Diagnosis and Physiologic Understanding of Low Gradient Severe AS

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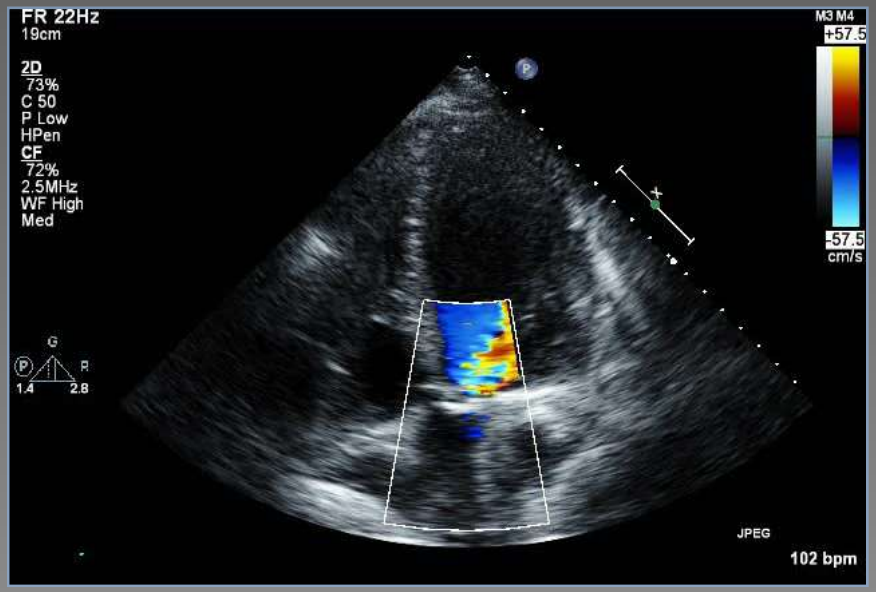
Two Indices of Quantification in Valvular Stenosis

Degree of Overloading	Lesion Severity
Pressure gradient	**Valve area**
Doppler equation: $\Delta P = 4V^2$	**Direct planimetry, PHT method, Continuity equation**
Invasive catheterization	**Gorlin method**

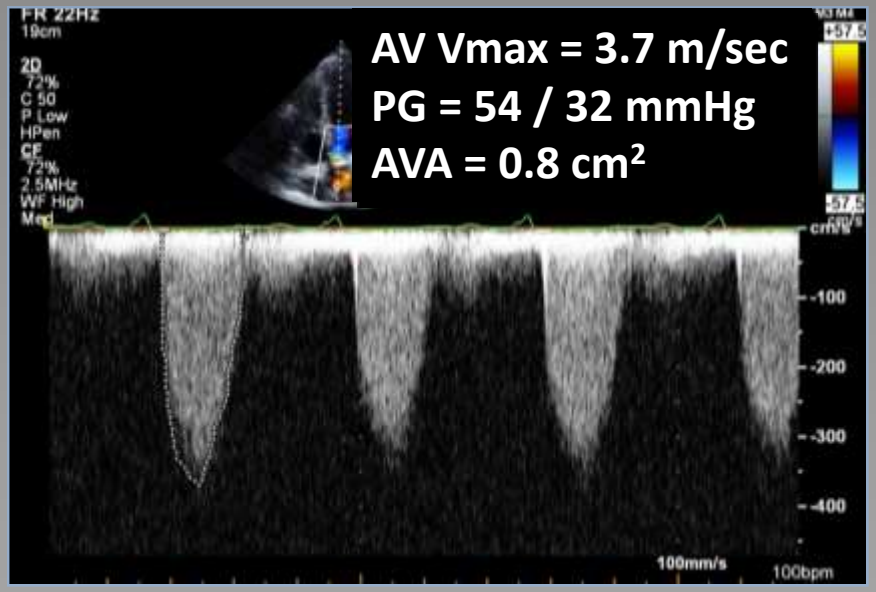
Current Definition of Tight AS

Guidelines/ recommendations	Parameter
AHA/ACC	AVA <1.0 cm^2
ESC	AVA/BSA <0.6 cm^2
Otto	Vmax >4.0 m/s
AHA/ACC	ΔPm >40 mmHg


FR 39Hz
16cm
2D
64%
C 50
P Low
HPen
M3
JPEG
106 bpm

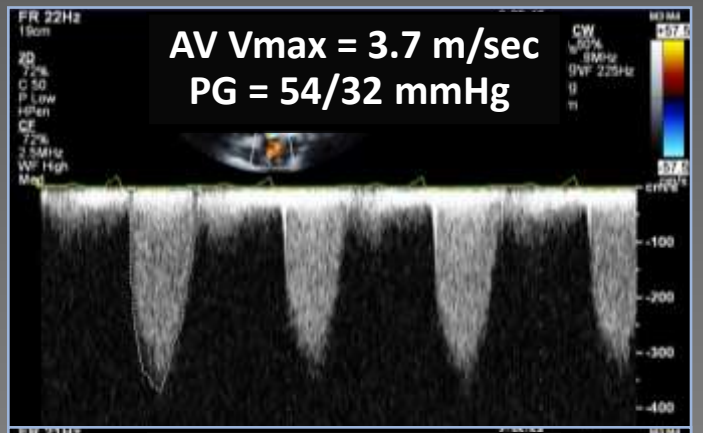

FR 22Hz
19cm
2D
73%
C 50
P Low
HPen
CF
72%
2.5MHz
WF High
Med
M3 M4
+57.5
-57.5
cm/s
JPEG
102 bpm

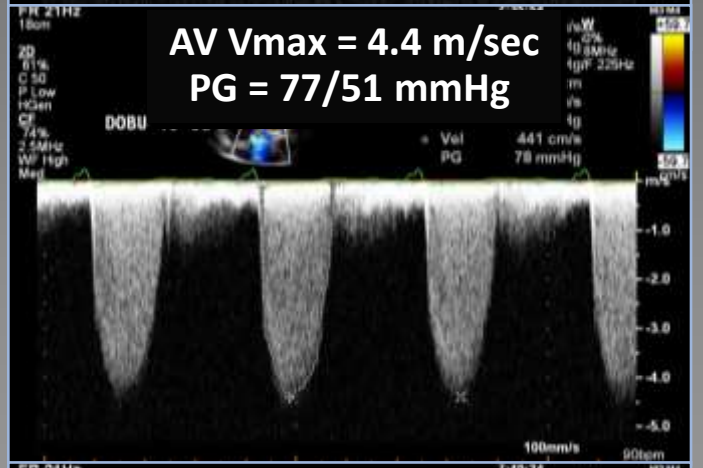

FR 39Hz
12cm
2D
64%
C 50
P Low
HPen
M3
JPEG
94 bpm

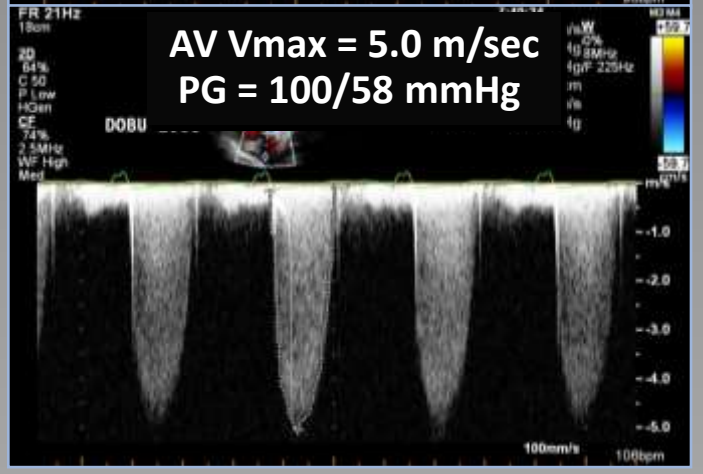

FR 22Hz
19cm
2D
72%
C 50
P Low
HPen
CF
72%
2.5MHz
WF High
Med
AV Vmax = 3.7 m/sec
PG = 54 / 32 mmHg
AVA = 0.8 cm²
cm/s
-100
-200
-300
-400
100mm/s
100bpm

