Michigan Society of Echocardiography
30th Year Jubilee

Stress Echocardiography in Valvular Heart Disease
Moving Beyond CAD

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Lantheus Medical Imaging

Consultant/Advisory Board :

Lantheus Medical Imaging
Astellas Pharma Global Development, Inc

No conflicts of interest for this talk

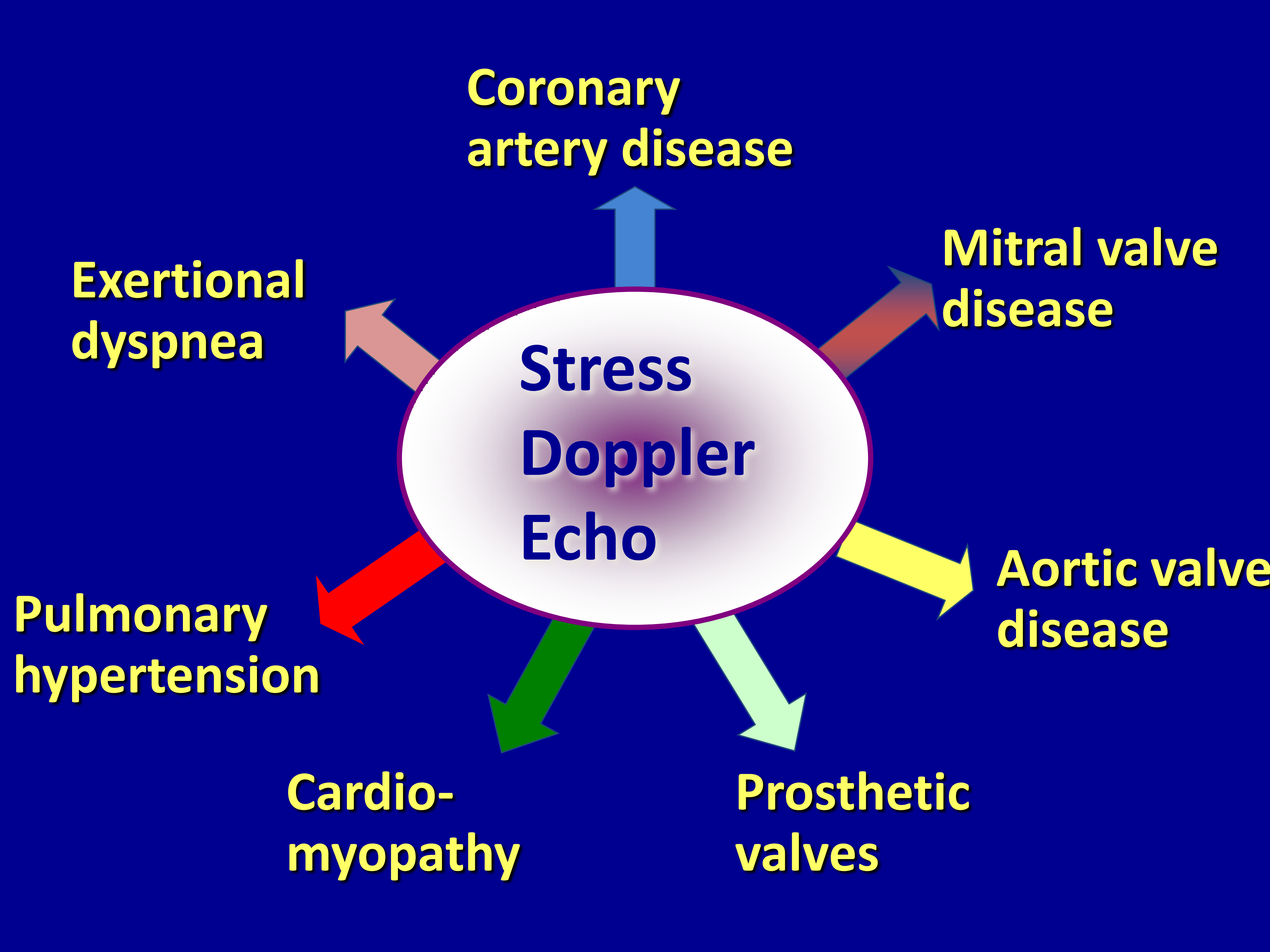
Stress Echo in Valve Disease

Who needs testing ?

What test to do ?

What parameters to measure and focus on ?

How to use the information in patient management ?


Coronary artery disease
Mitral valve disease
Exertional dyspnea
Stress Doppler Echo
Aortic valve disease
Pulmonary hypertension
Cardio-myopathy
Prosthetic valves

Superiority of Stress Echocardiography over ANY OTHER MODALITY

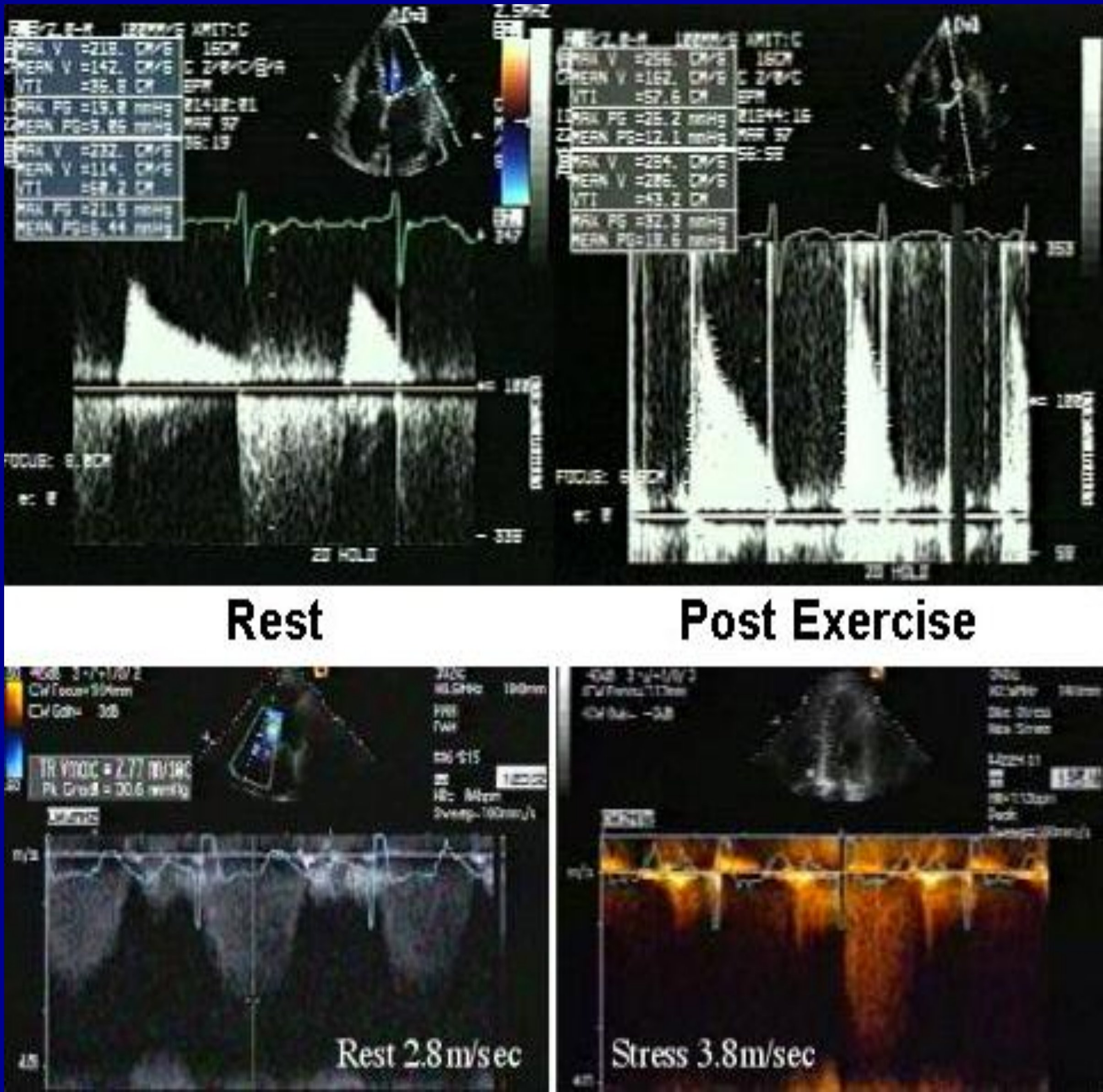
Diagnostic Evaluation and Planning strategies for Management in

