe
Rule out pseudo-severe AS:
- AoV Calcium by MDCT
- Dobutamine Stress Echo
STEP #4
Stenosis Severity?
True-Severe
Consider Surgical or Transcatheter AVR

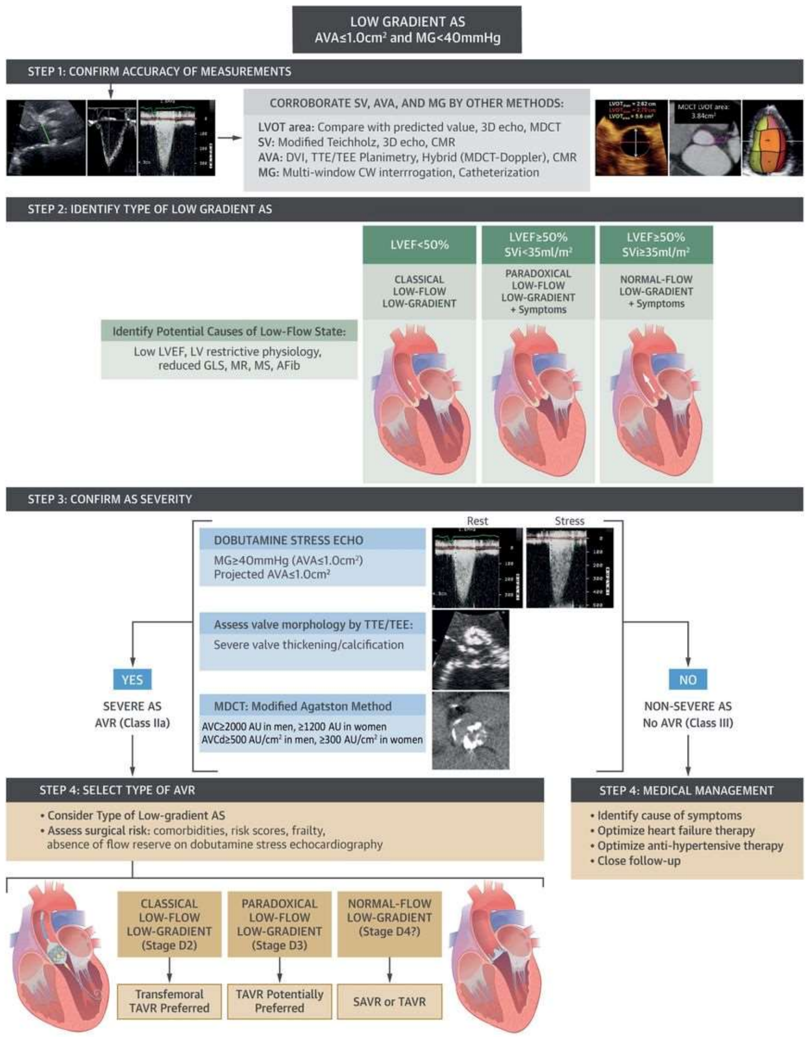


Algorithm for classification of patients with LGSAS


Stepwise Approach to Grading AS Severity
Valve morphology by echocardiography suspicious of aortic stenosis
Step 1
Assess velocity/gradient
LOW GRADIENT AS
Vmax <4m/s ΔPm <40mmHg
HIGH GRADIENT AS
Vmax ≥4m/s ΔPm ≥40 mmHg
Step 2
Assess AVA
High flow status excluded
AVA ≤1.0 cm²
No
Yes
Step 3
Exclude measurement errors that may cause gradient/-flow/AVA under-estimation!!
AVA 1.0 cm² -> moderate AS
Severe high gradient AS (normal flow/low flow) (normal EF/low EF)


Stepwise Approach to Grading AS Severity
Step 4
Define flow status (SV index)
Define whether high flow status is reversible
Low flow (SVI ≤ 35ml/m²)
Normal flow (SVI >35ml/m²) -> severe AS unlikely
Not reversible -> severe AS
Reversible -> re-assess at restored normal flow
Step 5
Assess LVEF
LVEF <50%
LVEF ≥50%
Integrated approach (table 5)
Step 7
Calcium Score by CT (see table 5)
Step 6
Dobutamine echo
Flow reserve
No flow reserve
Pseudosevere AS OR True severe AS
Step 7
Calcium Score by CT (see table 5)

CENTRAL ILLUSTRATION: Algorithm for the Management of Low-Gradient AS



Clavel, M.-A. et al. J Am Coll Cardiol Img. 2017;10(2):185-202.

Typical characteristics of 3 different entities of AS

	Normal-Flow, High-Gradient	Preserved LVEF (Paradoxical), Low-Flow, Low-Gradient	Reduced LVEF, Low-Flow, Low-Gradient
Aortic valve area, cm^2	≤1.0	≤1.0	≤1.0
Indexed aortic valve area, cm^2/m^2	<0.6	<0.6	<0.6
Mean gradient, mm Hg	>40	<40	<40
Z_{va}, mm Hg·ml^{-1}·m^2	>4.5	>4.5	>4.5
LV end-diastolic diameter, mm	45–55	<47	>50
Relative wall thickness	>0.43	>0.50	0.35–0.55
LVEF, %	>50	>50	<50
Mitral ring displacement, mm	5–15	<8	<8
Global longitudinal strain, %	14–20	<14	<14
Stroke volume index, ml/m^2	>35	<35	<35
Mean flow rate, ml/s	>200	<200	<200
Myocardial fibrosis	+	++	+++
CT valve calcium score, AU	>1,650	>1,650	>1,650
Plasma NT-proBNP, pg/ml	<1,500	>1,500	>1,500

Take Home Message

- Be meticulous in assessing AS severity (10 pitfalls)
- “Correct answer” derived from wrong steps is still invalid
- Integrated approach, additional imaging modalities
- Look at the patient, no just the numbers
- “Dichotomous” cutoff value in guideline – apply with caution

Heart Team / Cardiac Team

Have someone trained in Advanced Imaging in your team