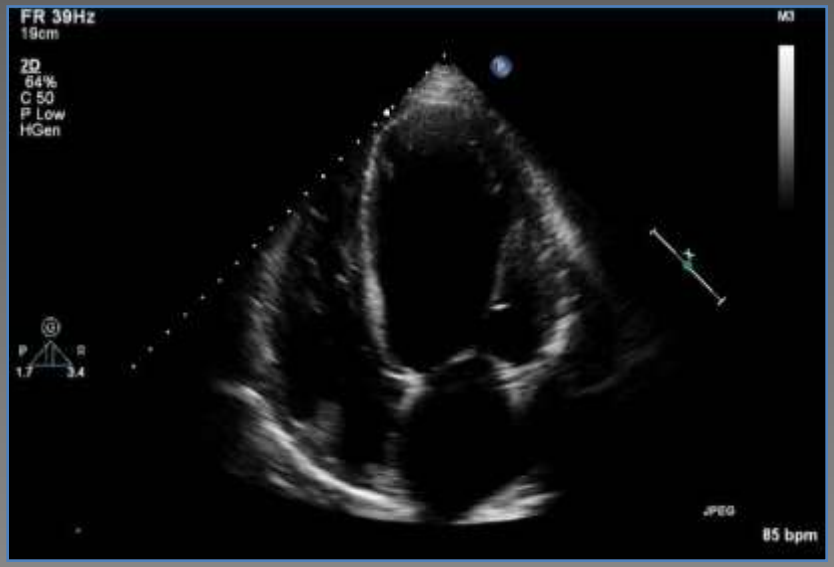

DOBU 10 UG


DOBU 20UG
115 bpm

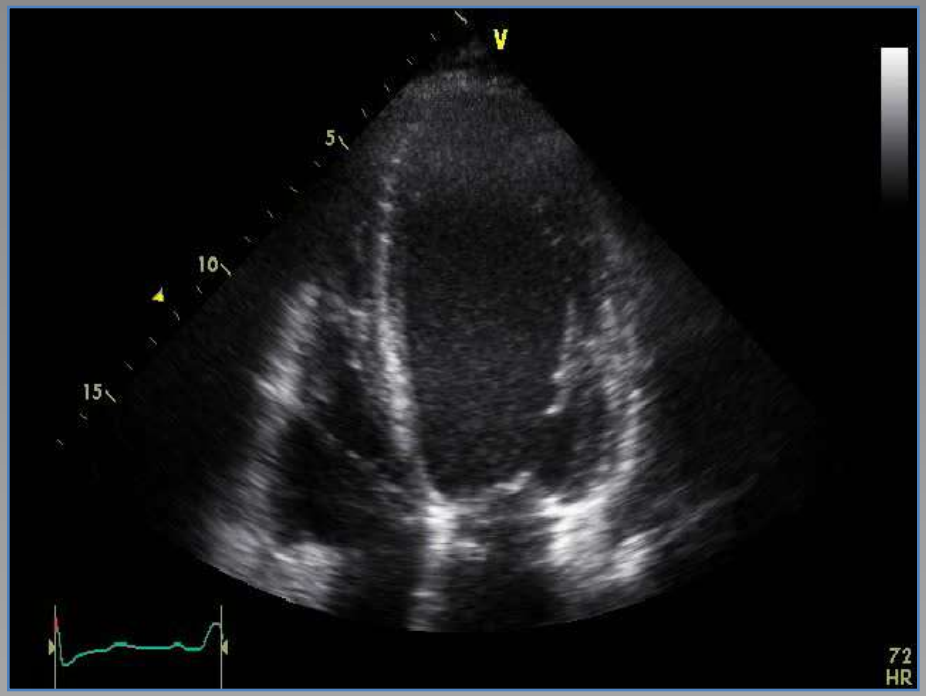

AV Vmax = 3.7 m/sec
PG = 54/32 mmHg


AV Vmax = 4.4 m/sec
PG = 77/51 mmHg
DOBU

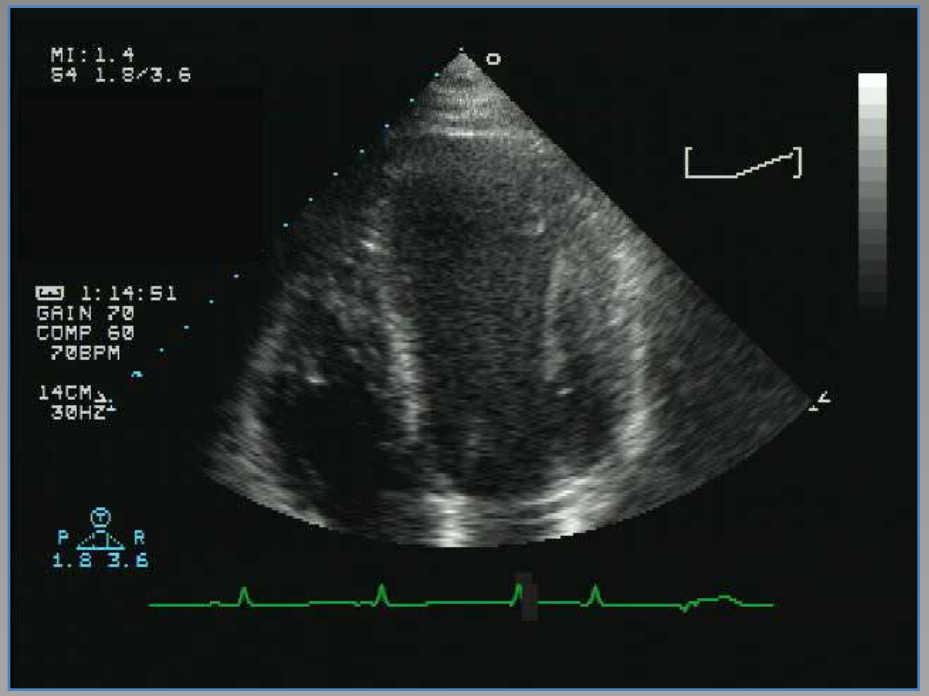

AV Vmax = 5.0 m/sec
PG = 100/58 mmHg
DOBU

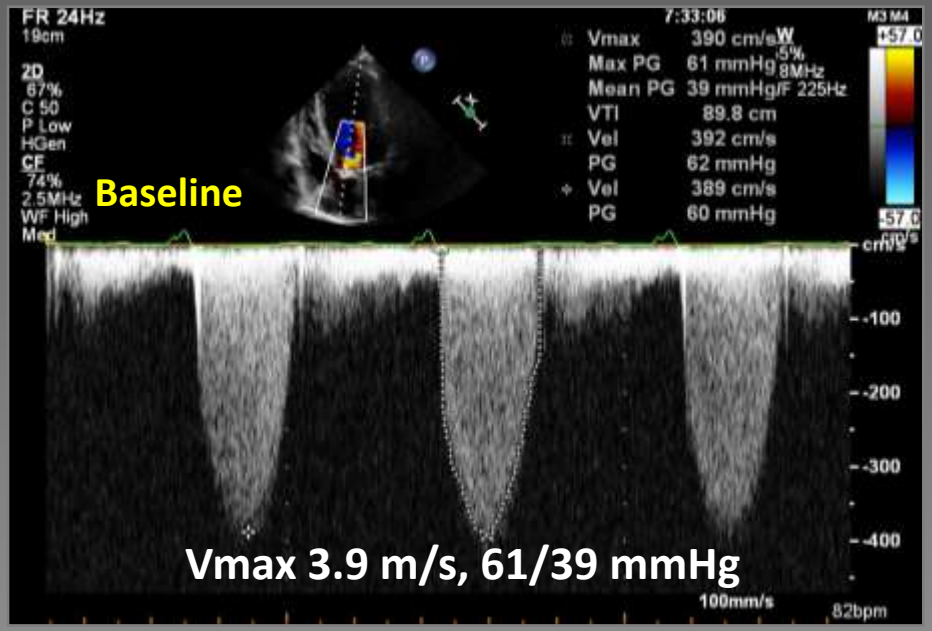


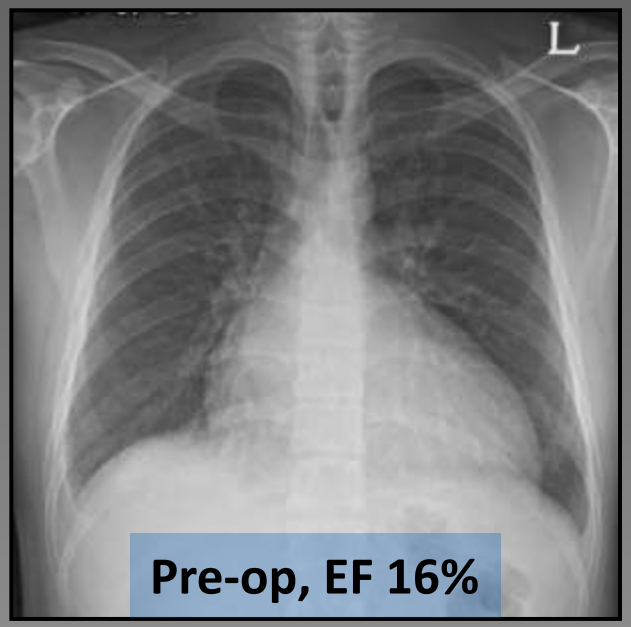
Immediate Post-op

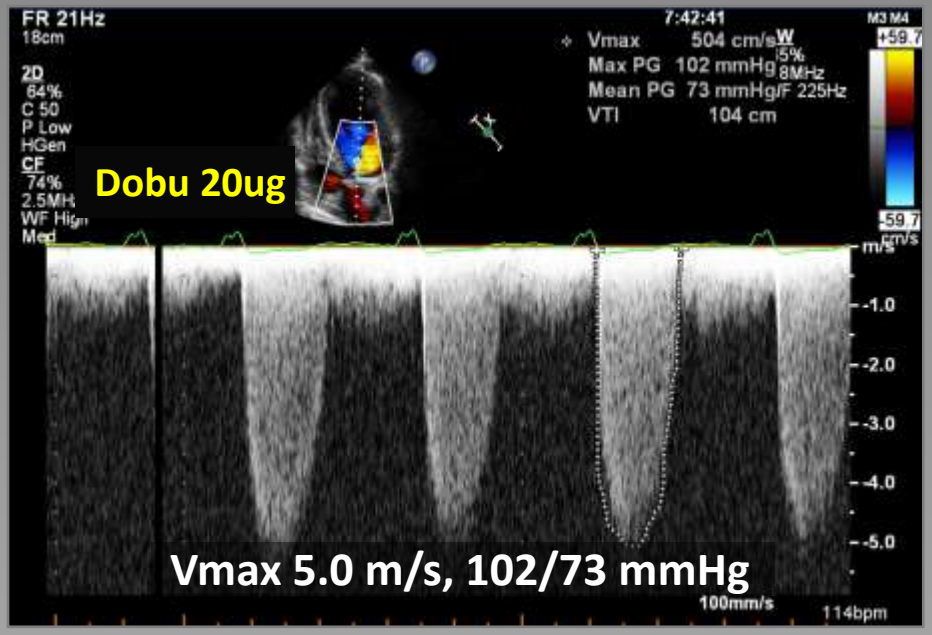


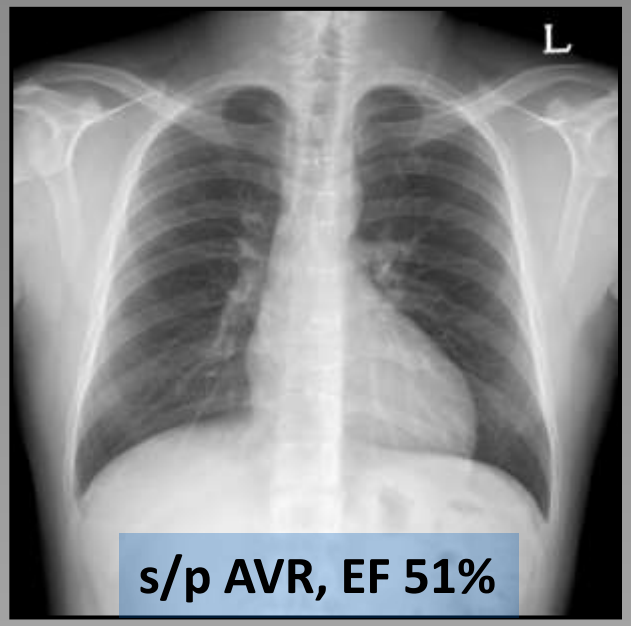
5 Mo later




FR 24Hz
19cm
2D
67%
C 50
P Low
HGen
CF
74%
2.5MHz
WF High
Med
Baseline
7:33:06
Vmax 390 cm/s
Max PG 61 mmHg
Mean PG 39 mmHg
VTI 89.8 cm
Vel 392 cm/s
PG 62 mmHg
Vel 389 cm/s
PG 60 mmHg
M3 M4
-100
-200
-300
-400
Vmax 3.9 m/s, 61/39 mmHg
100mm/s
82bpm


L
Pre-op, EF 16%


FR 21Hz
18cm
2D
64%
C 50
P Low
HGen
CF
74%
Dobu 20ug
7:42:41
Vmax 504 cm/s
Max PG 102 mmHg
Mean PG 73 mmHg
VTI 104 cm
M3 M4
-1.0
-2.0
-3.0
-4.0
-5.0
Vmax 5.0 m/s, 102/73 mmHg
100mm/s
114bpm


L
s/p AVR, EF 51%

European Heart Journal (2008) **29**, 1043–1048
doi:10.1093/eurheartj/ehm543

Inconsistencies of echocardiographic criteria for the grading of aortic valve stenosis

- 3,487 echo studies for AS with normal LV systolic function

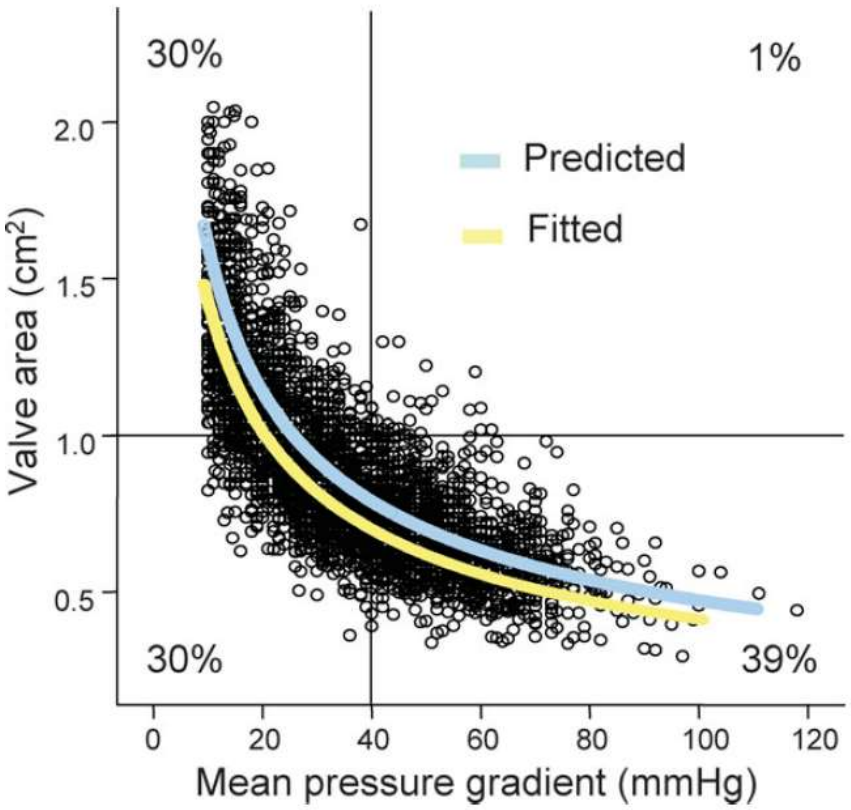
Percentage of pts diagnosed with severe AS depending on which echocardiographic criterion was used

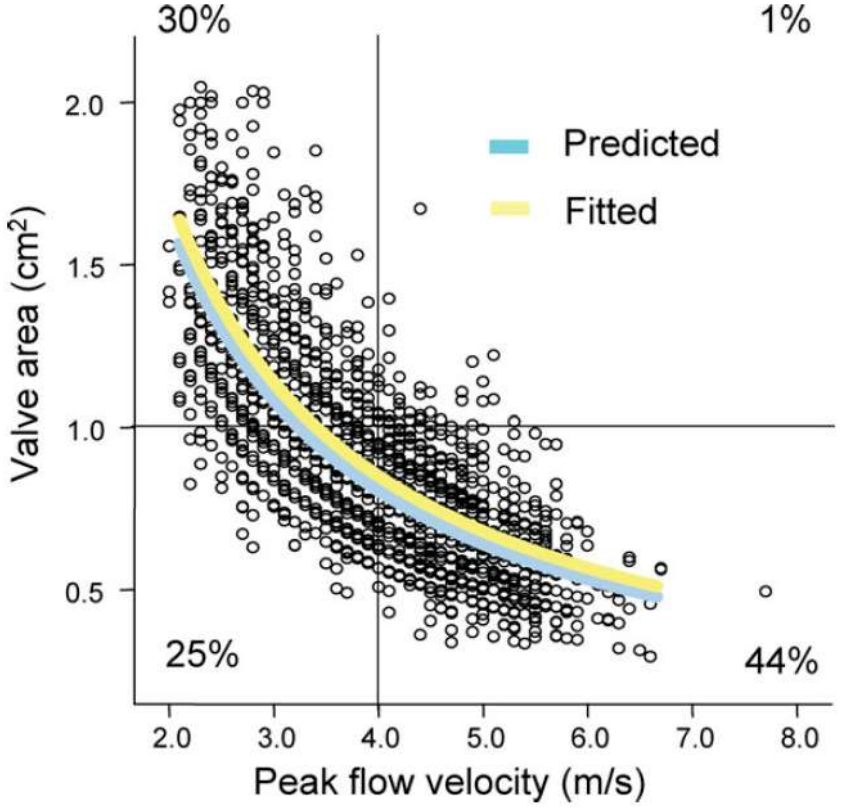
Guidelines/ recommendations	Parameter	Patients with severe stenosis
AHA/ACC	AVA <1.0 cm^2	69%
ESC	AVA/BSA <0.6 cm^2	76%
Otto	Vmax >4.0 m/s	45%
AHA/ACC	ΔPm >40 mmHg	40%

European Heart Journal (2008) **29**, 1043–1048
doi:10.1093/eurheartj/ehm543

Inconsistencies of echocardiographic criteria for the grading of aortic valve stenosis

- 3,487 echo studies for AS with normal LV systolic function





European Heart Journal (2008) **29**, 1043–1048
doi:10.1093/eurheartj/ehm543

Inconsistencies of echocardiographic criteria for the grading of aortic valve stenosis

- 3,487 echo studies for AS with normal LV systolic function

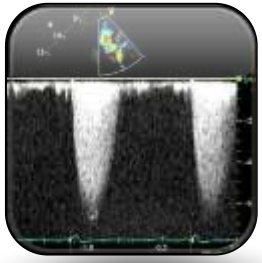
AVA (cm^2)	Mean gradient (mmHg)
4	1.7
3	2.9
2	6.6
1	26
0.9	32
0.8	41
0.7	53
0.6	73
0.5	105

- *Curve fitting for the relationship between AVA and PG using Gorlin equation*
- AVA 1.0 cm^2: PG = 21mmHg
  Vmax = 3.3m/s
- PG 40mmHg: AVA = 0.75cm^2
- Vmax 4m/s: AVA = 0.82cm^2

$$\text{AVA(Gorlin formula)} = \frac{\text{CO} \div (\text{SEP} \times \text{HR})}{44.3\sqrt{\text{mean gradient}}}$$

How to Overcome Inconsistency?