1Co-existing Valvular Heart Disease

2. Dynamic obstructive disease,

3. Unexplained dyspnea, correlating

4. Exercise hemodynamics to function, pressures and diastology

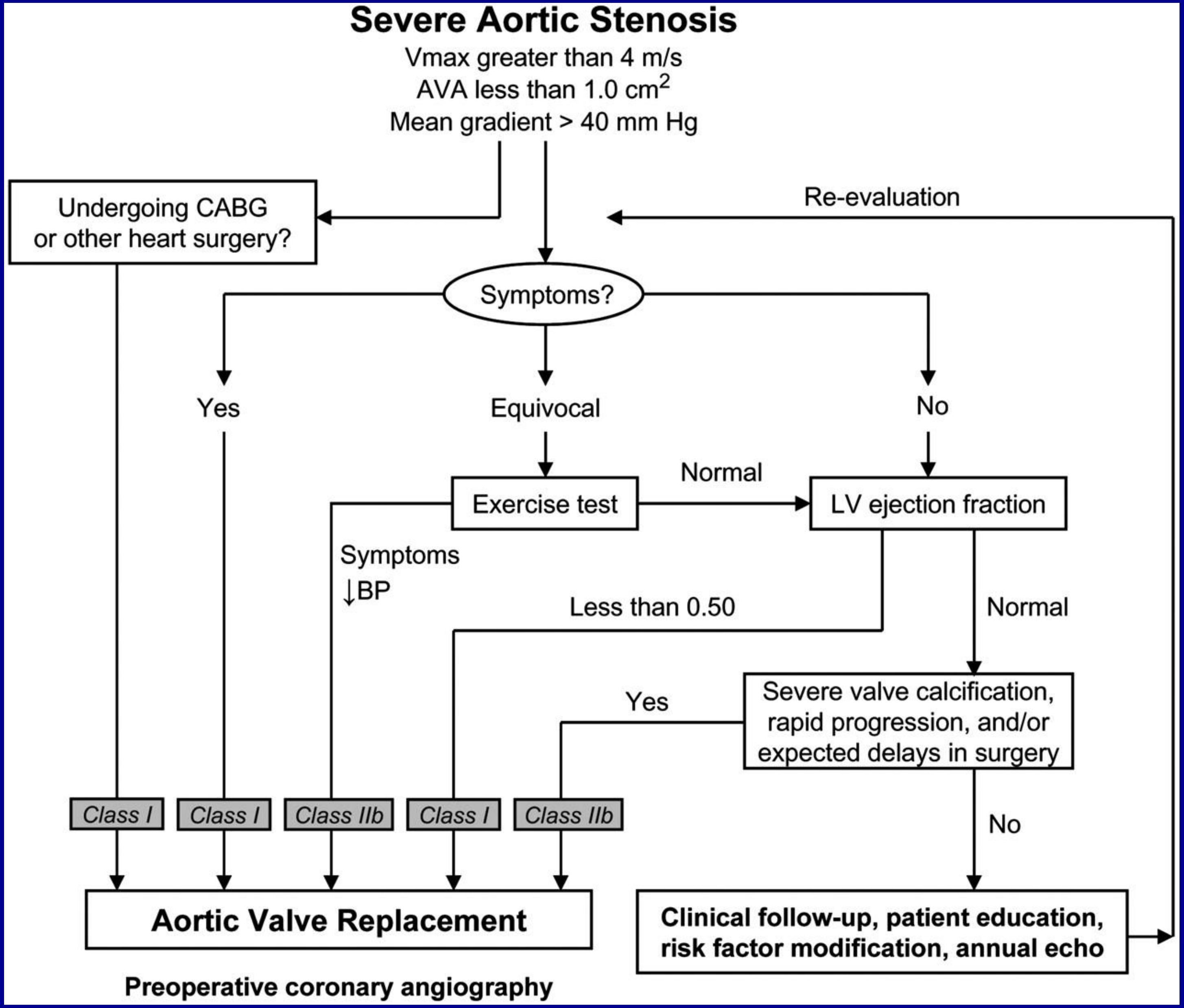


Exercise Vs Bicycle Echo

Cardiopulmonary Pathologies Which Can Be Evaluated by Exercise Echocardiography

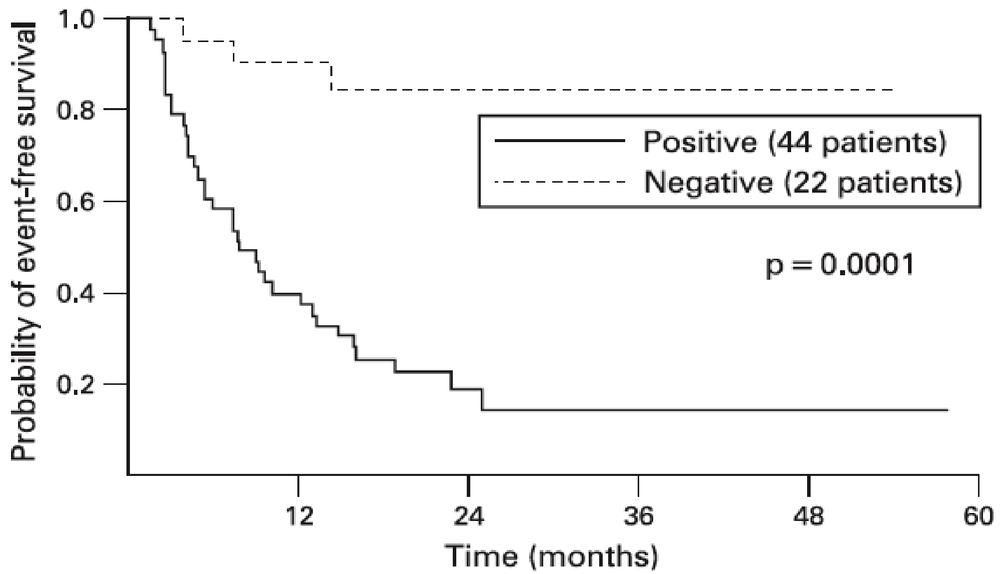
Pathology	TSE	BSE
Myocardial ischemia	+++	+++
Contractile reserve	+	++
Exercise-induced PHTN	+	++
Exercise-induced LVDD	+	++
Exercise-induced IAS	+	++
Exercise-induced AVF	+	++
Valvular function	+	++
Dynamic LV obstruction	++	++
Perioperative risk	?	?

Management strategy for patients with severe aortic stenosis

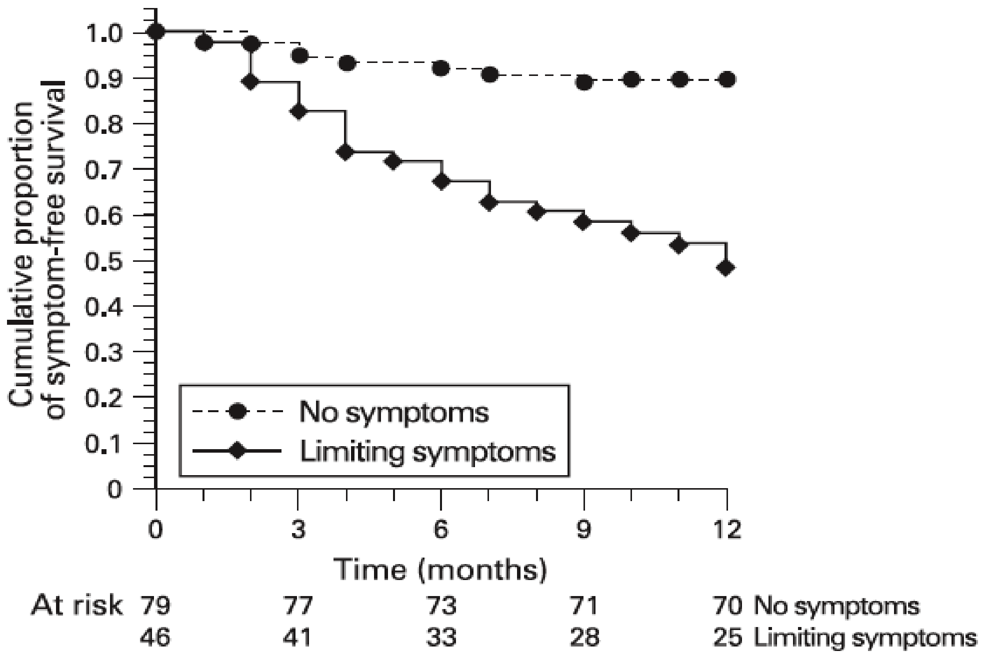


Bonow, R. O. et al. J Am Coll Cardiol 2006;48:e1-e148

Exercise Test in AS : Clinical and EKG

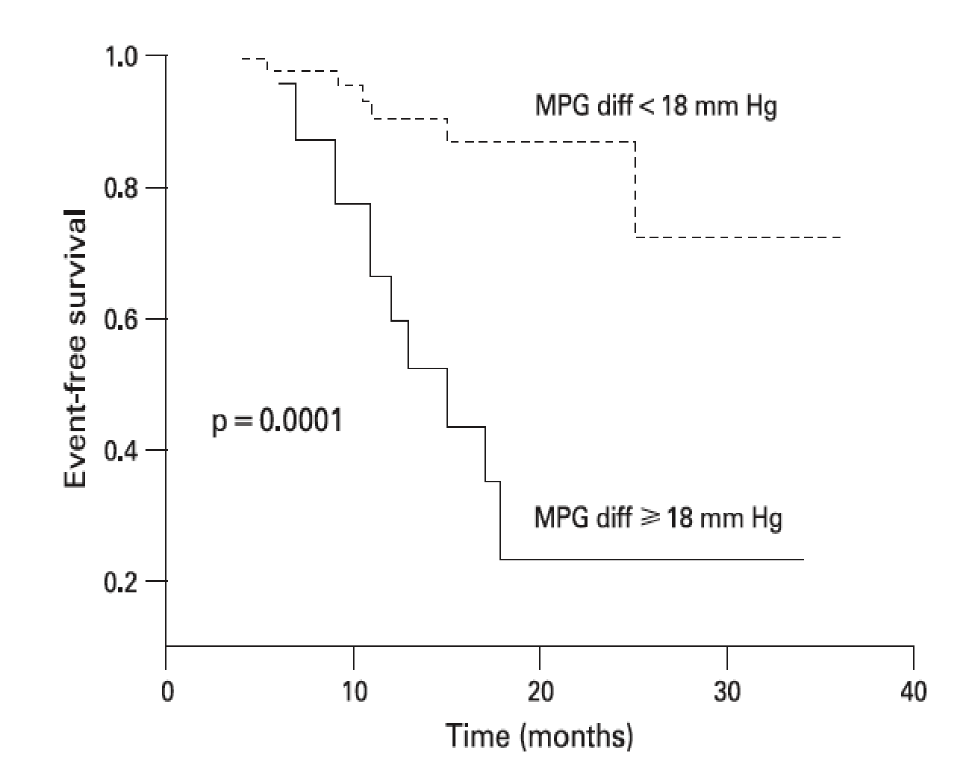


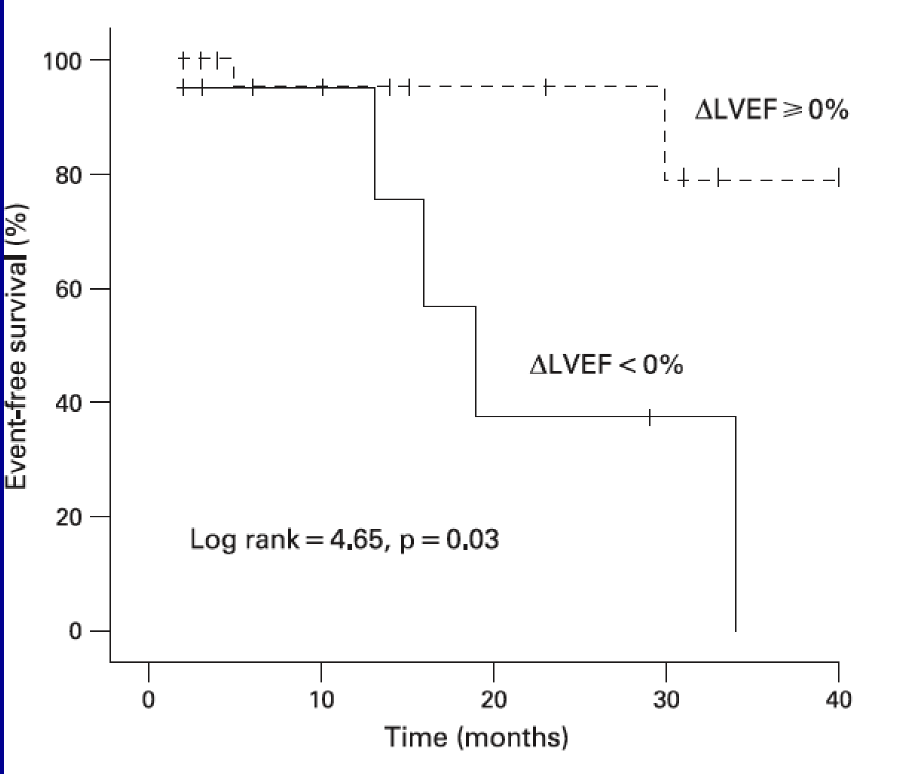
Amato et al Heart 2001
ST depression and outcomes



Das et al , Eur Heart J 2005
Symptoms and outcomes

Exercise Echo and Outcomes in AS
Role of Gradient and EF Reserve





Lancelloti et al Circulation 2005

Marechaux et al Echocardiography 2007

Usefulness of exercise-stress echocardiography for risk stratification of true asymptomatic patients with aortic valve stenosis