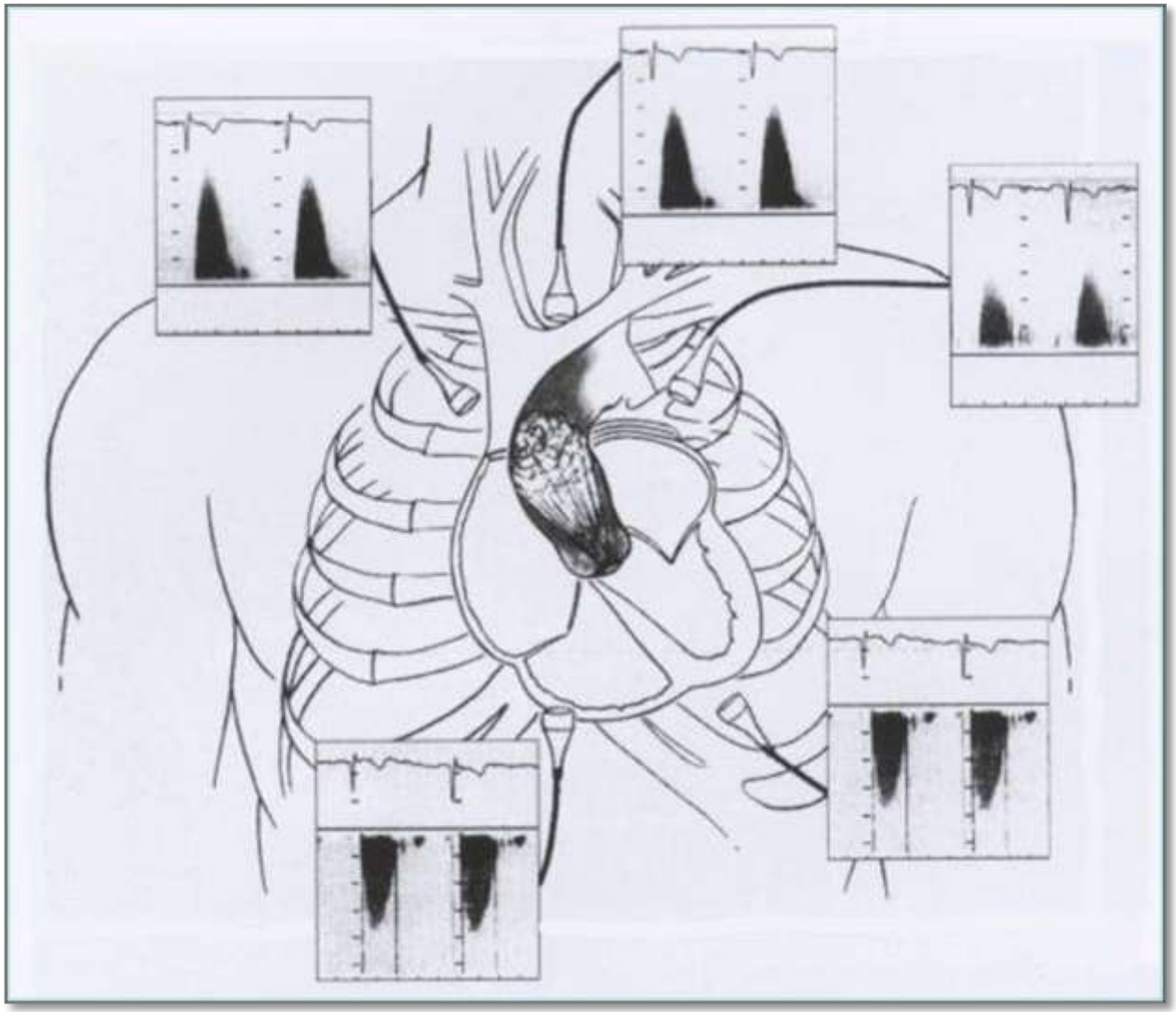
Validation of your numbers

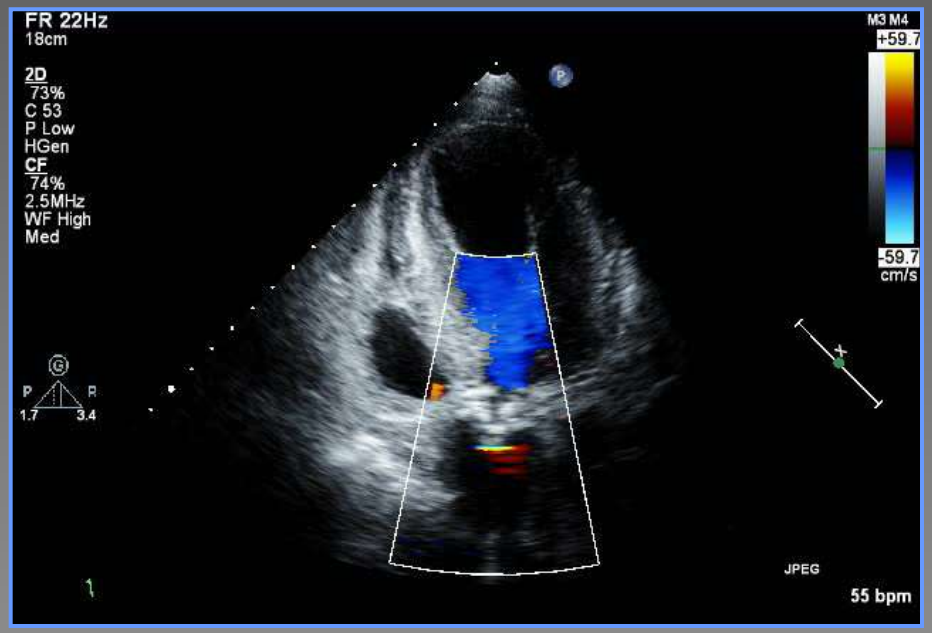


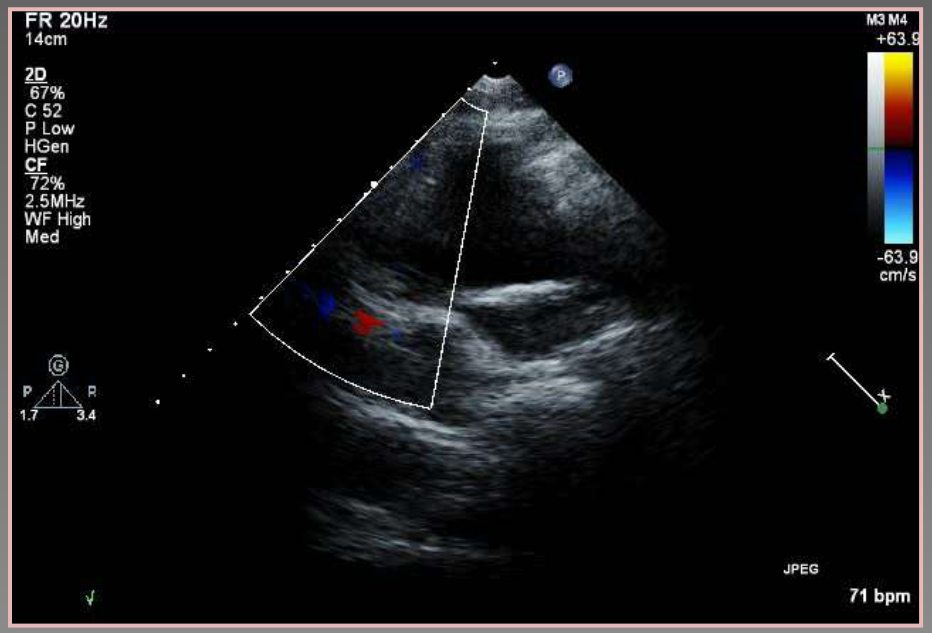
Pressure recovery

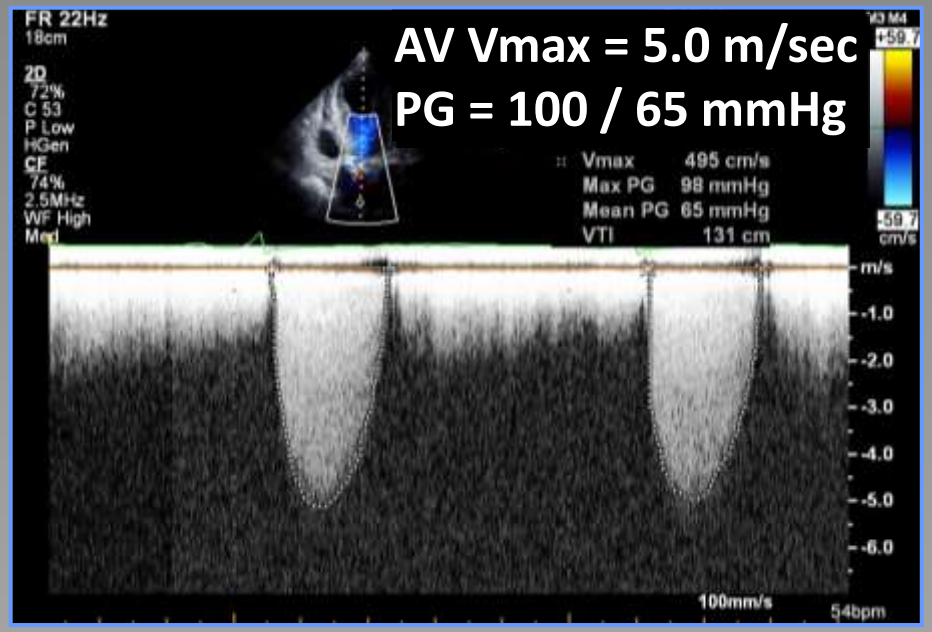
AS as a systemic disease

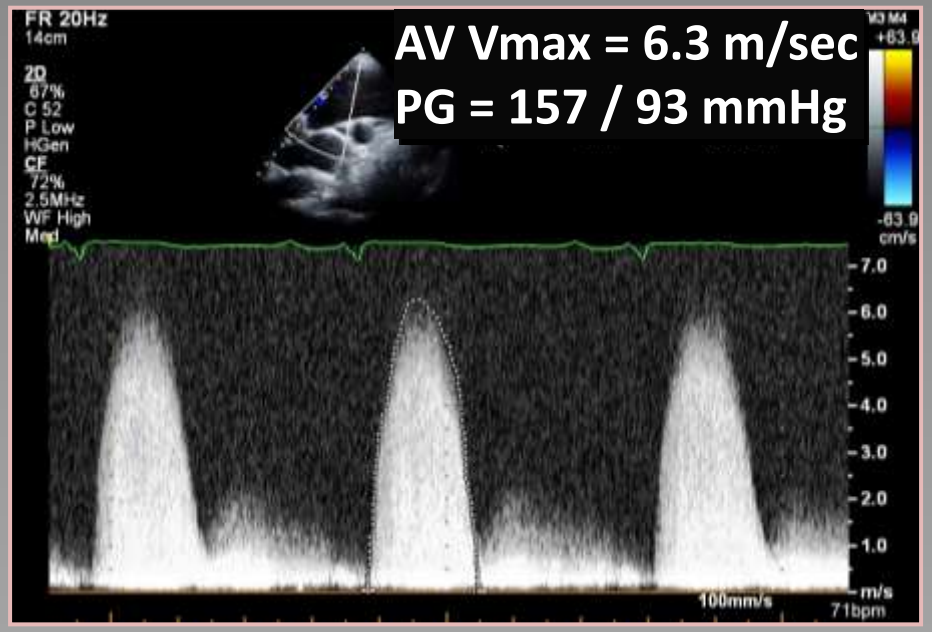
Pitfalls of PG in AS

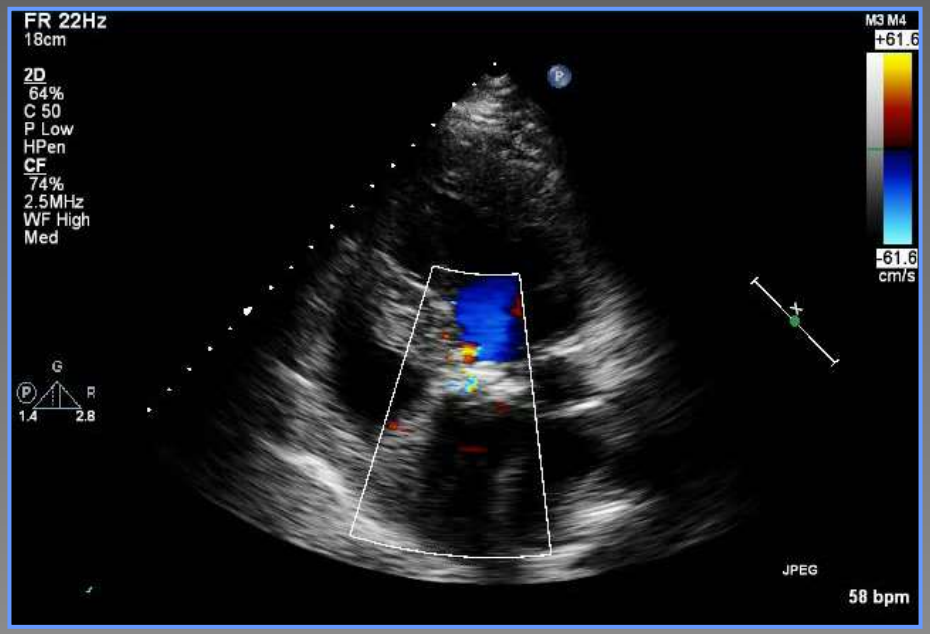


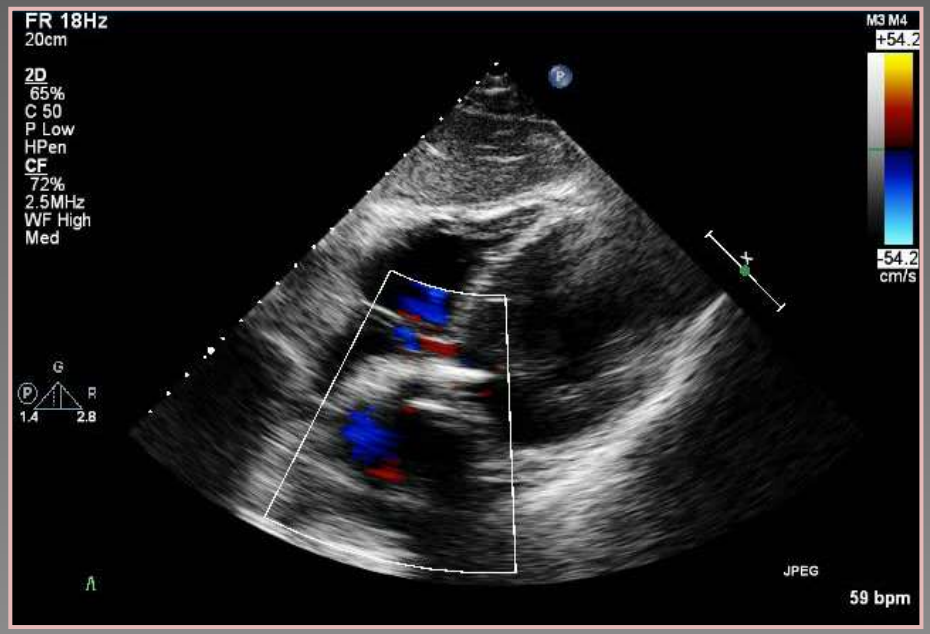

FR 22Hz
18cm
2D
73%
C 53
P Low
HGen
CF
74%
2.5MHz
WF High
Med
M3 M4
+59.7
-59.7
cm/s
JPEG
55 bpm

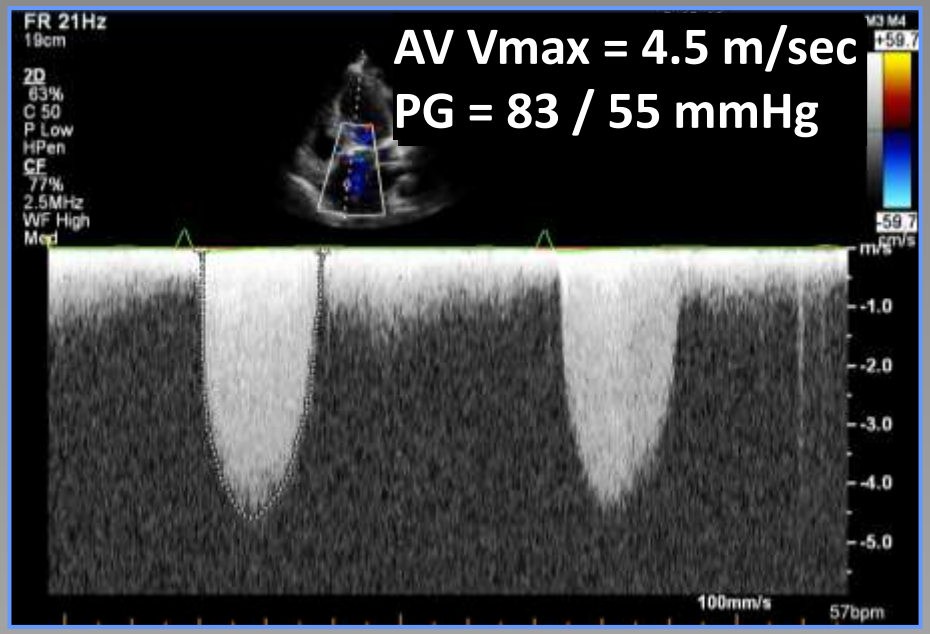

FR 20Hz
14cm
2D
67%
C 52
P Low
HGen
CF
72%
2.5MHz
WF High
Med
M3 M4
+63.9
-63.9
cm/s
JPEG
71 bpm