Sylvestre Maréchaux[1†], Zeineb Hachicha[2†], Annaïk Bellouin[1], Jean G. Dumesnil[2], Patrick Meimoun[3], Agnès Pasquet[4], Sébastien Bergeron[2], Marie Arsenault[2], Thierry Le Tourneau[1], Pierre Vladimir Ennezat[1*], and Philippe Pibarot[2*]

European Heart Journal (2010) **31**, 1390–1397

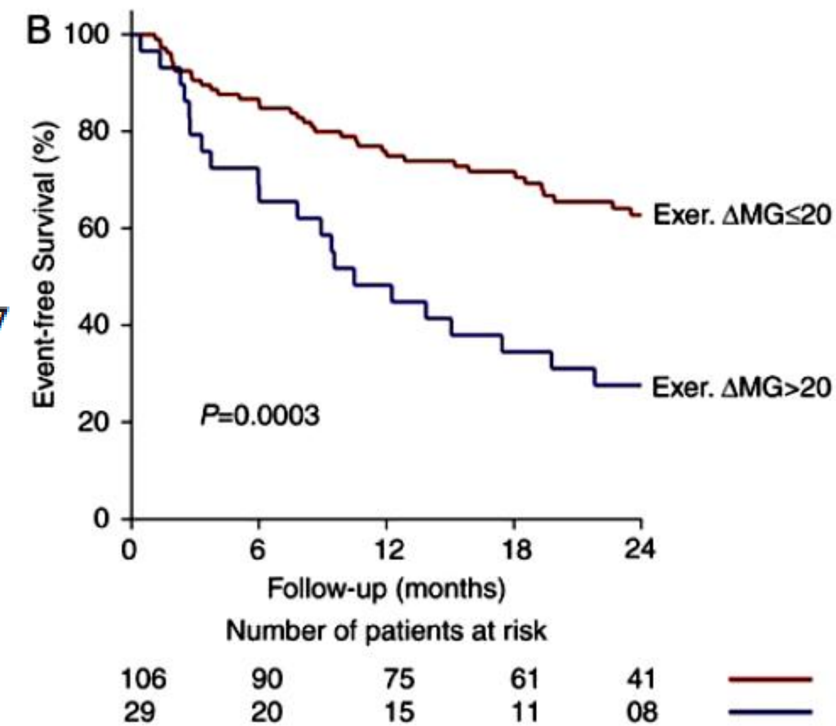
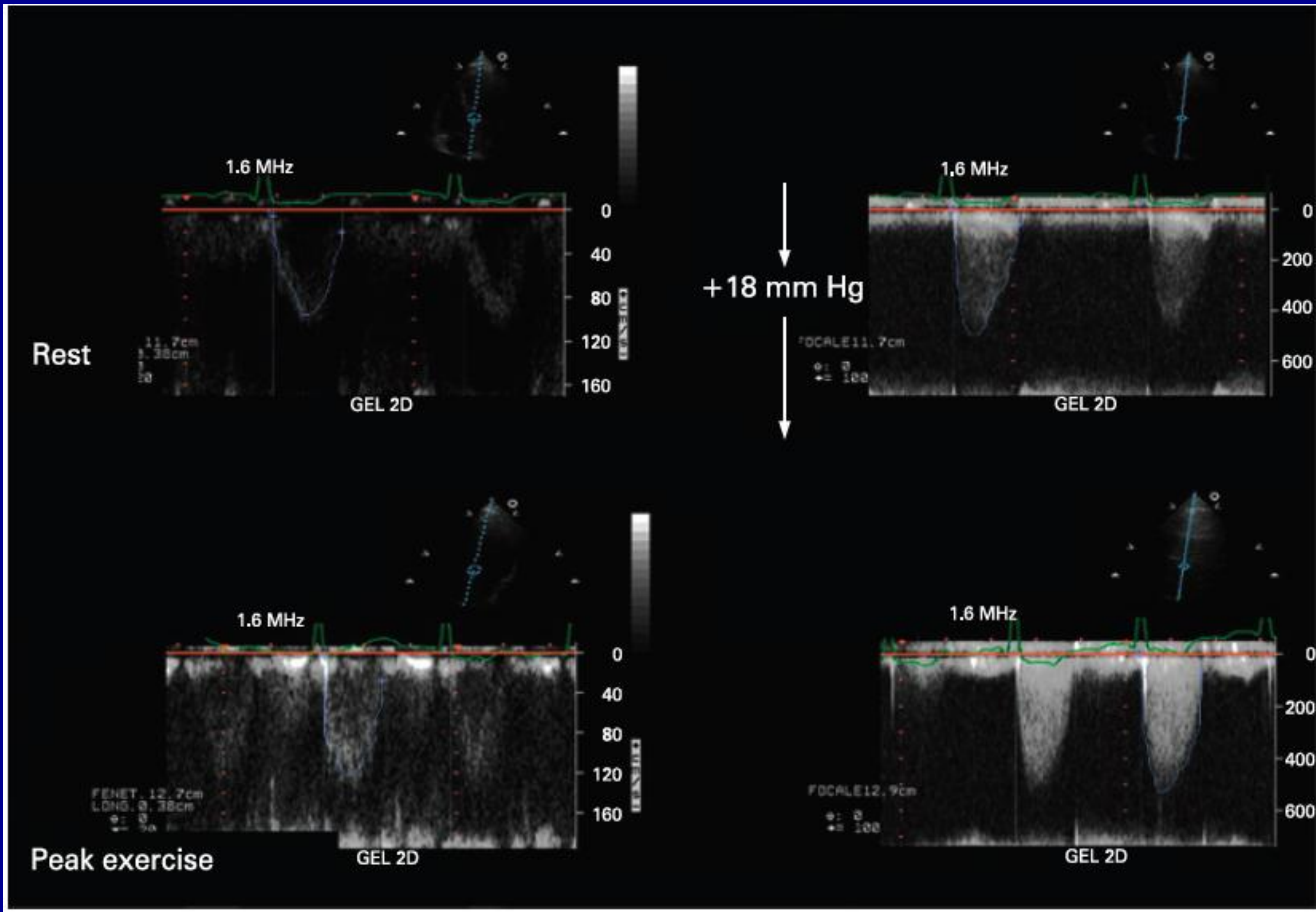


Table 4 **Univariate and multivariate analysis of association between baseline variables and event risk in the whole cohort (n = 135) with variables entered in dichotomous format**

Variables	(%) of patients with variable	Univariate analysis		Multivariate analysis	
		HR (95% CI)	P-value	HR (95% CI)	P-value
Age ≥65 years	58	2.16 (1.30–3.72)	0.003	1.96 (1.15–3.47)	0.01
Diabetes	10	2.10 (0.90–4.10)	0.08	3.20 (1.33–6.87)	0.01
Rest systolic blood pressure >135 mmHg	55	1.71 (0.78–2.85)	0.03	1.30 (0.78–2.23)	0.32
LV hypertrophy	41	1.90 (1.17–3.08)	0.009	1.96 (1.17–3.27)	0.01
Rest mean gradient >35 mmHg	50	3.70 (2.21–6.41)	<0.0001	3.60 (2.11–6.37)	<0.0001
Exercise Δ mean gradient >20 mmHg	21	2.10 (1.22–2.52)	0.008	3.83 (2.16–6.67)	<0.0001
Exercise LV ejection fraction <70%	38	1.61 (1.00–2.62)	0.05	1.61 (0.95–2.71)	0.07

Exercise Echo in AS



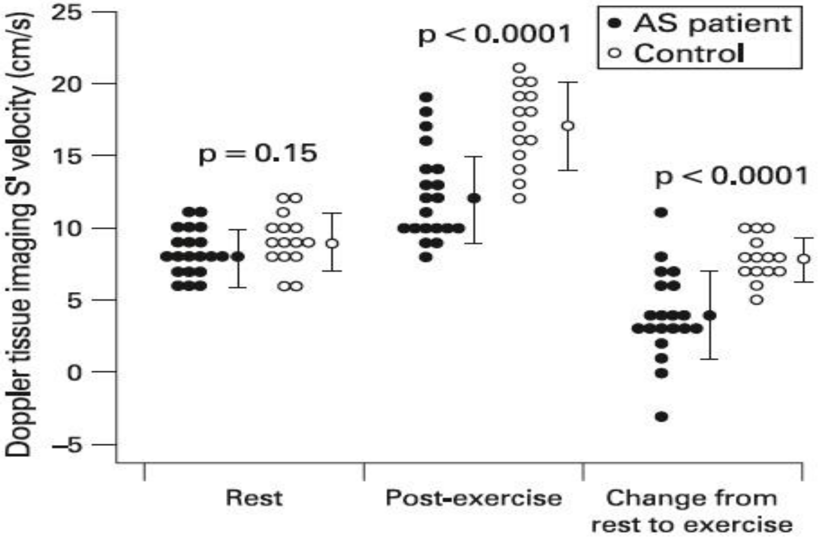
Stress Data AORTIC STENOSIS	Parameters	Impact on Outcome	Impact on AVR ESC versus ACC guidelines
Clinical	Symptoms BP response	Onset of symptoms indaily life, cardiac death, AVR	ESC 1 ACC 2b ESC 2A ACC 2b
EKG	Vent Arrhythmias ST depression	Onset of symptoms in daily life, cardiac death, AVR	ESC 2B
Echo	Increase in mean gradient > 18 ; > 20 mm hg Decrease or minimal increase in EF	Spontaneous symptoms, cardiac death, AVR Spontaneous symptoms, cardiac death, AVR	

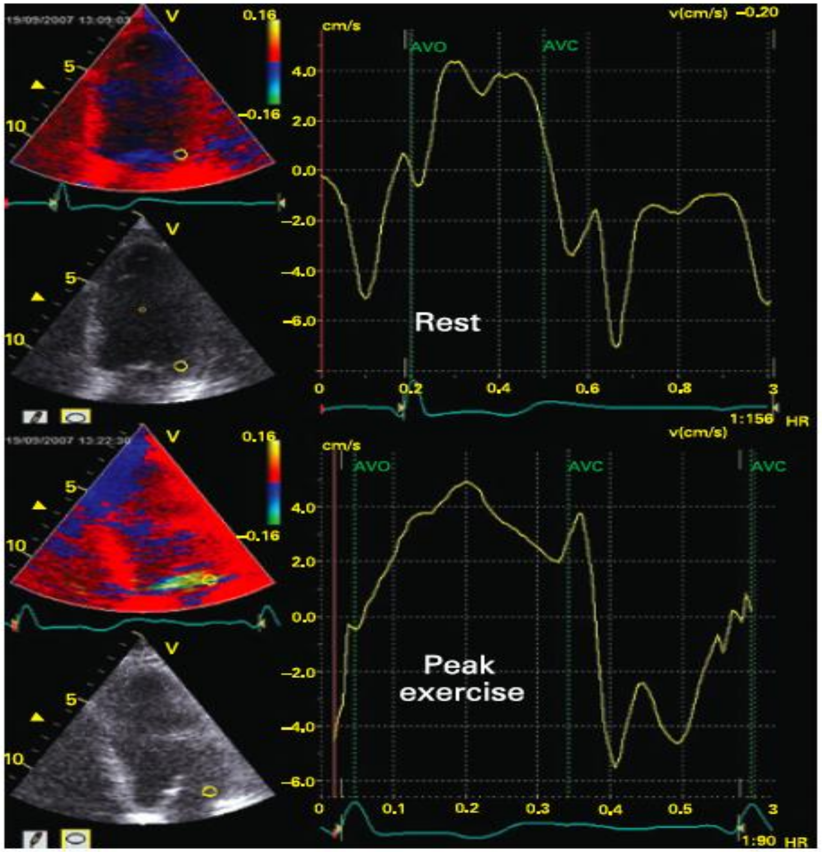
Caveats

Increase in transvalvular gradient may not always correlate with presence or onset of symptoms during stress echo in AS

Transvalvular gradient depends on

1. severity of AS at rest
2. aortic valve compliance
3. concomitant CAD
4. LV contractile reserve
5. duration of exercise
6. maximal heart rate
7. workload achieved





Newer Stress Parameters in AS

Tissue Doppler and Stress Echocardiography
Van Pelt et al Heart 2007

Lack of substantial increase in S' between rest and exercise as a sign of LV contractile abnormality in AS

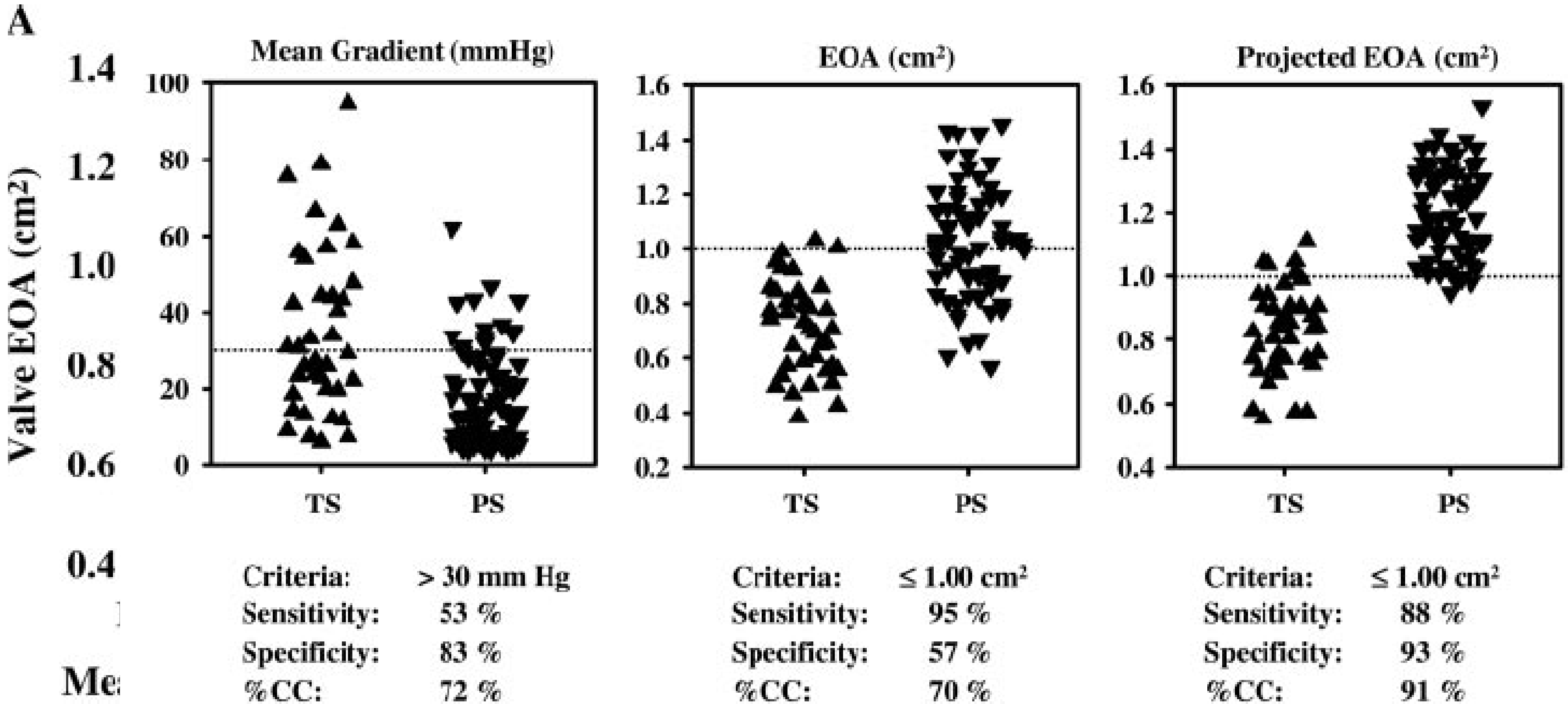
Correlates with BNP, exercise duration and increase in systolic pressure

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, Ian G. Burwash, Gerald Mundigler, Jean G. Dumesnil, Nicole Loho, Florian Rader, Helmut Baumgartner, Rob S. Beanlands, Boris Chayer, Lyes Kadem, Damien Garcia, Louis-Gilles Durand and Philippe Pibarot

Circulation 2006, 113:711-721

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.



Some Formulas

EOA (proj) = EOA res + Valve compliance x (250- Q rest)

Valve compliance =slope of the regression equation of the EOA to flow rate(mil/sec)

or absolute increase in AVA with dobutamine infusion / increase in flow rate

Valve resistance = 1333 x mean gradient / flow rate = SV/ejection time)

Stroke work loss = 100 x (mean gradient /mean gradient +systolic pressure)