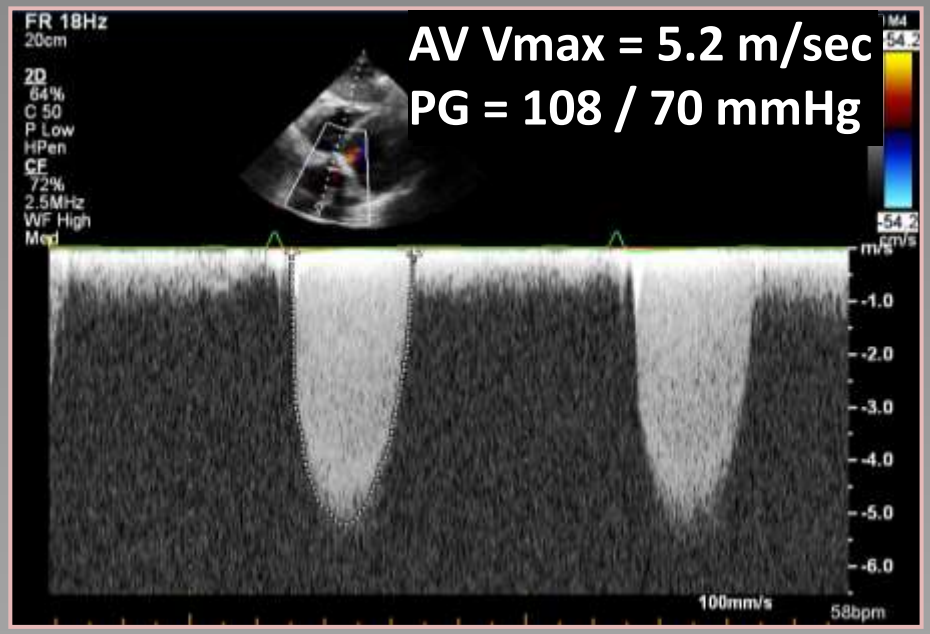

AV Vmax = 5.0 m/sec
PG = 100 / 65 mmHg
Vmax 495 cm/s
Max PG 98 mmHg
Mean PG 65 mmHg
VTI 131 cm
m/s
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
100mm/s
54bpm


AV Vmax = 6.3 m/sec
PG = 157 / 93 mmHg
7.0
6.0
5.0
4.0
3.0
2.0
1.0
m/s
100mm/s
71bpm


FR 22Hz
18cm
2D
64%
C 50
P Low
HPen
CF
74%
2.5MHz
WF High
Med
M3 M4
+61.6
-61.6
cm/s
JPEG
58 bpm

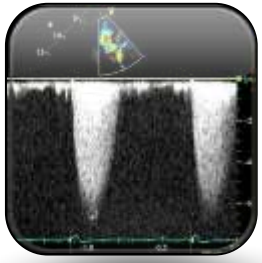

FR 18Hz
20cm
2D
65%
C 50
P Low
HPen
CF
72%
2.5MHz
WF High
Med
M3 M4
+54.2
-54.2
cm/s
JPEG
59 bpm


FR 21Hz
19cm
2D
63%
C 50
P Low
HPen
CF
77%
2.5MHz
WF High
Med
AV Vmax = 4.5 m/sec
PG = 83 / 55 mmHg
m/s
-1.0
-2.0
-3.0
-4.0
-5.0
100mm/s
57bpm


FR 18Hz
20cm
2D
64%
C 50
P Low
HPen
CF
72%
2.5MHz
WF High
Med
AV Vmax = 5.2 m/sec
PG = 108 / 70 mmHg
m/s
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
100mm/s
58bpm

How to Overcome Inconsistency?

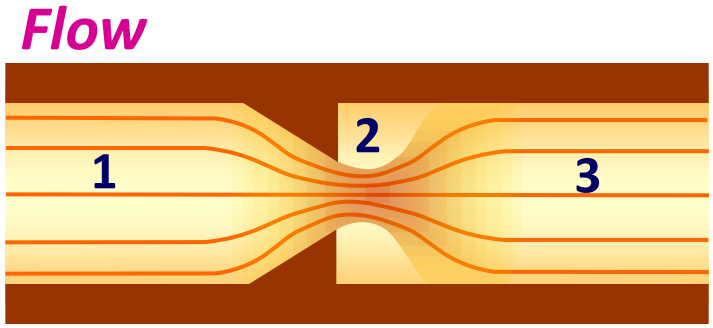
Validation of your numbers

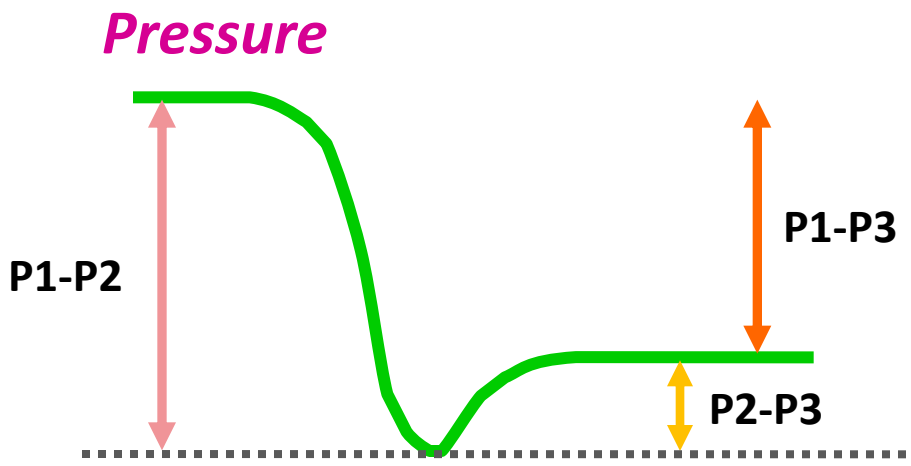


Pressure recovery

AS as a systemic disease

Pressure Recovery (1)





1. Proximal convergence

2. Vena contracta distal to the limiting orifice:

   - Contraction coefficient

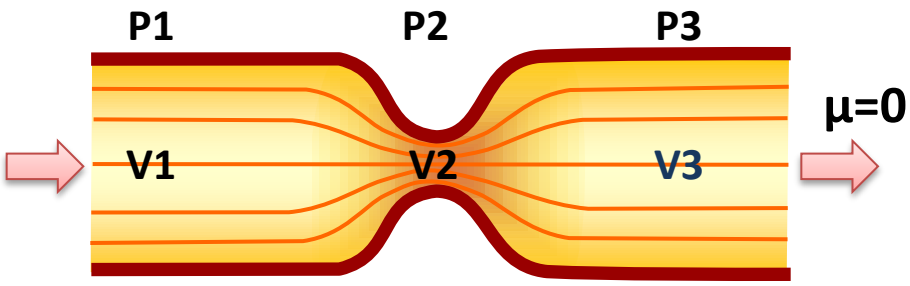
$$= \frac{\text{effective area}}{\text{anatomic area}}$$

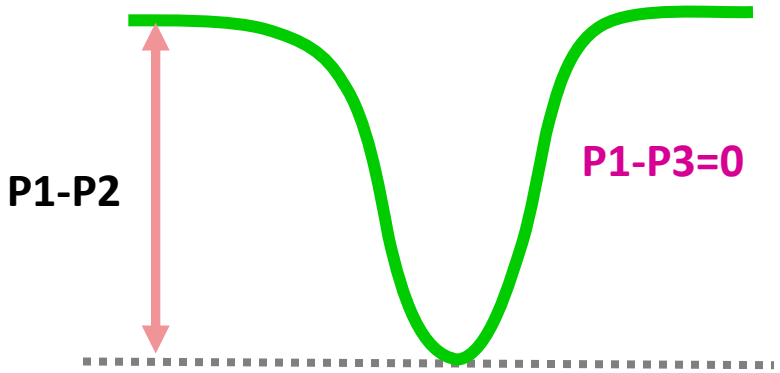
3. Distal expansion: pressure recovery (P2-P3)