Low Flow/Low-Gradient AS

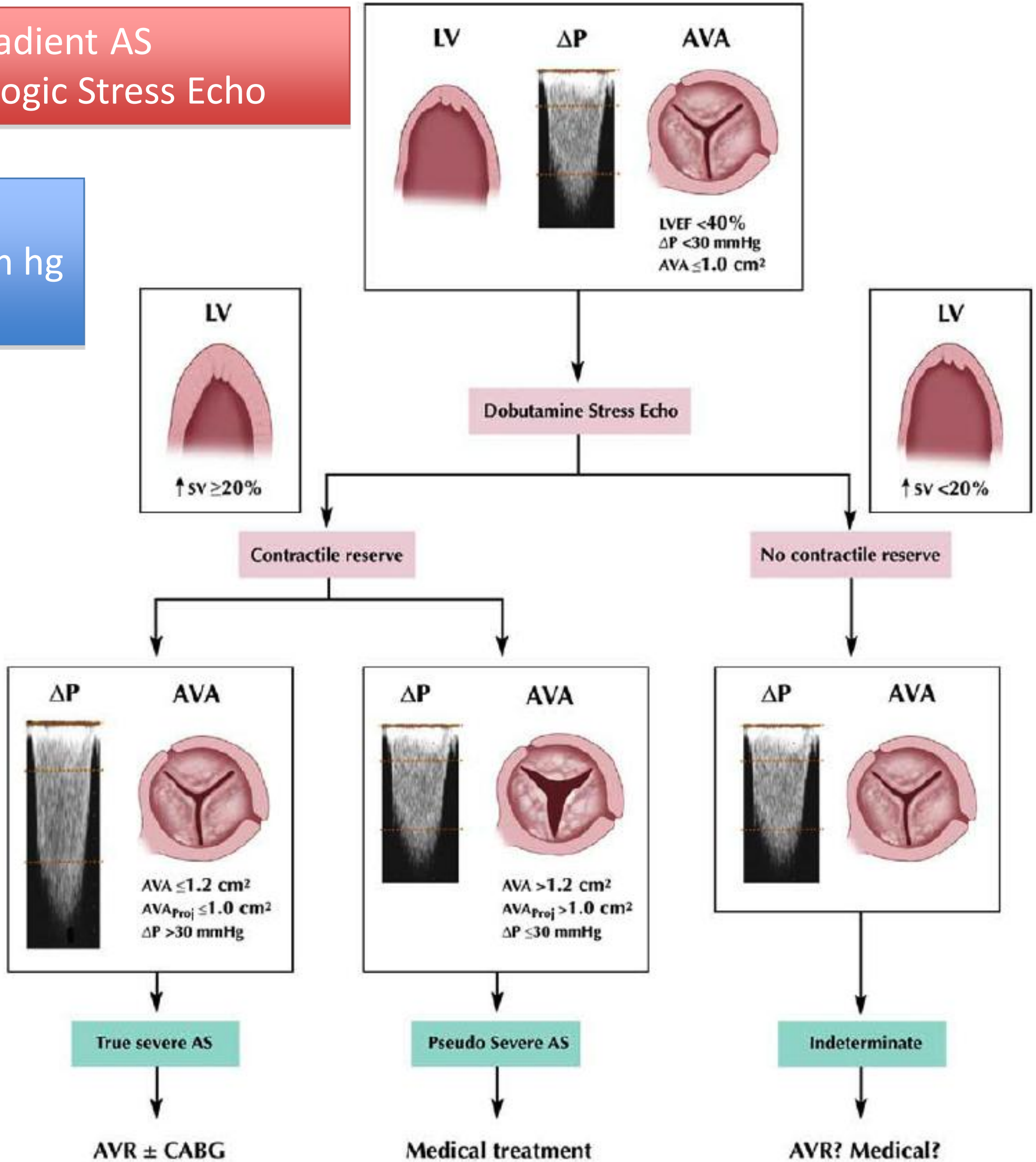
Class IIa

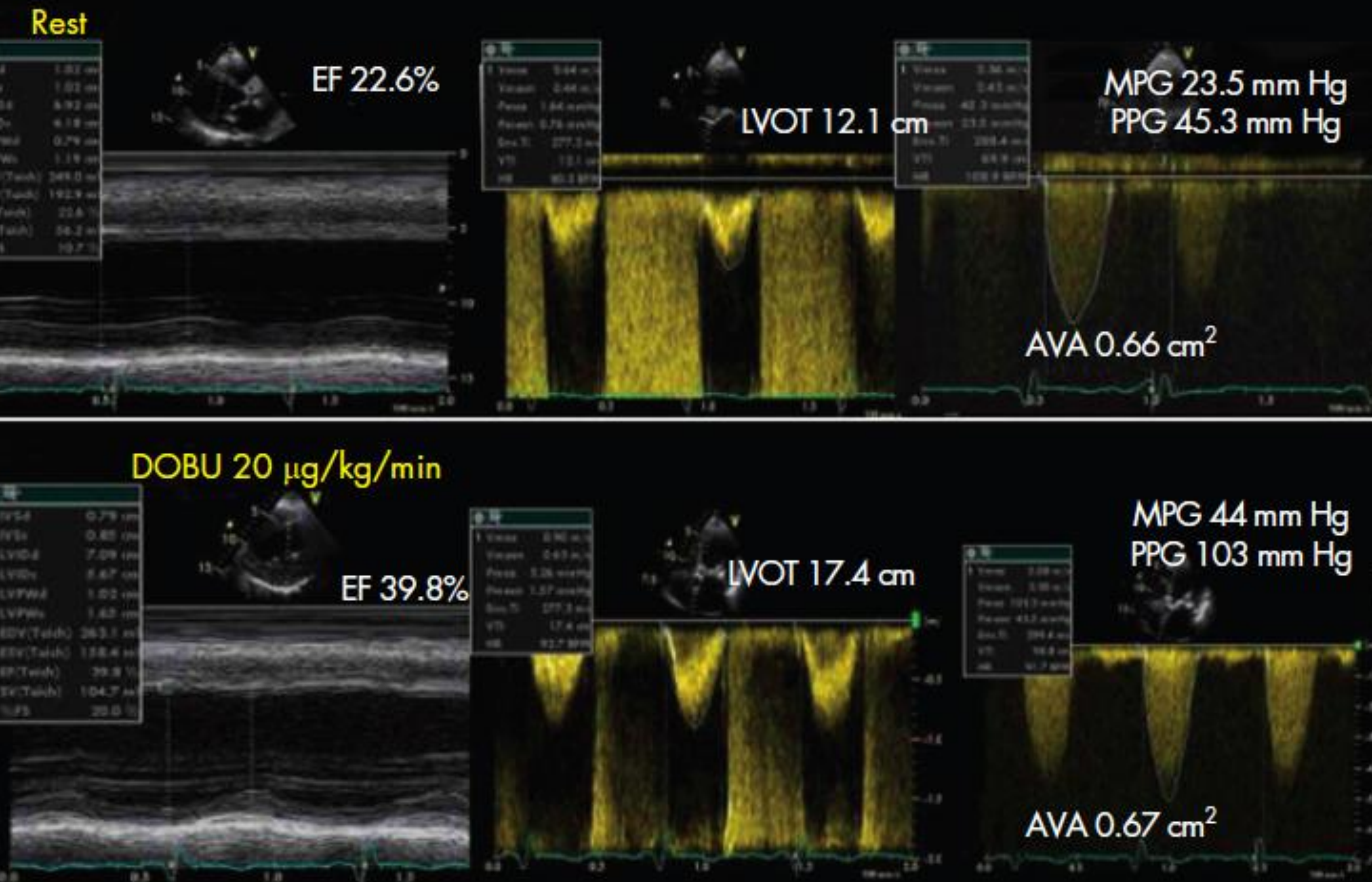
1 Dobutamine stress echocardiography is reasonable to evaluate patients with low-flow/low-gradient AS and LV dysfunction. *(Level of Evidence: B)*

2 Cardiac catheterization for hemodynamic measurements with infusion of dobutamine can be useful for evaluation of patients with low-flow/low-gradient AS and LV dysfunction. *(Level of Evidence: C)*

Low Flow Low Gradient AS
Role of Phamacologic Stress Echo

AVA < 1 sq cm
MG : <30-<40 mm hg
EF < 40%

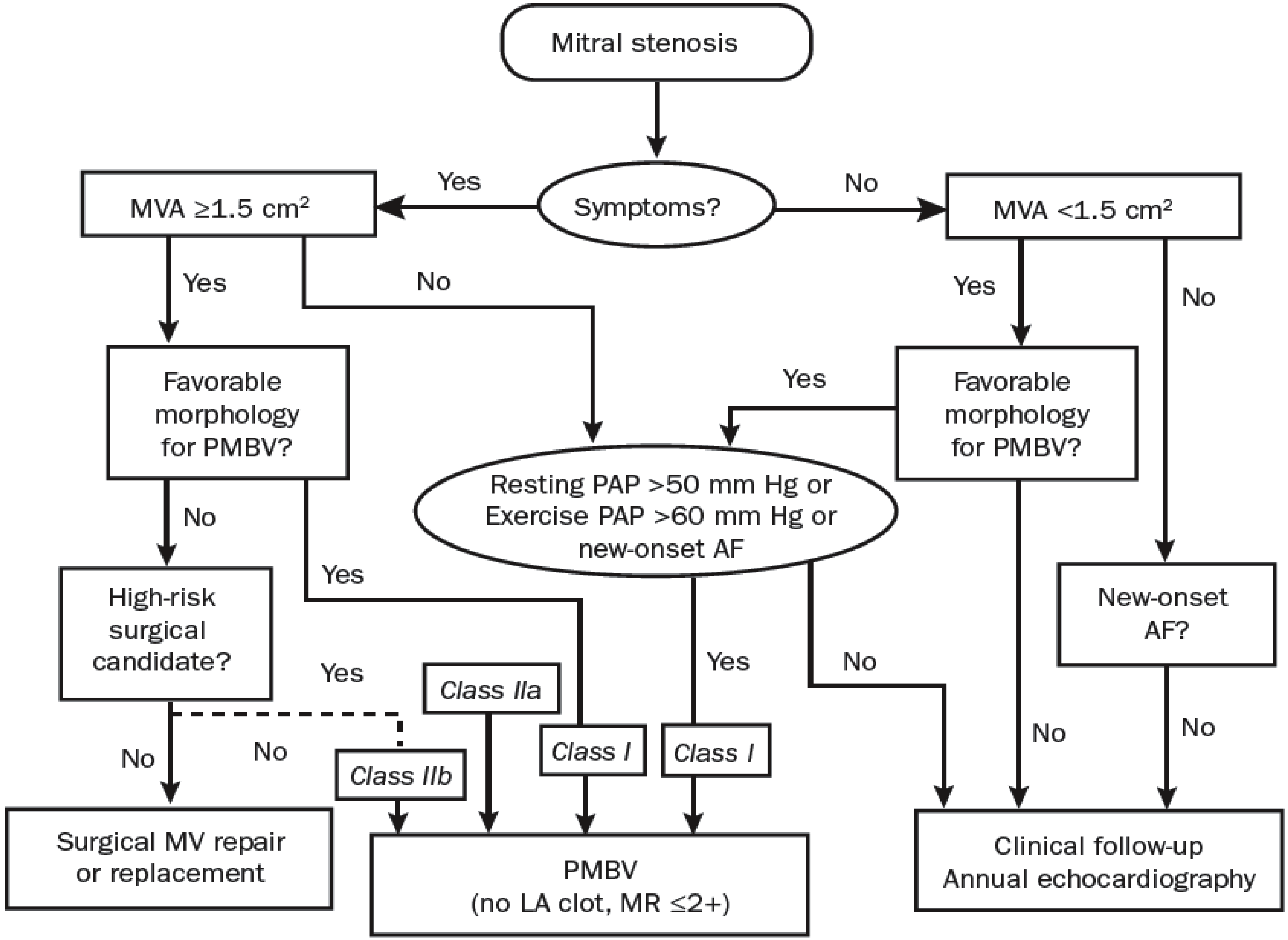


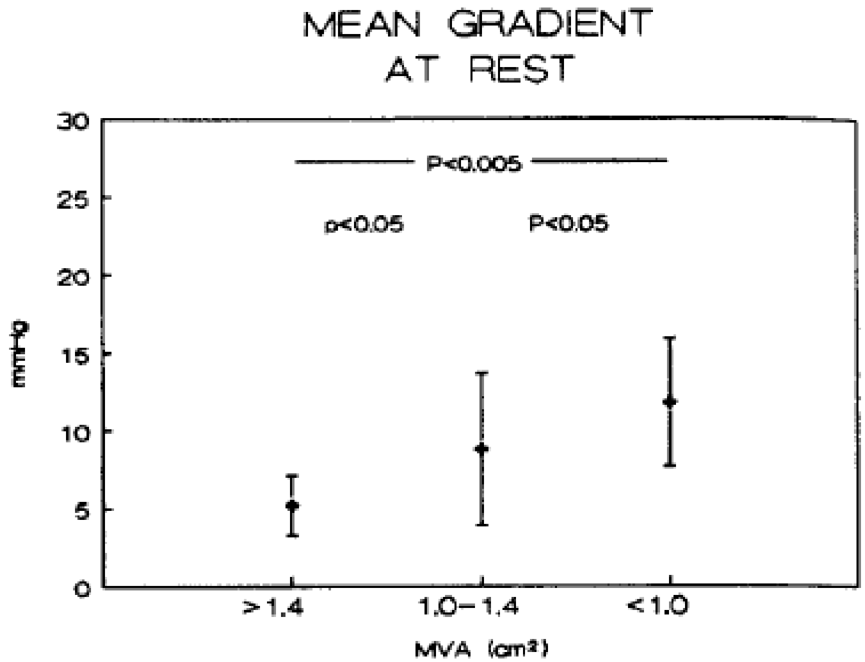

Rest
EF 22.6%
LVOT 12.1 cm
MPG 23.5 mm Hg
PPG 45.3 mm Hg
AVA 0.66 cm2
DOBU 20 μg/kg/min
EF 39.8%
LVOT 17.4 cm
MPG 44 mm Hg
PPG 103 mm Hg
AVA 0.67 cm2

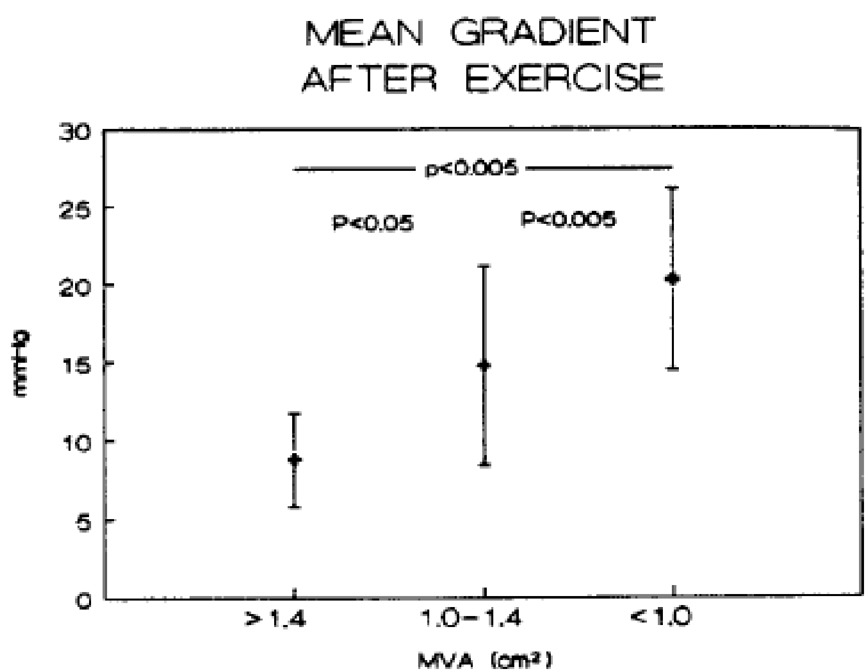
DSE in Low Flow Low Gradient AS and Normal Ejection Fraction

1. Increasingly recognized and challenging entity
2. EF >/= 50% , low mean gradients < 30 mm hg, AVA < 1 sq cm
3. Low indexed stroke volume , < 35ml/sqm, small concentric remodelled ventricles
4. Important to rule out technical errors prior to making the diagnosis. Consider EOA projected, Zva, Energy Loss index
5. ? Role of Dobutamine challenge to increase CO to differentiate

Indications **MITRAL STENOSIS**	Stress Data	Parameters	Impact on Outcome	Impact of decision making ESC and ACC Guidlelines
Asymptomatic MS (MVA < 1.5 sq cm)	Clinical Echo	Symptoms or PASP > 60 mm hg exercise testing`		ESC 2A ACC1 ACC 1
Symptomatic MS (MVA < 1.5 sq cm)	Echo	PASP > 60 or mean mitral gradient> 15 mm hg with exercise Mean mitral gradient > 20 mm hg with DSE	Clinical deterioration and need for surgery	ACC 2b ACC 2b


Mitral stenosis
Symptoms?
Yes
No
MVA ≥1.5 cm²
MVA <1.5 cm²
Yes
No
Yes
No
Favorable morphology for PMBV?
Yes
Favorable morphology for PMBV?
Resting PAP >50 mm Hg or Exercise PAP >60 mm Hg or new-onset AF
No
Yes
New-onset AF?
High-risk surgical candidate?
Yes
Class IIa
Yes
No
No
Class I
Class I
No
No
No
Class IIb
Surgical MV repair or replacement
PMBV (no LA clot, MR ≤2+)
Clinical follow-up Annual echocardiography



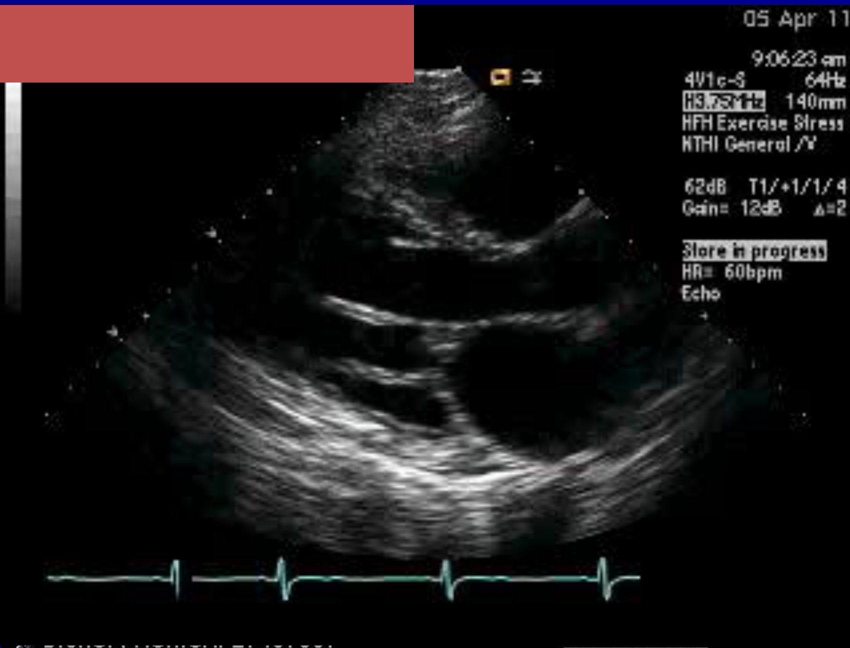


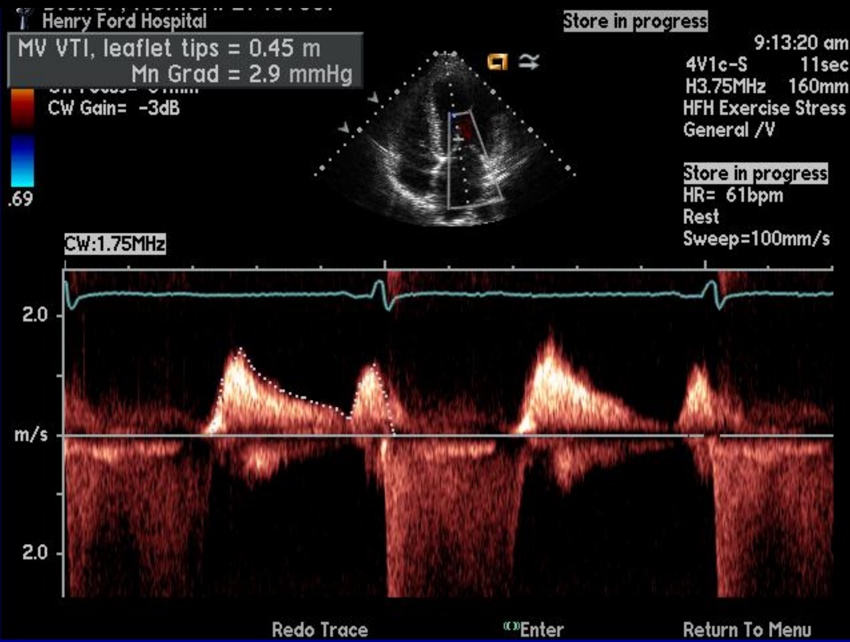
At rest there is significant overlap of gradients in patients with varying severity of MS

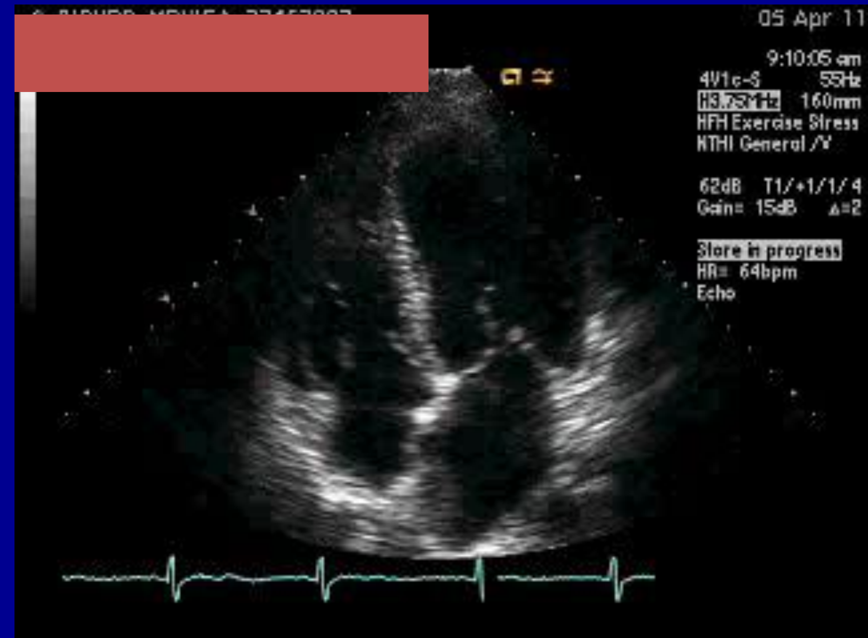
Exercise echo helps to further stratify patients based on their severity