P1-P2 = PG by Doppler

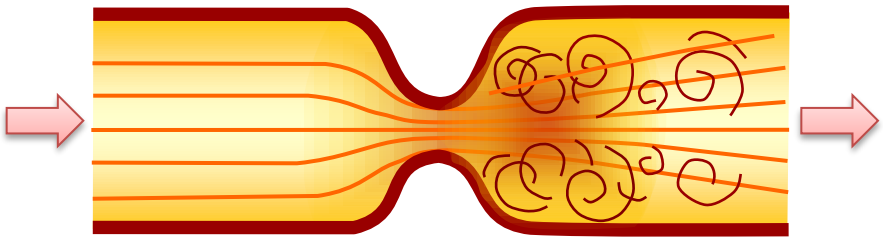
P1-P3 = PG by Cath

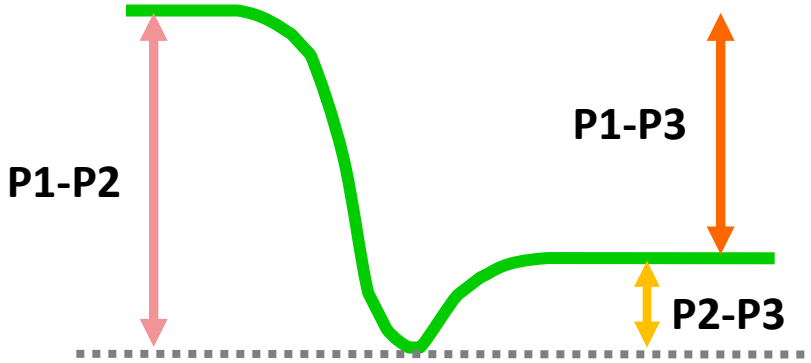
Pressure Recovery



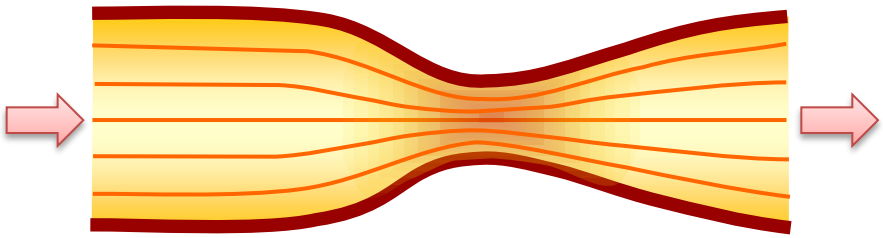


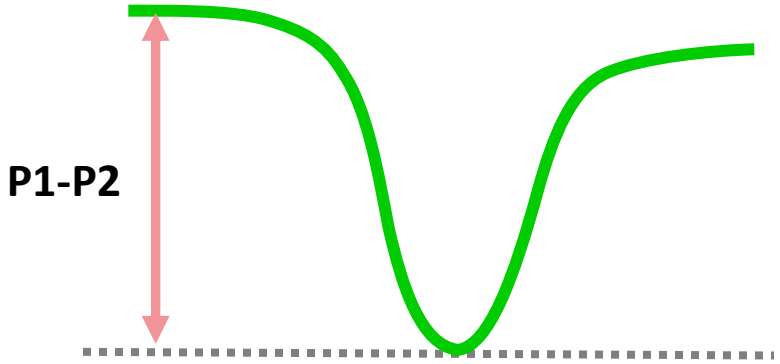
Viscous Losses



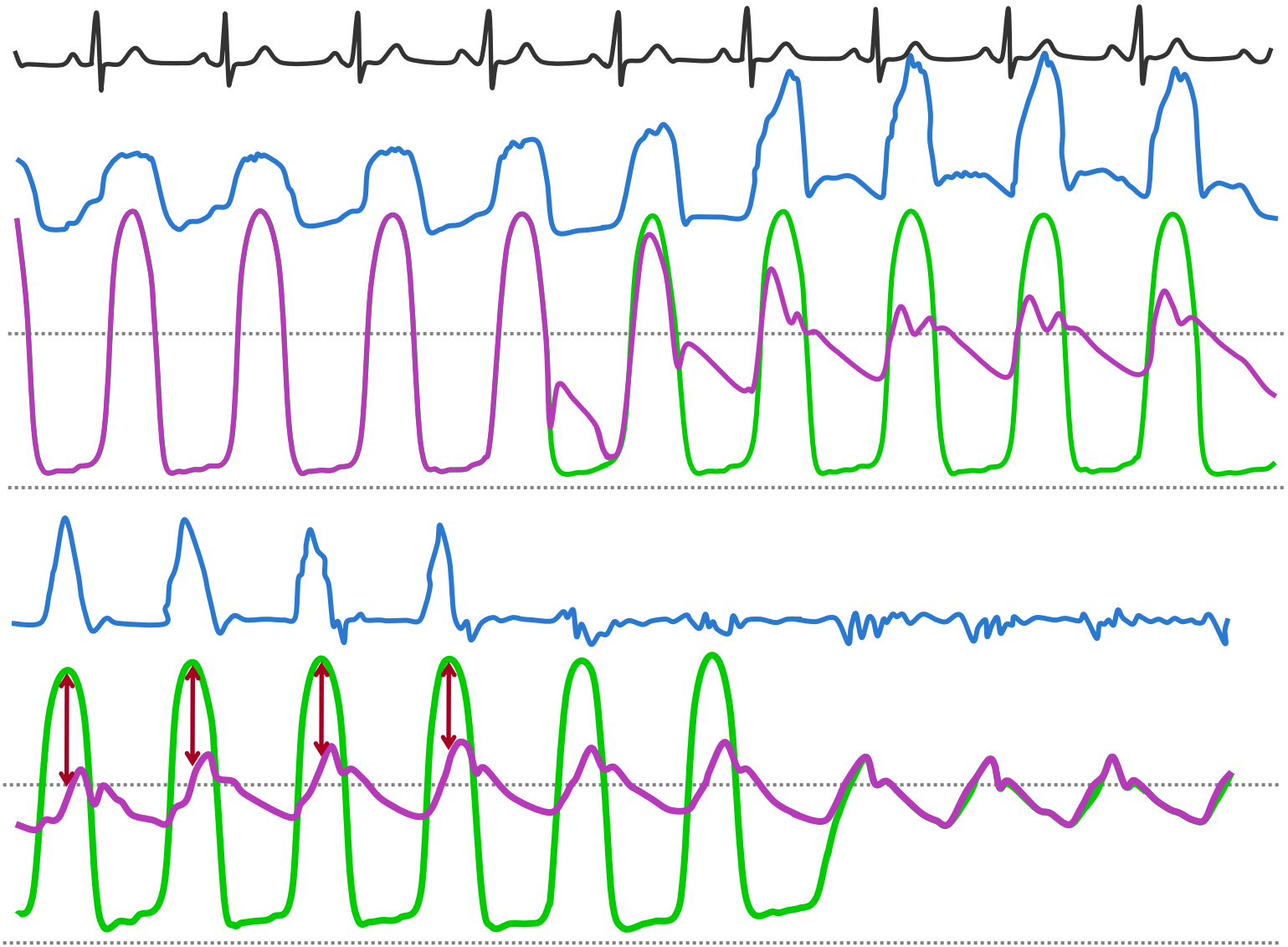


Streamlining





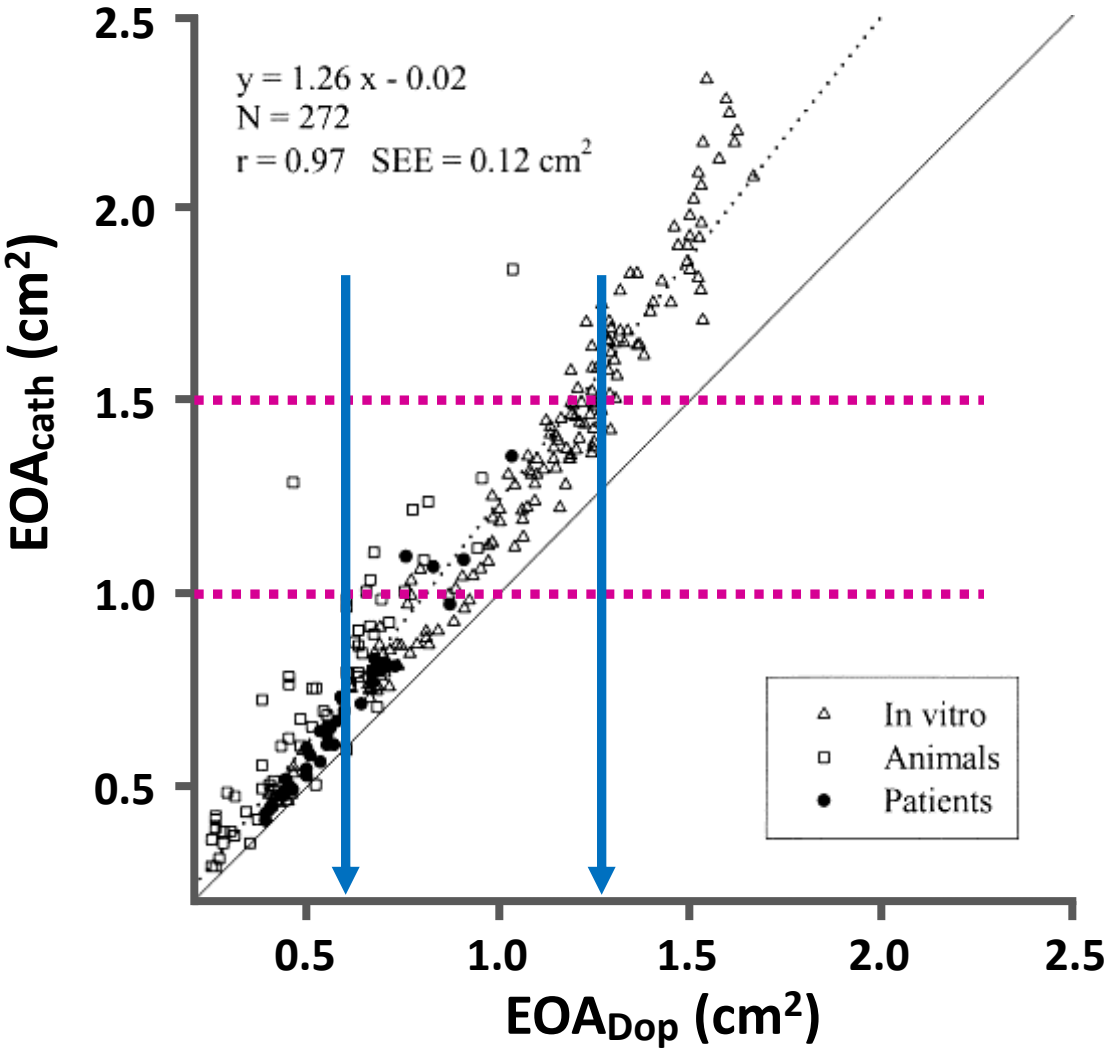
Pressure Recovery in Human



Circ 1994;89:116

Catheterization vs. Doppler

Misclassification Toward Higher Degrees



JACC 2003;41:435

Pressure Recovery (2)

- Real physical phenomenon
- Reduce the work load on the LV, which is proportional to the net pressure head loss x flow rate
- Should be predictable

$$P3 - P2 = 4Vmax^2 \times \frac{2 \times AVA}{AoA} \times \frac{AoA - AVA}{AoA}$$

AVA = effective orifice area (Doppler)
AoA = area of the ascending aorta

J Biomechanics 1976;9:521
J Biomechanics 1976;9:567

Pressure Recovery (3)

- Correction using “energy loss coefficient”

  Doppler EOA x AoA / (AoA-EOA)

- The need for correction occurs primarily in patients with mild to moderate AS and smaller aorta

  (EOA > 0.8 cm^2 & aortic diameter < 3.0 cm)

EOA = 0.9 cm^2	**Aortic diameter**	**EOA by cath**
	2.6 cm	**1.1 cm^2**
	4.0 cm	**0.9 cm^2**

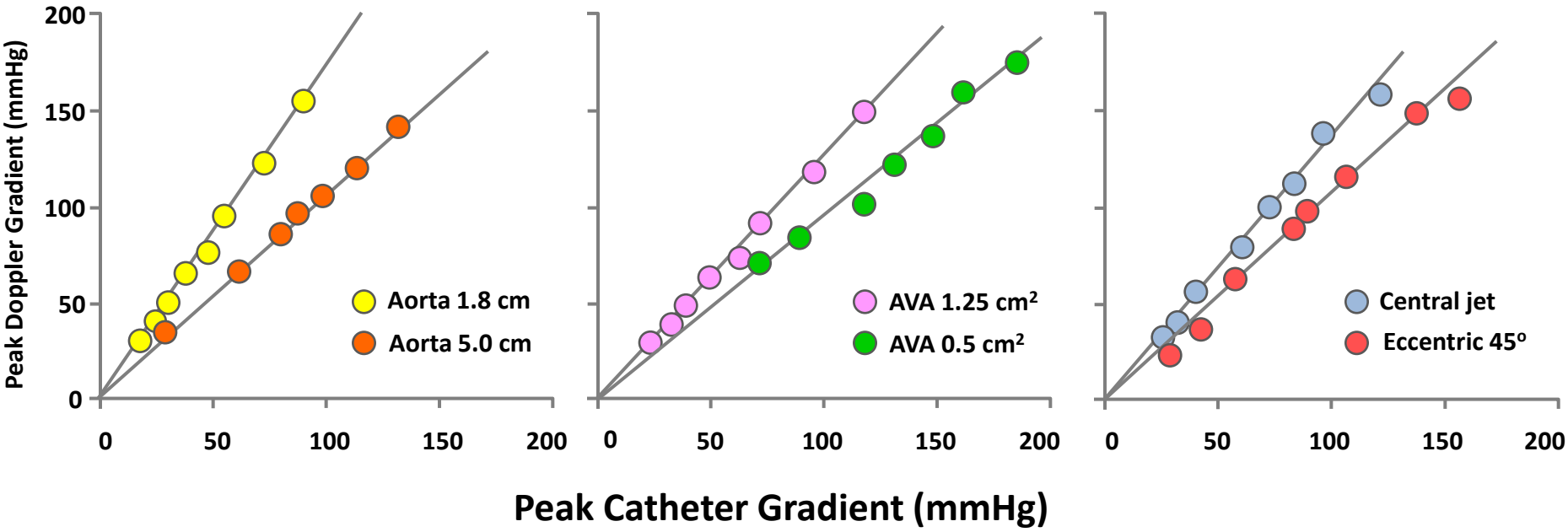
- Different definition of tight AS: 0.75 vs. 1.0 cm^2

JACC 2003;41:435
JACC 2003;41:443

Pressure Recovery (4)

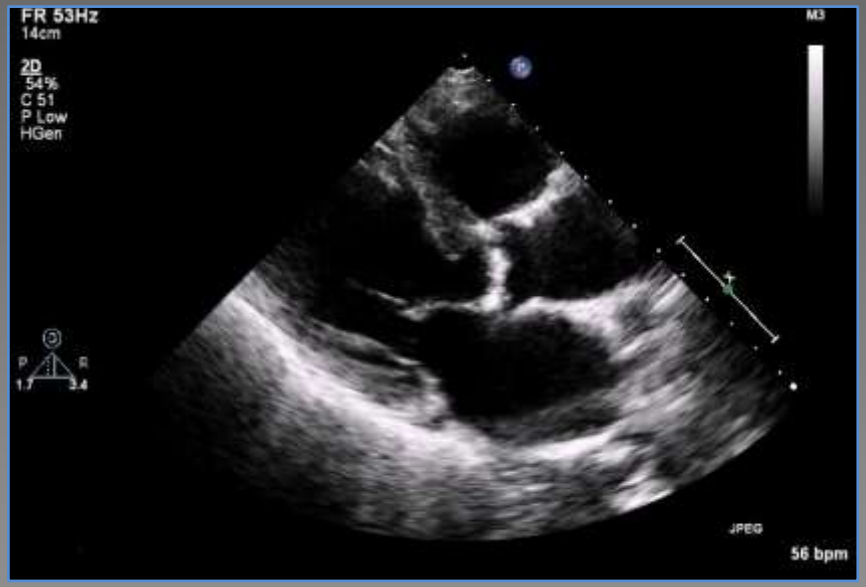
3 geometric variables of the stenosis and the receiving compartment determining the degree of PR

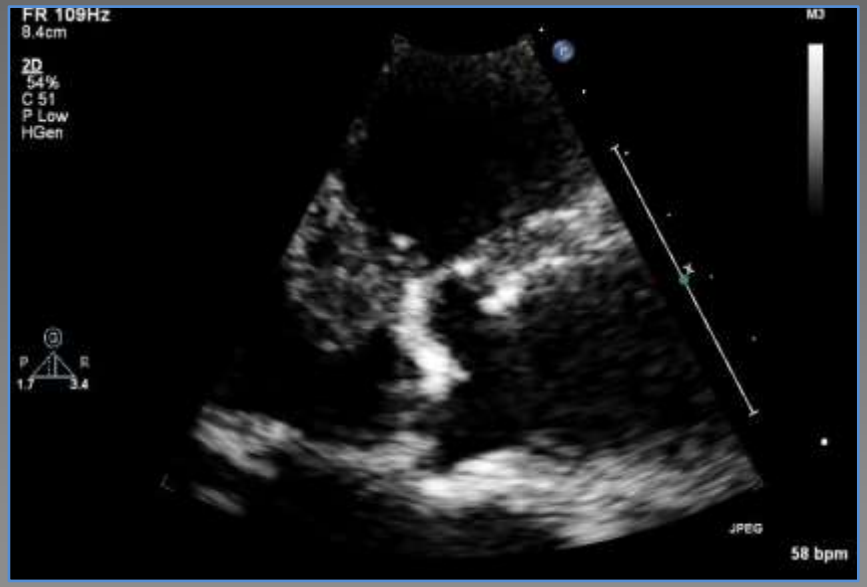
- ✓ Aorta size
- ✓ Aortic valve area
- ✓ Direction of stenotic jet (eccentric vs. central)

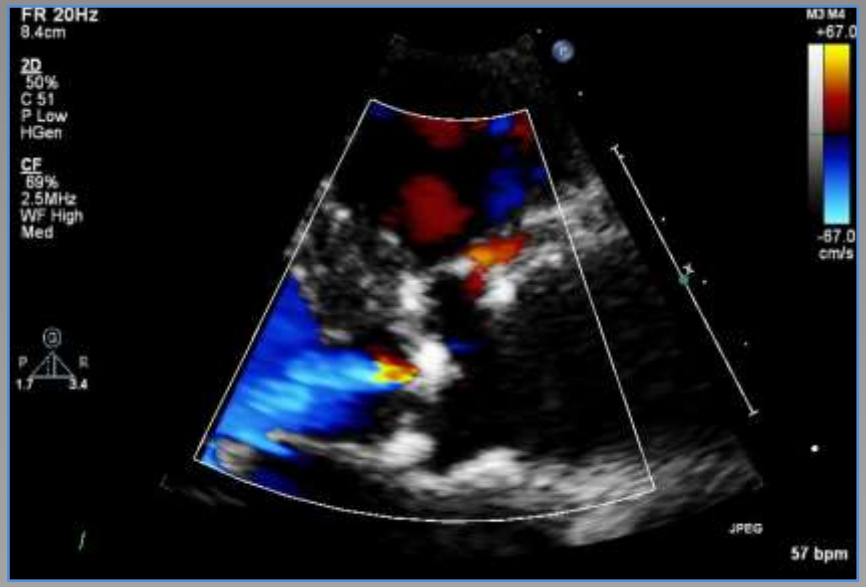


Circ 1996;94:1934

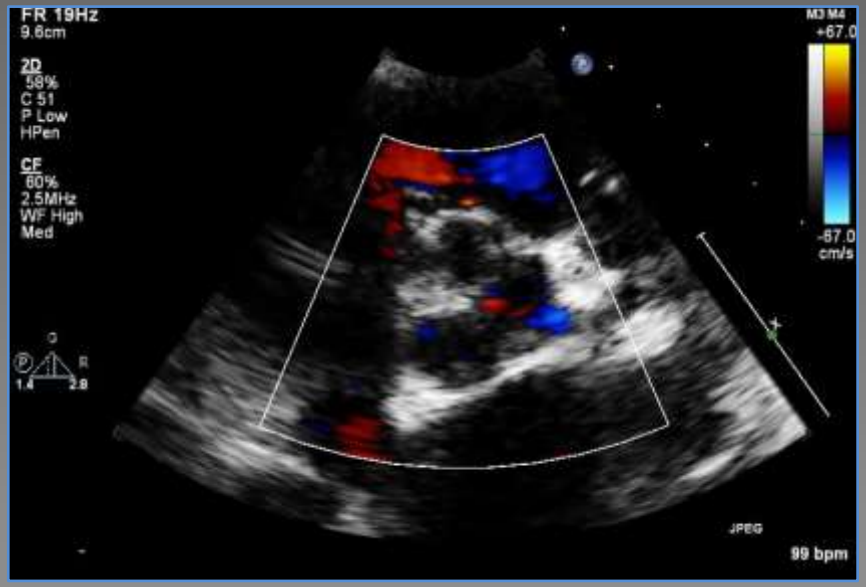
Pressure Recovery: “energy loss coefficient”

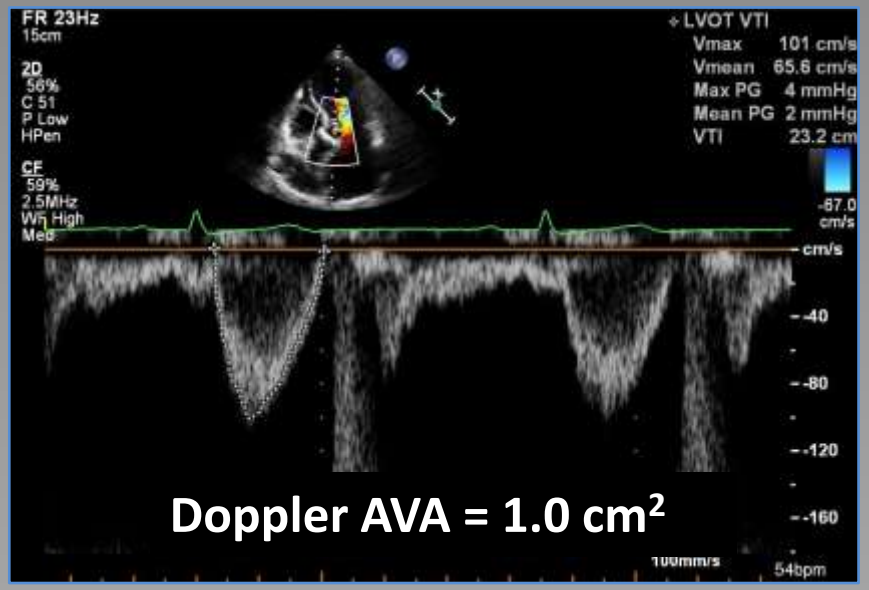




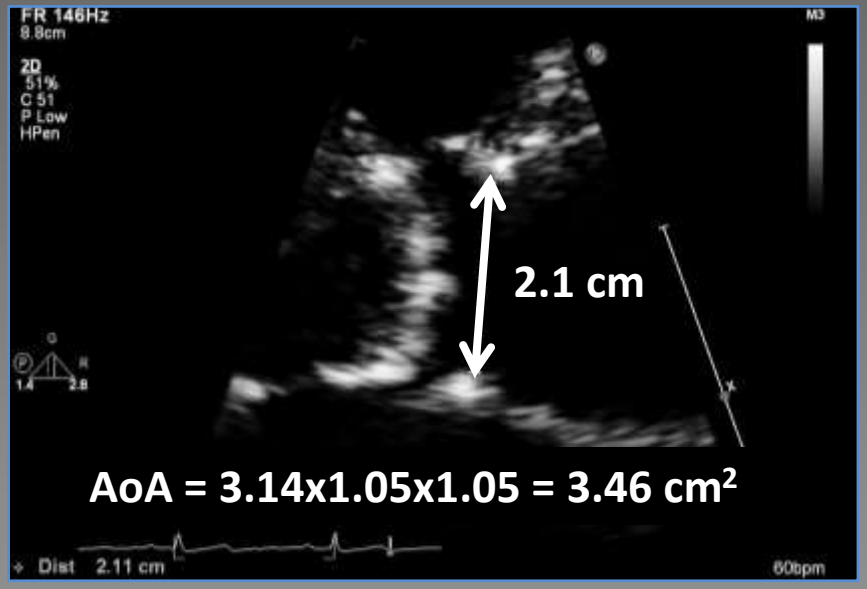


Pressure Recovery: “energy loss coefficient”





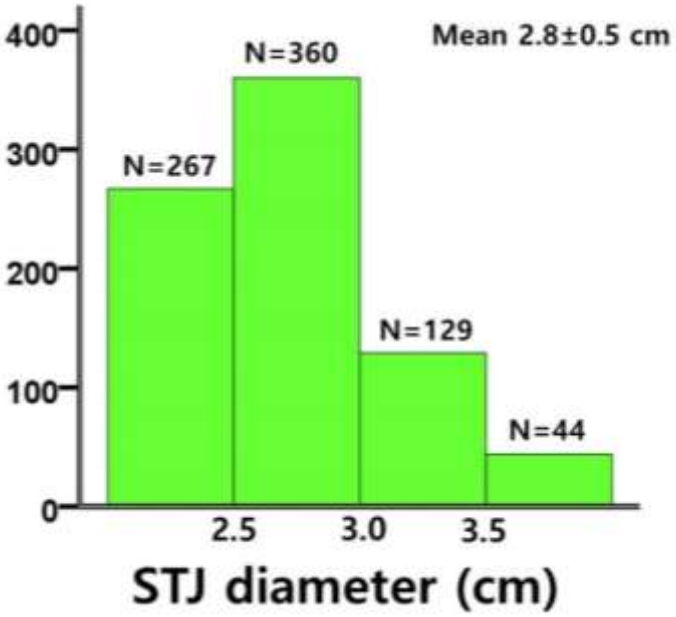
Pressure Recovery: “energy loss coefficient”

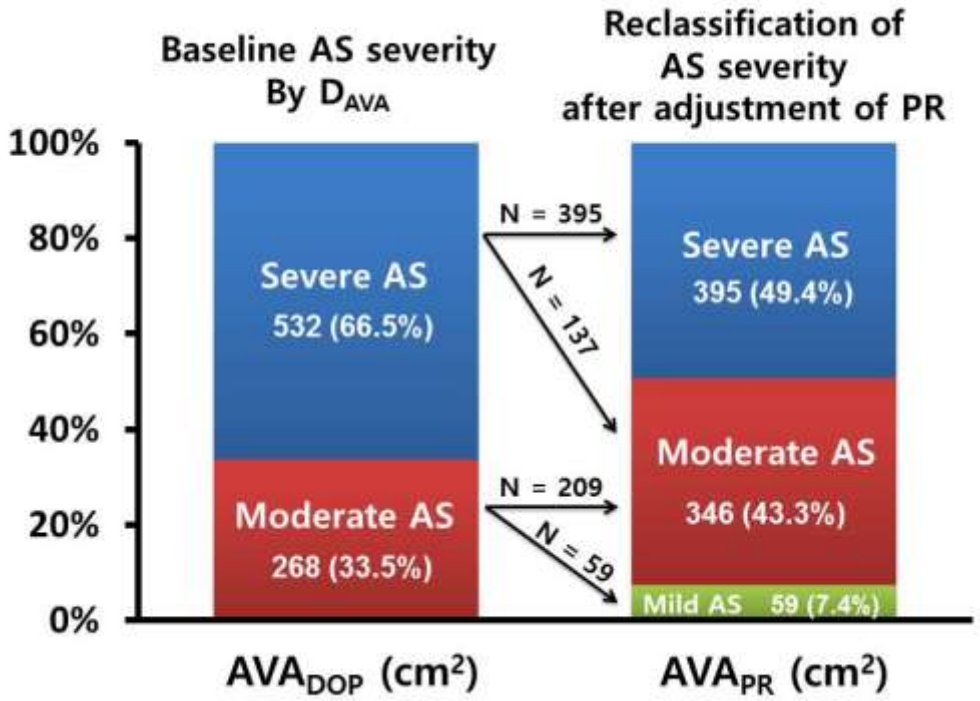


- Correction using “energy loss coefficient”

  Doppler EOA x AoA / (AoA-EOA)
  = 1.0 x 3.46/(3.46-1.0)
  = 1.4 cm^2

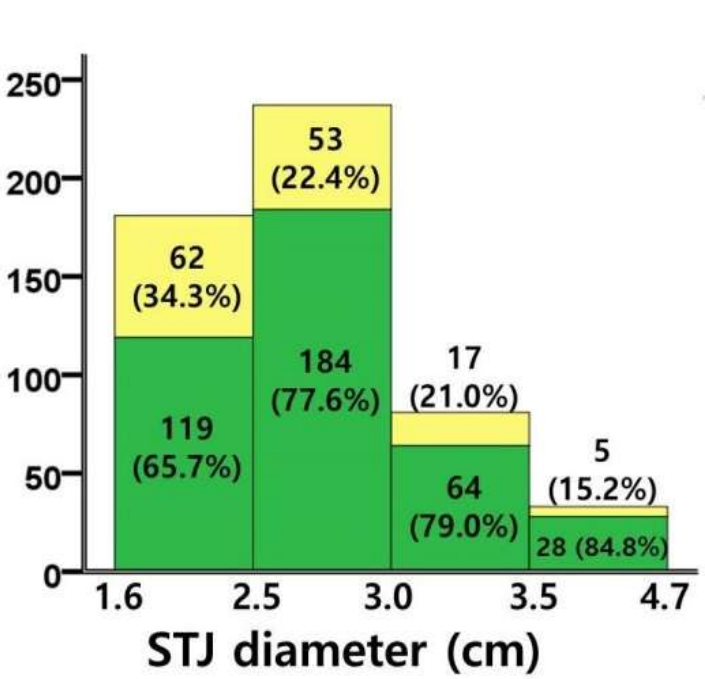
Pressure Recovery: "energy loss coefficient"

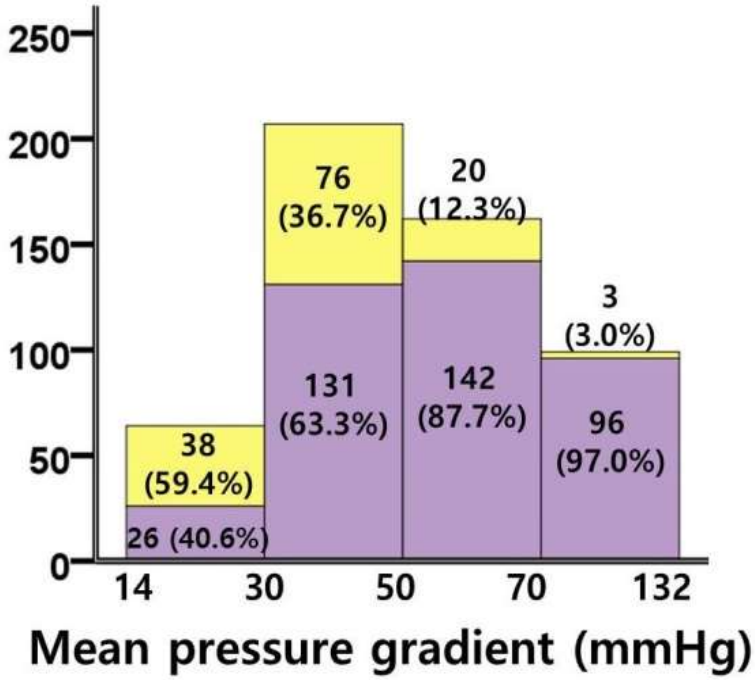




Asian Valve Registry Data

Pressure Recovery: "energy loss coefficient"



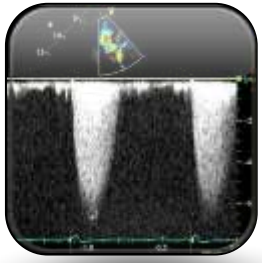


Frequency of Reclassification from Severe to Moderate AS
According to STJ Diameter and Mean PG

Asian Valve Registry Data

How to Overcome Inconsistency?

Validation of your numbers

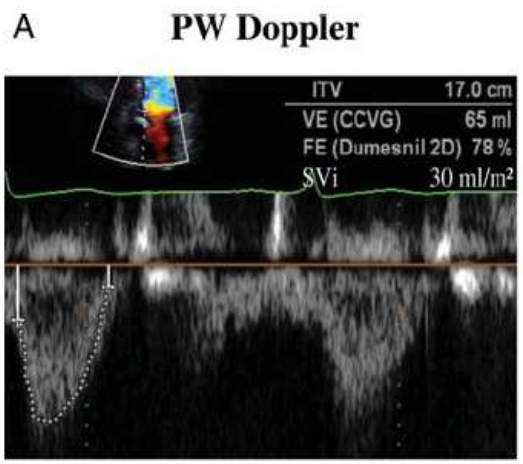


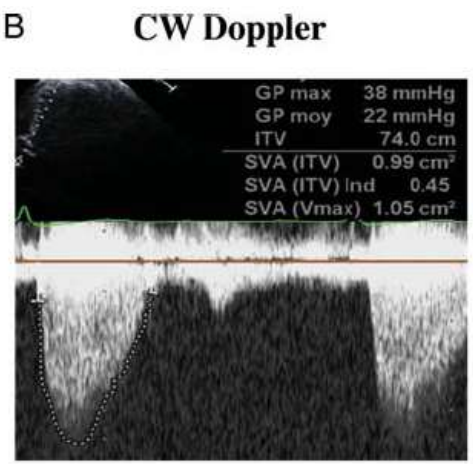
Pressure recovery

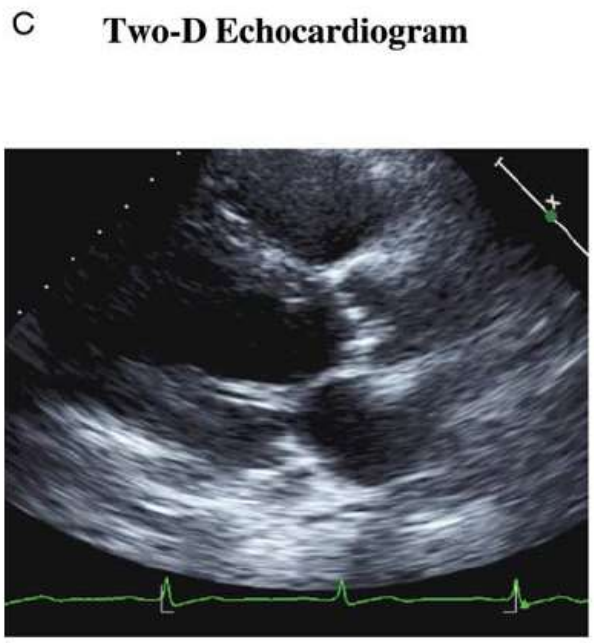
AS as a systemic disease

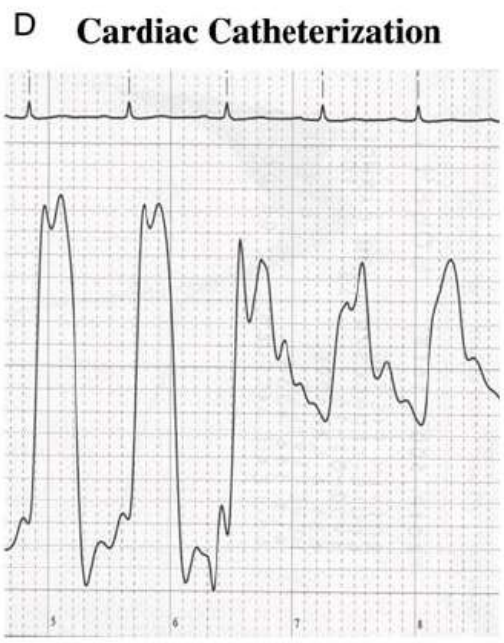
Paradoxical Low Flow Low Gradient AS

- 57/male
- classic angina
- calcified Ao valve
- LVH with small cavity volume
- Mean gradient = 22 mmHg
- AVA = 1.0 cm2
- BP 150/76 mmHg
- LV systolic p = 175 mmHg