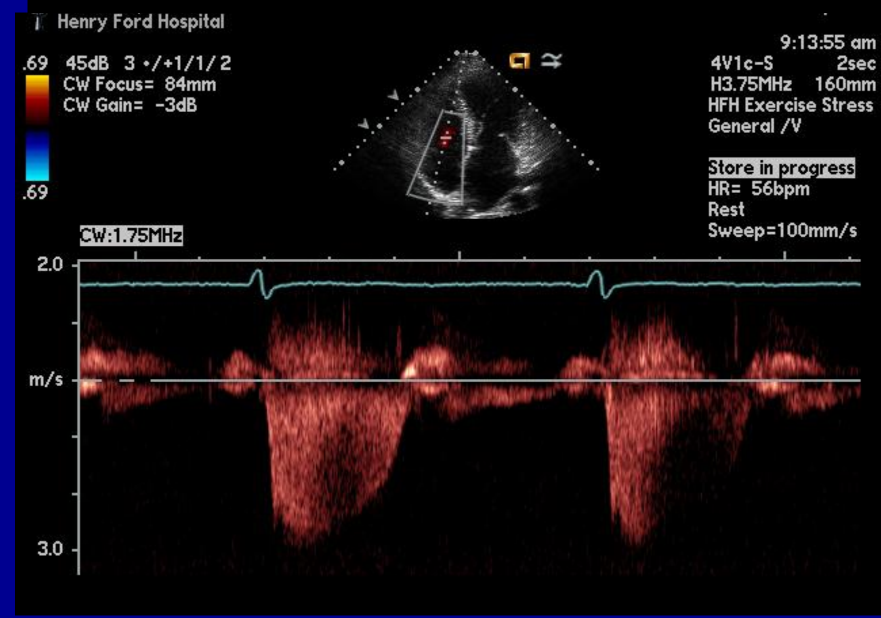
Cheriex et al
In Jnl of Cardiol 1994

Stress Echo in MS

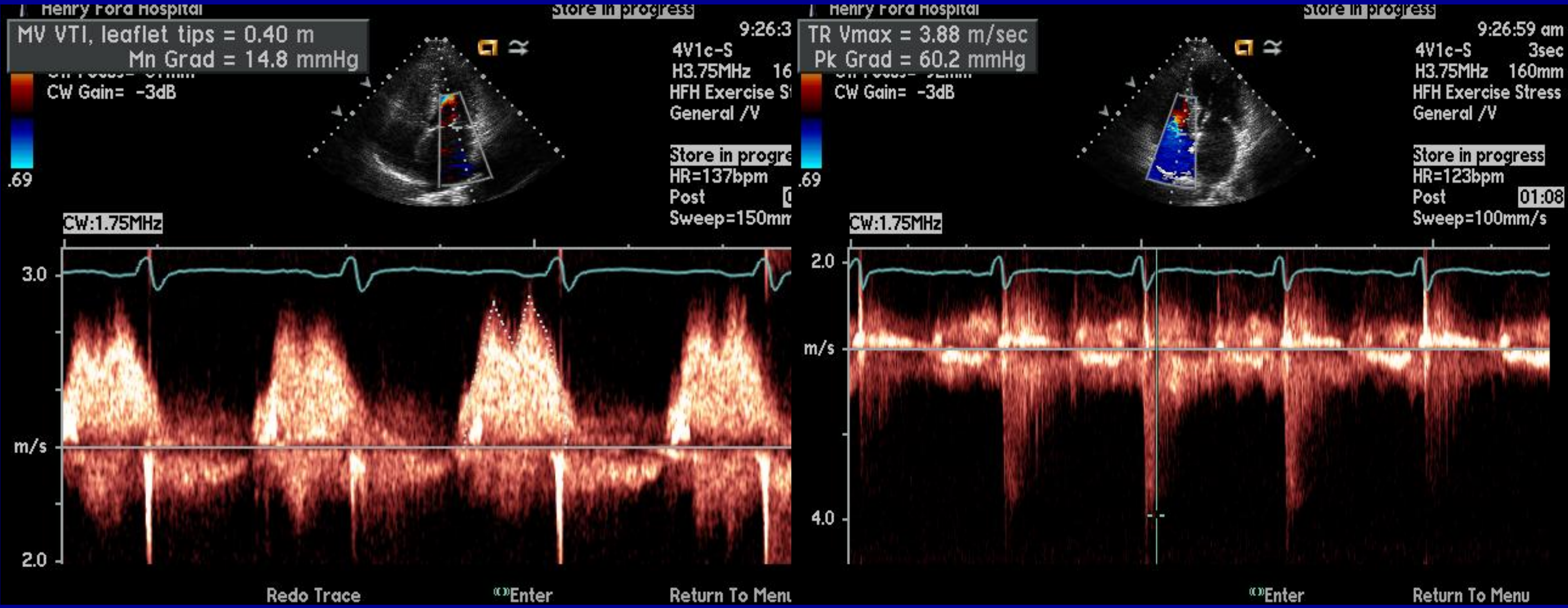








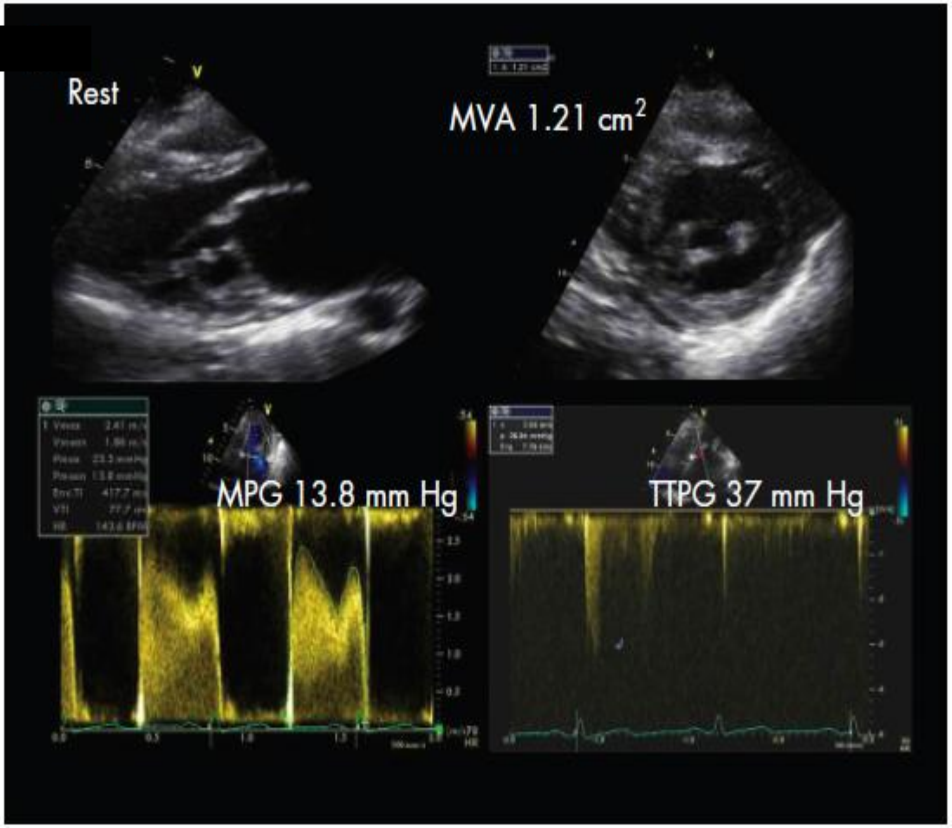
Stress Echo in MS

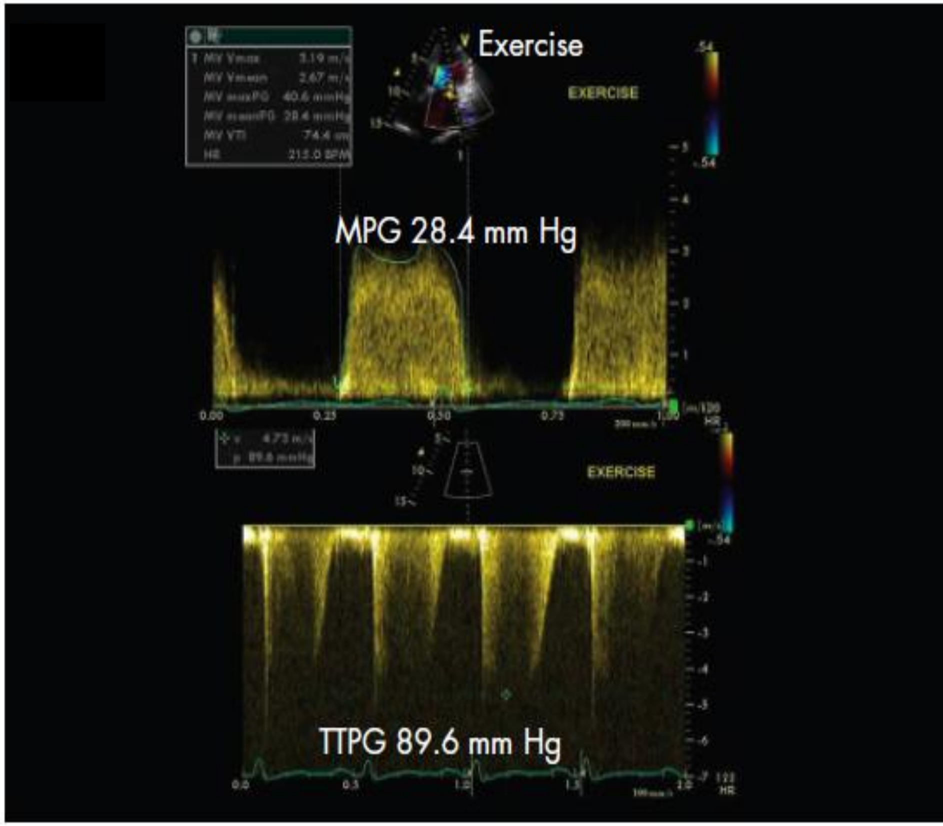


CAVEATS

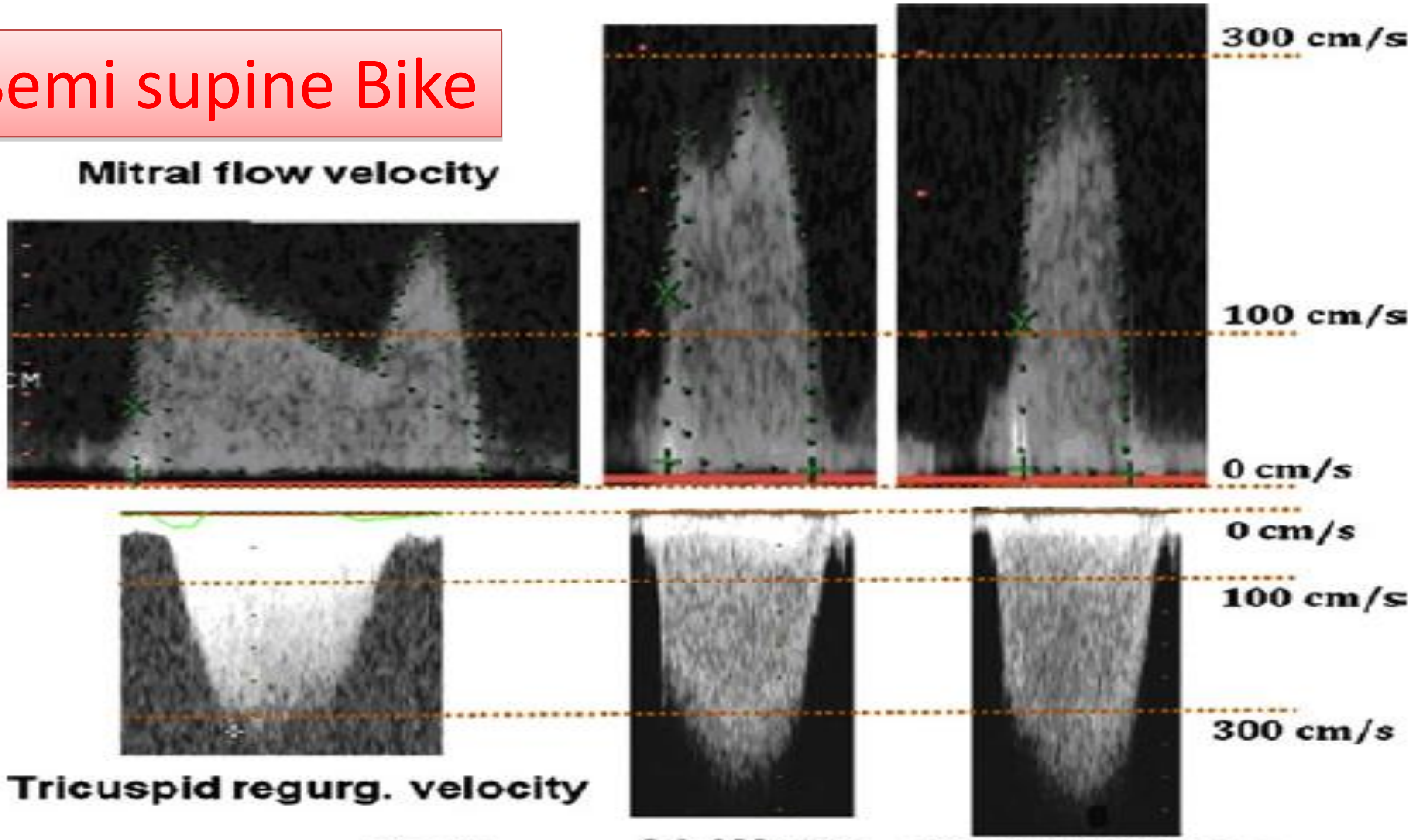
1. Atrial fibrillation : importance of averaging
2. Avoidance of use of pressure half time which can be shortened with tachycardia
3. Presence of cocomitant mitral regurgitation which may increase gradient and PA pressure

Exercise Echo in MS





Semi supine Bike



	Rest	30-Watts	Peak Exercise
HR (b/min):	55	116	159
DFT (ms):	607	228	200
SV (ml):	66	59	57
Q_{mean} (ml/s):	109	259	284
ΔP_{mean} (mmHg):	5	23	27
TTPG (mmHg):	42	69	74