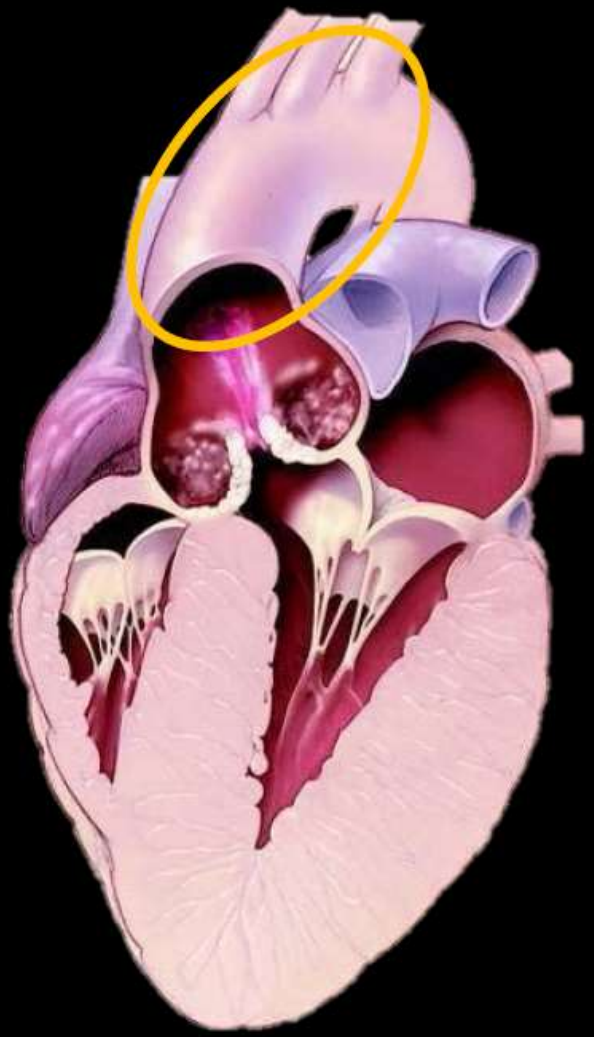






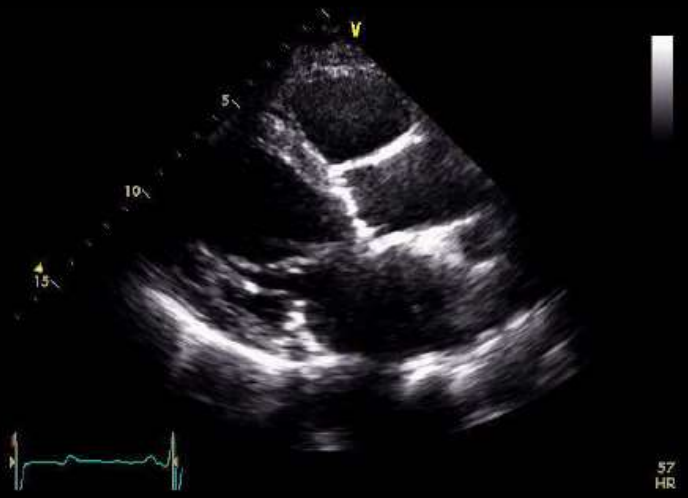


Look at the Aorta And Arteries



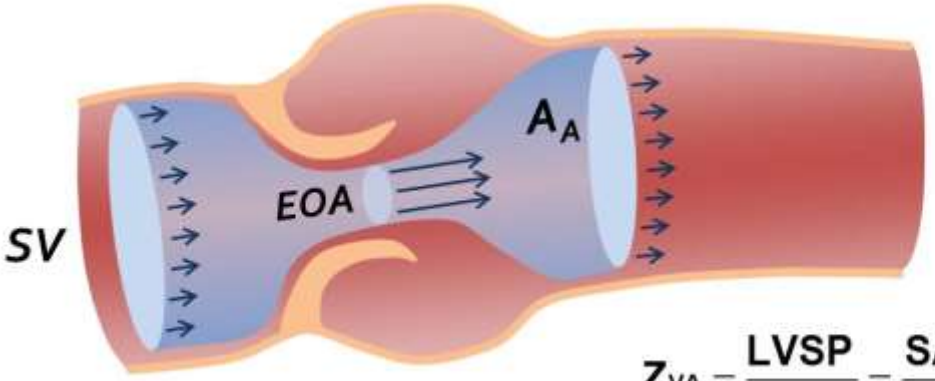
Courtesy of Dr. Pibarot

Patients with calcific AS often have concomitant hypertension



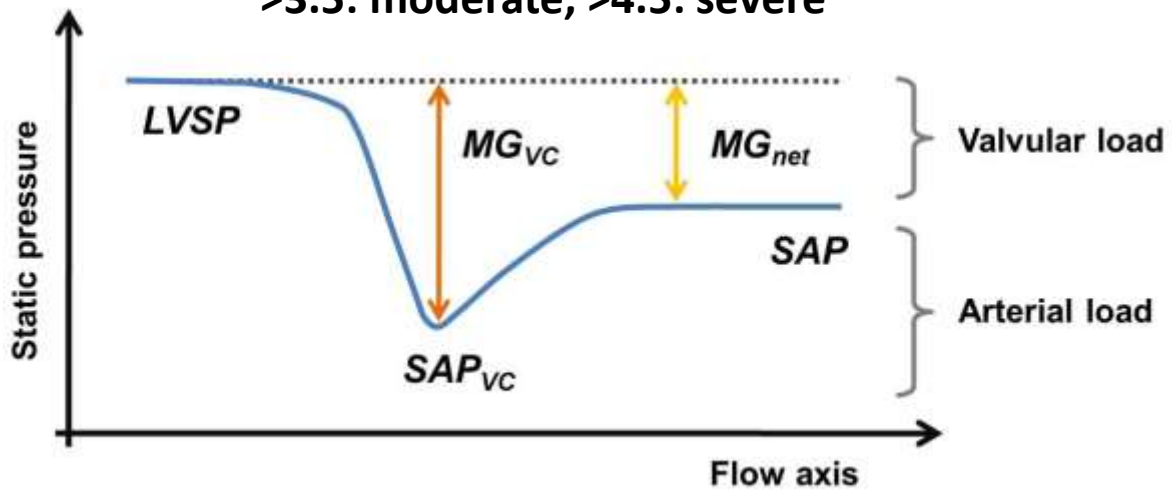
30-80% of patients with calcific AS have hypertension

Valvulo-arterial Impedance (Zva)



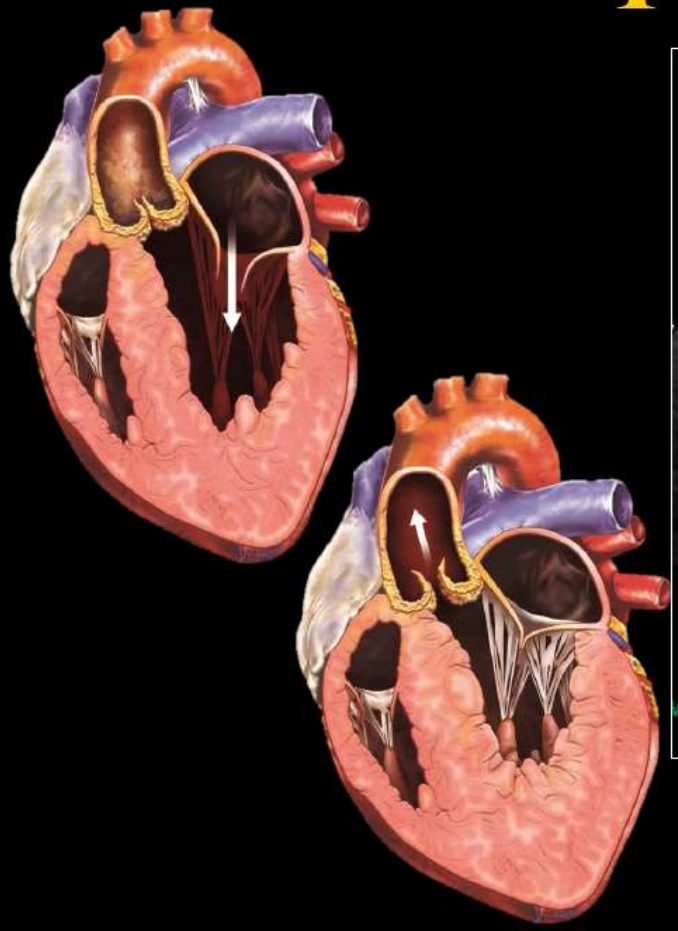
$$Z_{VA} = \frac{LVSP}{SVi} = \frac{SAP + MG_{net}}{SVi}$$

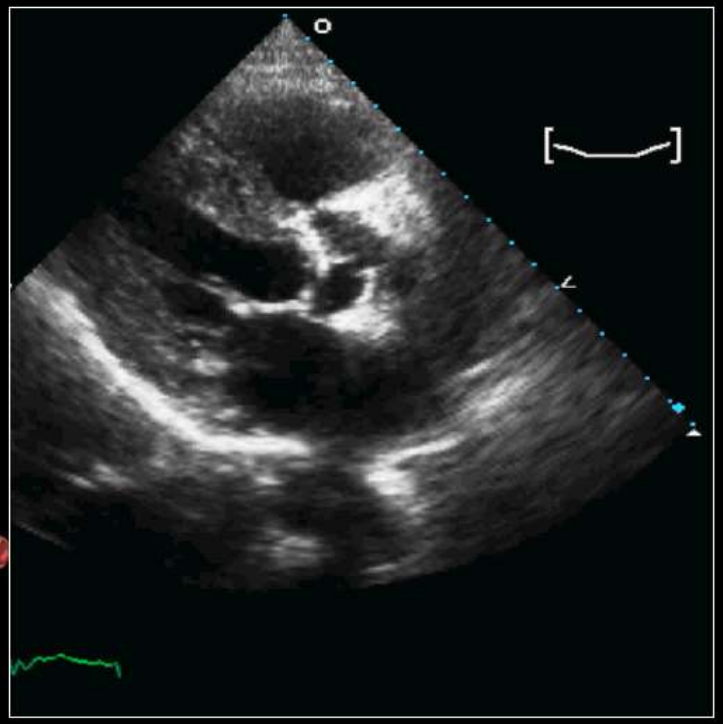
>3.5: moderate, >4.5: severe



JACC 2005;46:291 & Circ 2007;115:2856

"Paradoxical" Low-Flow, Low-Gradient AS with Preserved LVEF



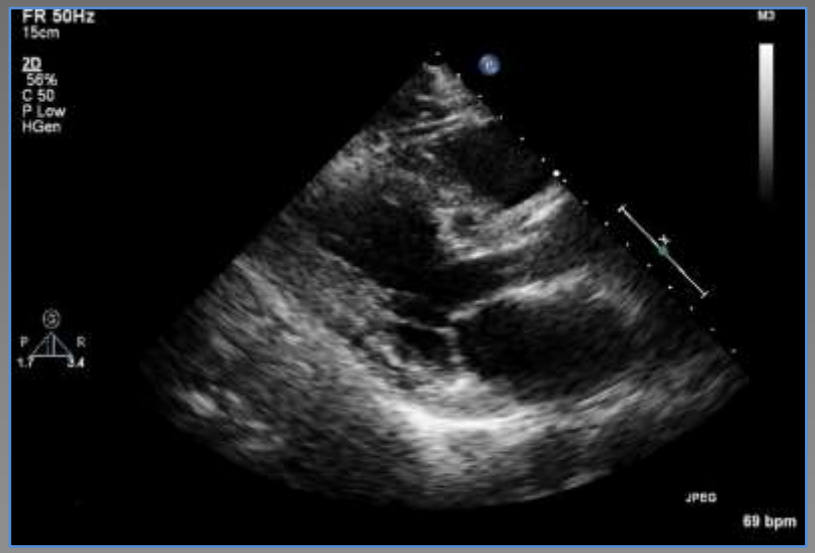


↑Age
Women
Hypertension
MetS – Diabetes

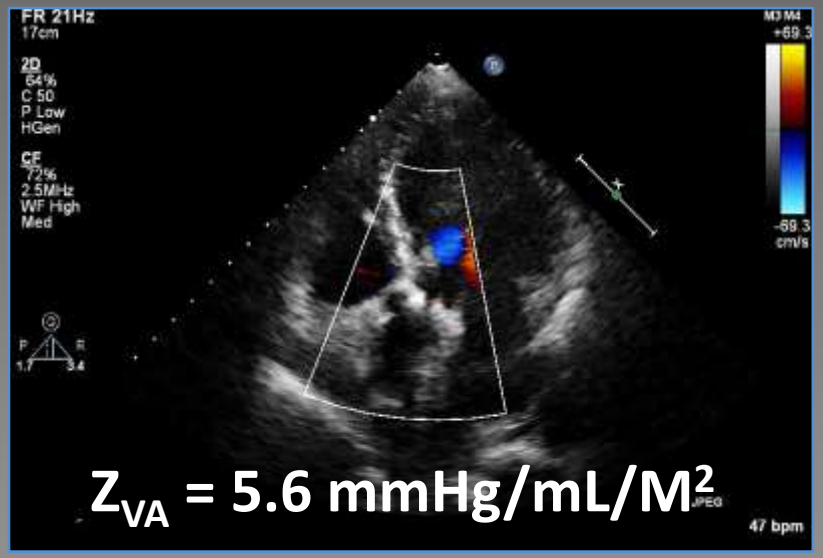
LVEF=60%
SV=46 mL
MG=29 mmHg

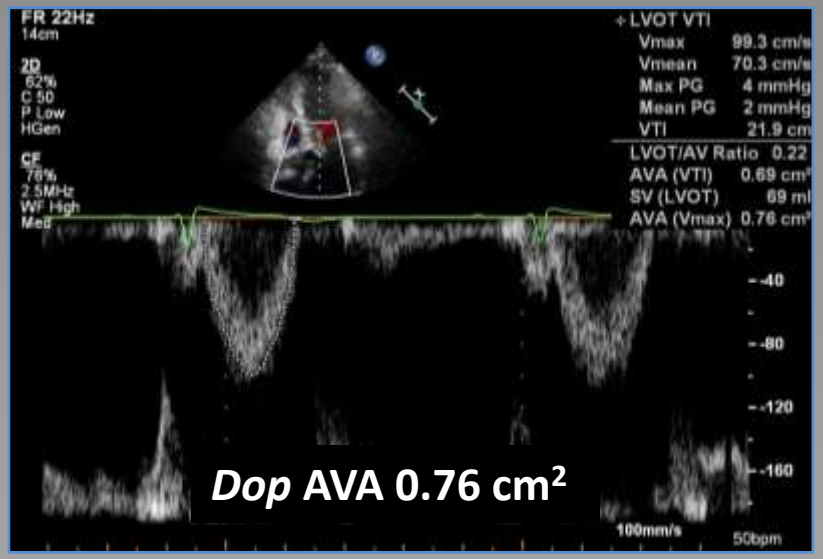
Courtesy of Dr. Pibarot

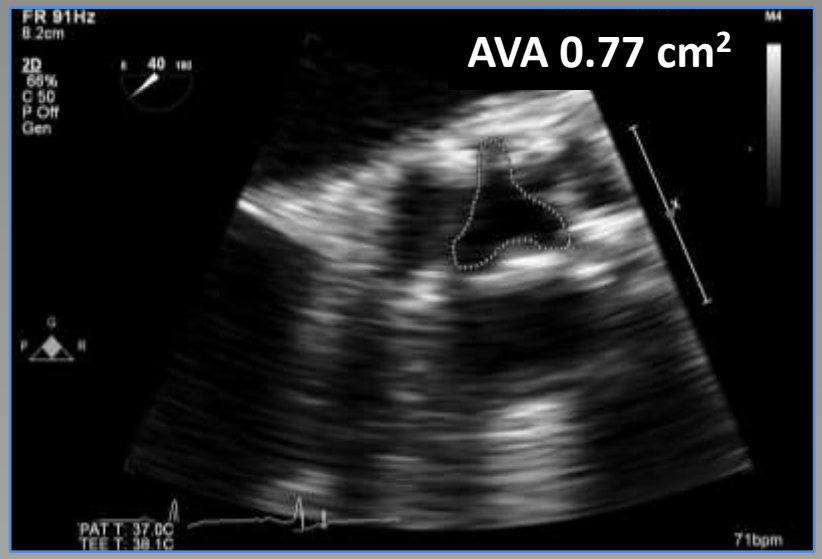
Paradoxical Low Flow Low Gradient AS with High Valvuloarterial Impedance (Zva)



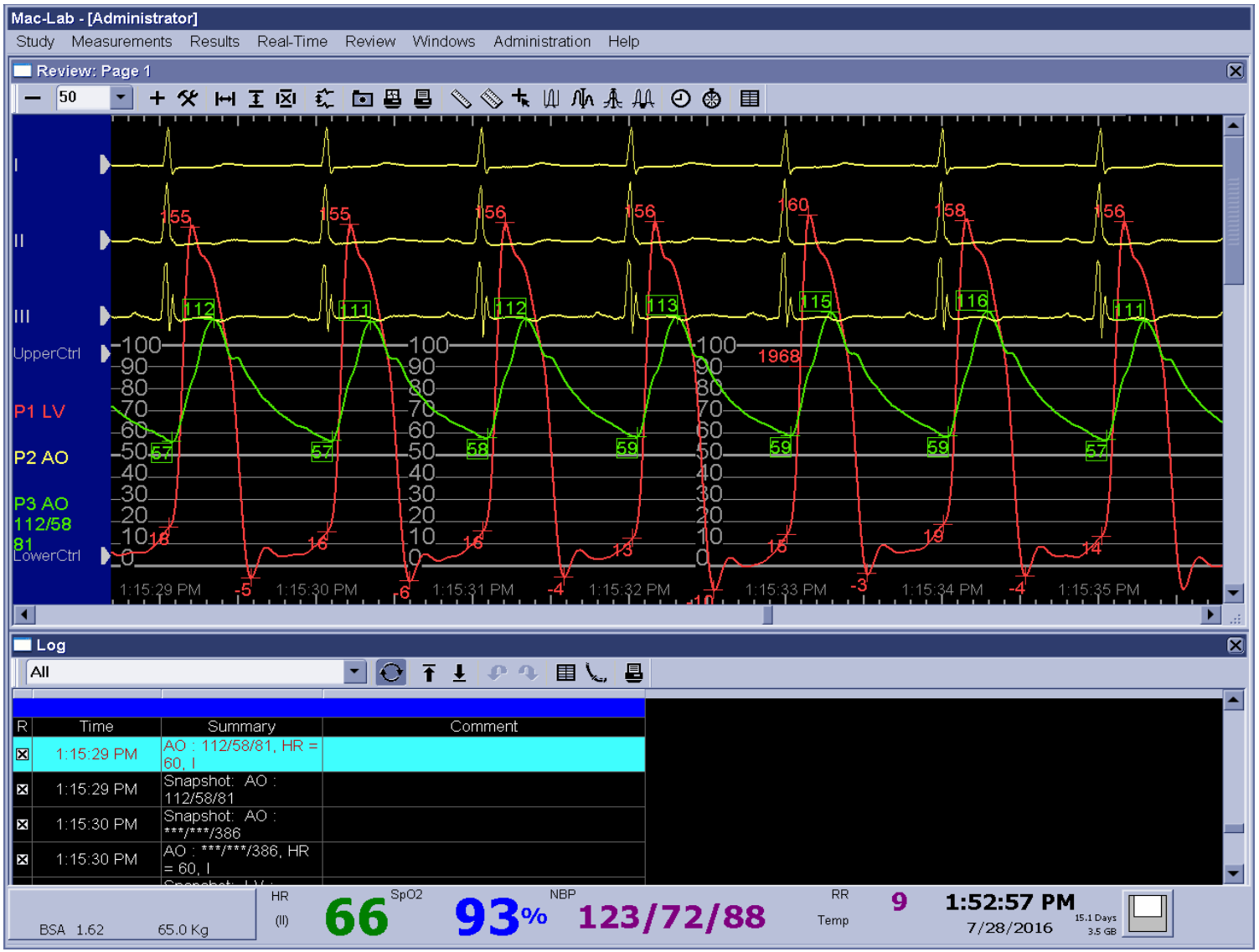
Paradoxical Low Flow Low Gradient AS with High Valvuloarterial Impedance (Zva)





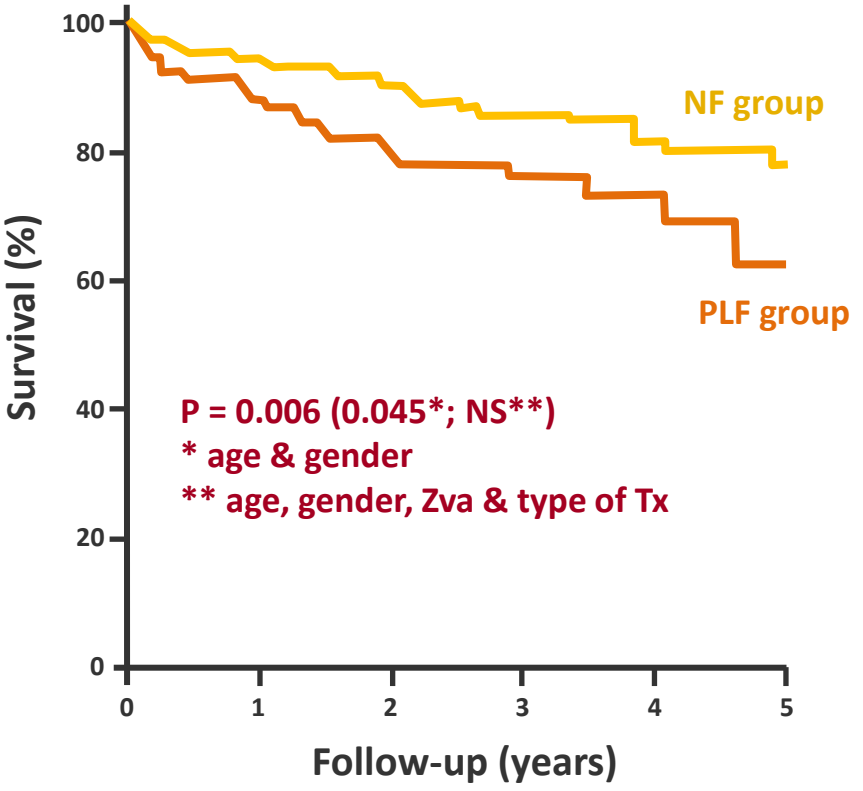


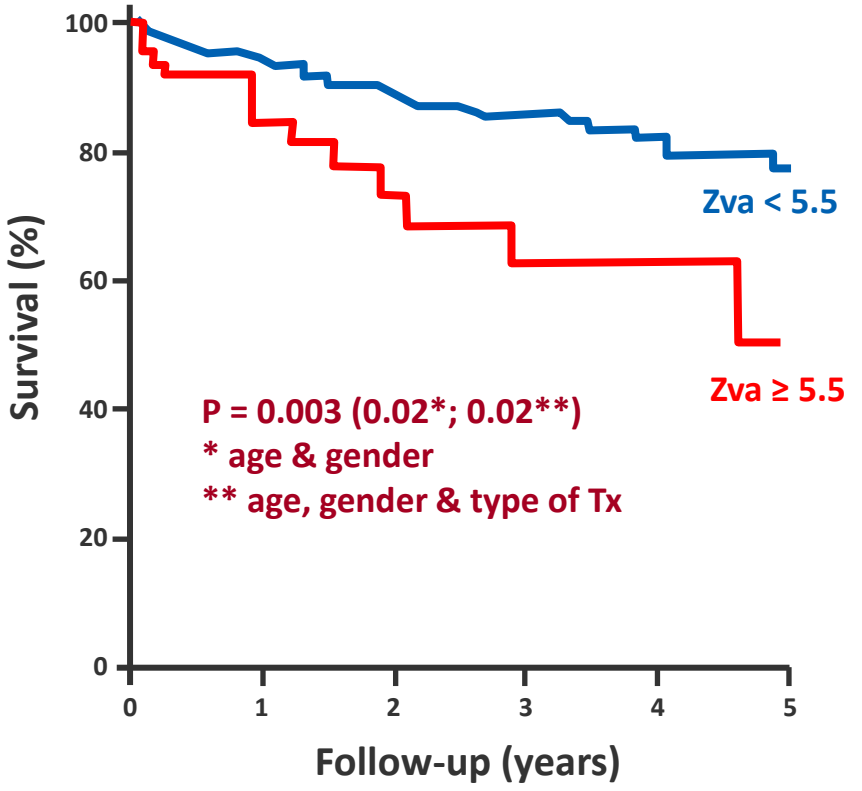
Paradoxical Low Flow Low Gradient AS



Paradoxical Low-Flow, Low-Gradient Severe Aortic Stenosis Despite Preserved Ejection Fraction Is Associated With Higher Afterload and Reduced Survival

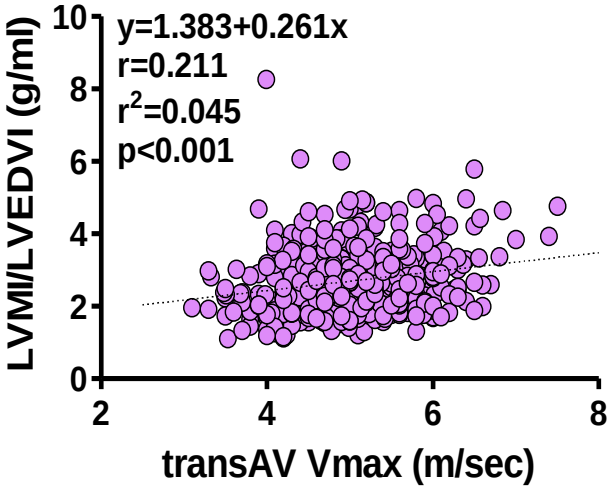
AV area ≤ 0.6 cm^2/m^2 and LV EF $\geq 50\%$
Stroke volume index: 35 mL/m^2

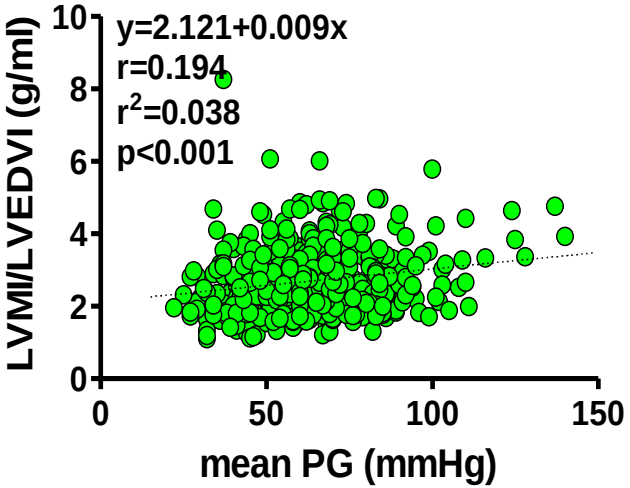


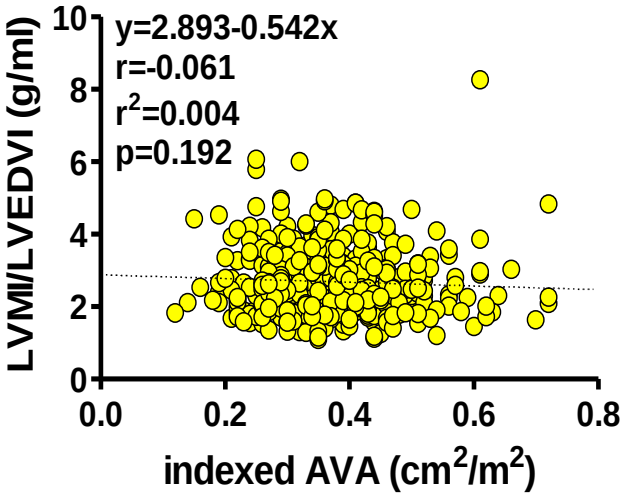


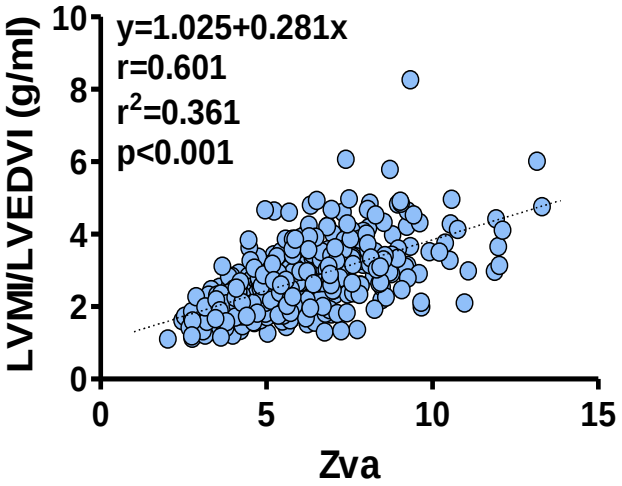
Circ 2007;115:2856

Factors Associated with LVH in AS









AMC data – AHA'11

European Heart Journal (2010) **31**, 281–289
doi:10.1093/eurheartj/ehp361

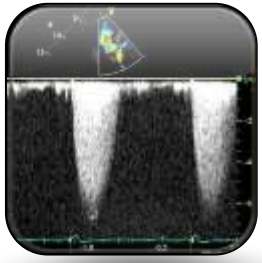
REVIEW

Paradoxical low flow and/or low gradient severe aortic stenosis despite preserved left ventricular ejection fraction: implications for diagnosis and treatment

- A recently described clinical entity
- Relatively frequent (up to 35% of cases)
- A more advanced stage
- Poorer prognosis if treated medically rather than surgically
- Definition: PG (40 mmHg) and SV (35 mL/m^2)

How to Overcome Inconsistency?

Validation of your numbers



Pressure recovery

AS as a systemic disease