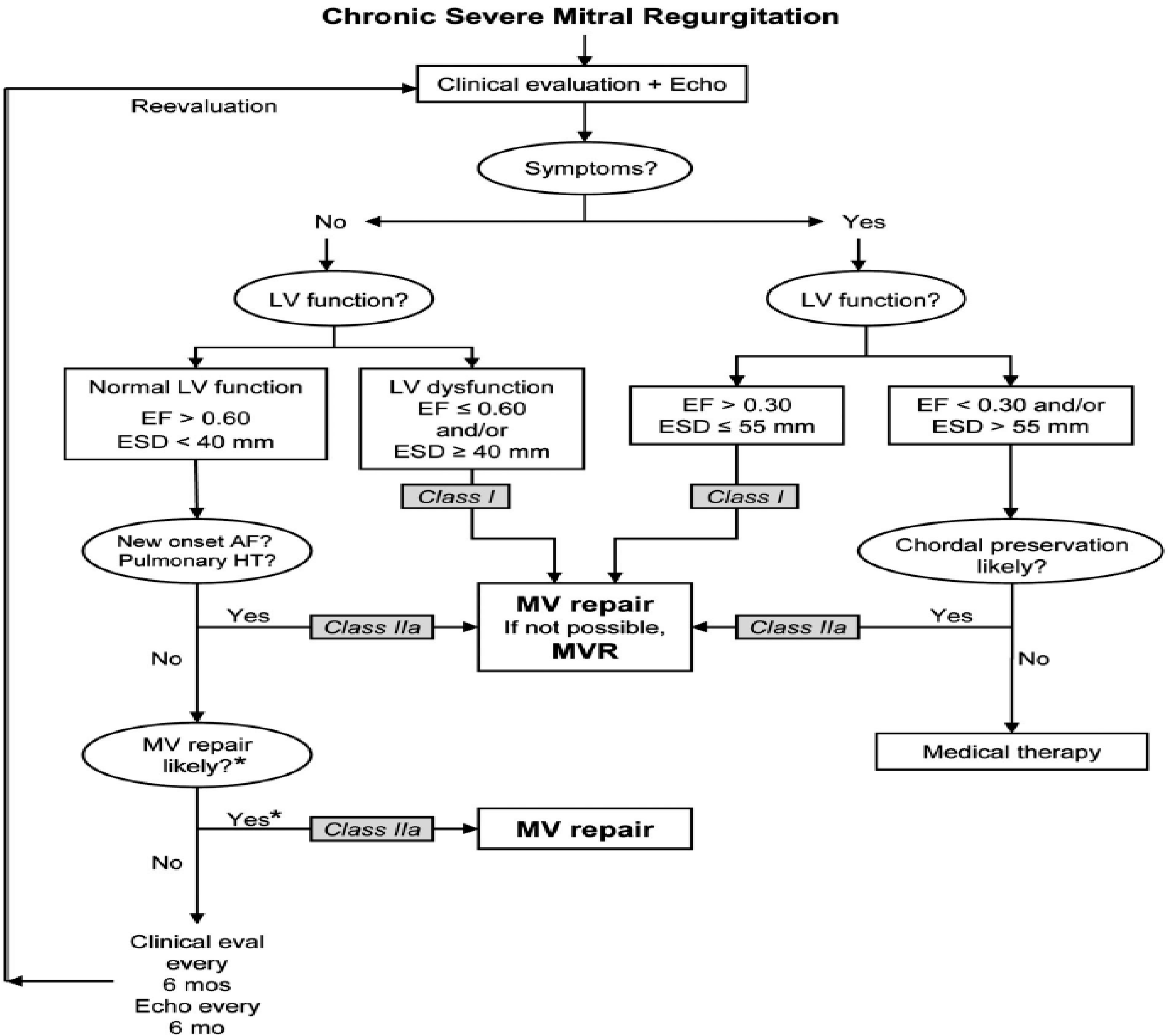
Stress Echo and Mitral Regurgitation

Known Severe MR

1. Look for Exercise capacity
2. Pulmonary HTN new / worse
3. LV response

Mild or No MR and Unexplained Dyspnea, Pulmonary HTN

1. Exercise capacity
2. New or worsening MR
3. Worsening Pul HTN
4. LV response



Chronic Severe Mitral Regurgitation
Clinical evaluation + Echo
Reevaluation
Symptoms?
No
Yes
LV function?
LV function?
Normal LV function
EF > 0.60
ESD < 40 mm
LV dysfunction
EF ≤ 0.60
and/or
ESD ≥ 40 mm
EF > 0.30
ESD ≤ 55 mm
EF < 0.30 and/or
ESD > 55 mm
Class I
Class I
New onset AF?
Pulmonary HT?
Chordal preservation
likely?
Yes
Class IIa
MV repair
If not possible,
MVR
Class IIa
Yes
No
No
MV repair
likely?*
Medical therapy
Yes*
Class IIa
MV repair
No
Clinical eval
every
6 mos
Echo every
6 mo

Class I (evidence and/or general agreement that surgery is useful and effective)

- Symptoms caused by mitral regurgitation (acute or chronic)
- Asymptomatic patients with severe MR and mild-moderate LV dysfunction defined as an:
  - –ejection fraction 30–60% **and**
  - –end systolic dimension 45–55 mm

Class IIa (conflicting evidence and/or divergence of opinion but the weight of evidence/opinion favours surgical intervention)

- Asymptomatic patients with normal LV function and
  - –atrial fibrillation **or**
  - –pulmonary hypertension (>50 mm Hg at rest or >60 mm Hg with exercise)
- Asymptomatic patients with
  - –ejection fraction 50–60% **or**
  - –end systolic dimension 45–55 mm
- Severe left ventricular systolic dysfunction (ejection fraction <30% and/or end systolic dimension >55 mm) if chordal preservation is highly likely

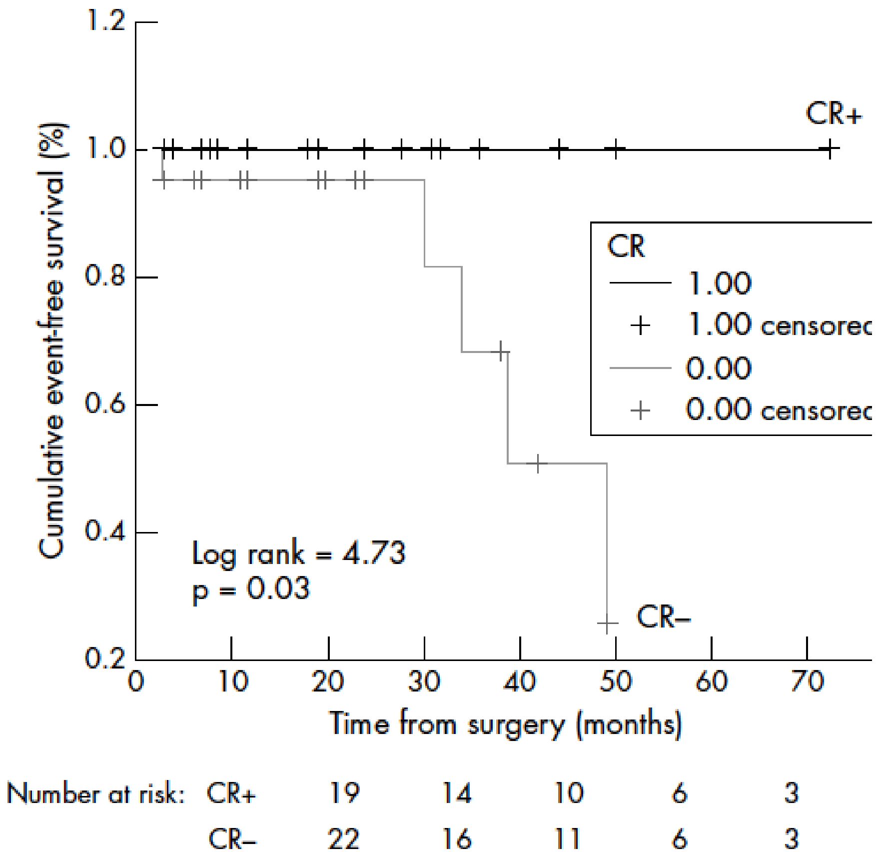
Indications MITRAL REGURGITATION	Stress Data	Parameters	Impact on Outcome	Impact of decision making ESC and ACC Guidelines
Asymptomatic MR	Clinical Echo	-Exercise capacity -Symptoms PASP > 60 mm hg with exercise testing` Increase in ERO >/=10 sq mm Increase in EF < 4 % Increase in LVESV index > 25ml/sq m increase in GLS < 1.9%	Development of symptoms reduced symptom free survival post-op LV dysfunction cardiac morbidity deterioration of LV function	ACC 2A
Symptomatic MR	Echo	PASP > 60mm hg Severe MR during exercise		ACC 2b

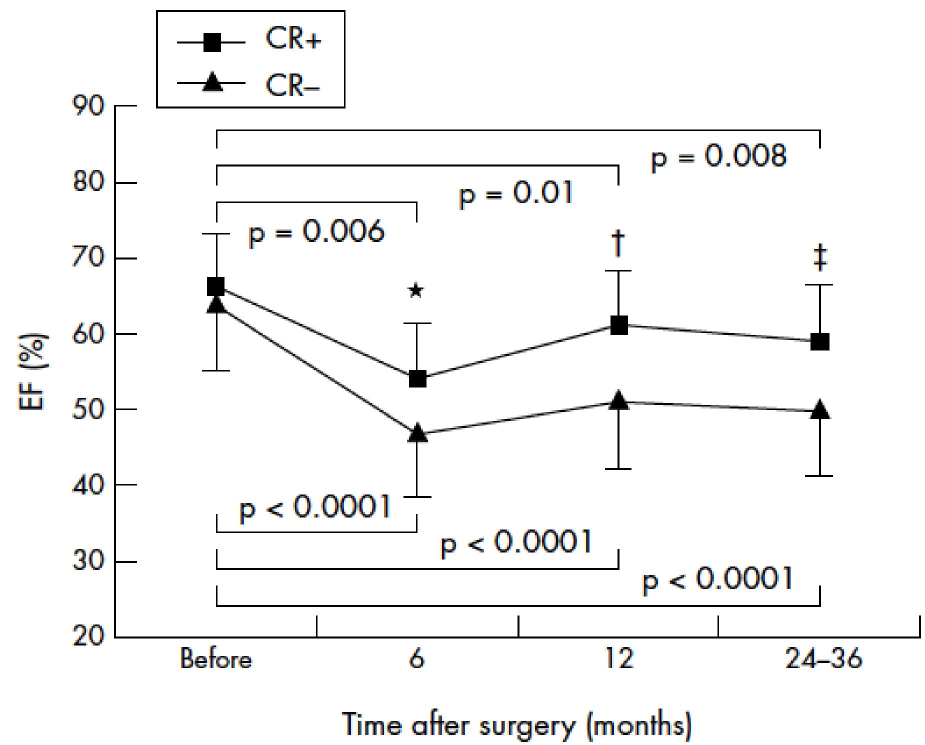
CARDIOVASCULAR MEDICINE

Functional and prognostic implications of left ventricular contractile reserve in patients with asymptomatic severe mitral regurgitation

R Lee, B Haluska, D Y Leung, C Case, J Mundy, T H Marwick

Heart 2005;91:1407–1412. doi: 10.1136/hrt.2004.047613





Stress Echo in Ischemic MR

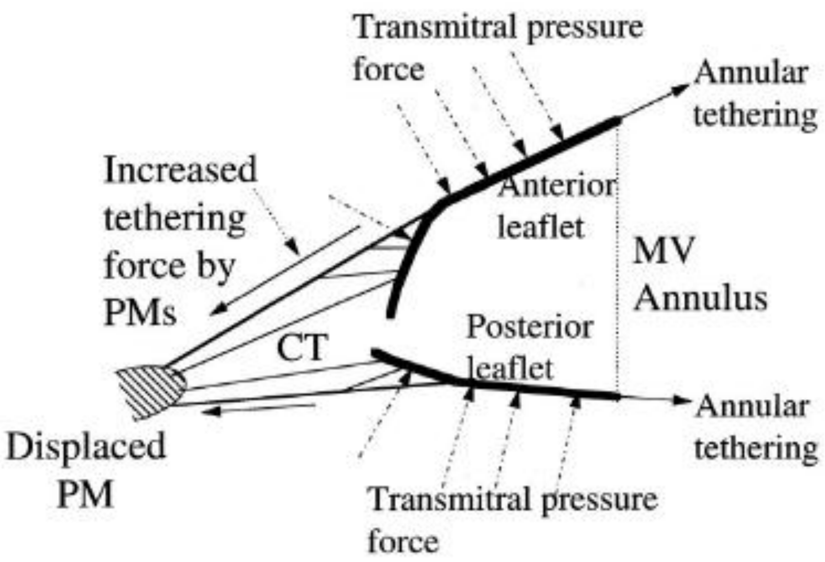
LV Parameters	Mitral Valve Deformation Parameters	MR Parameters
LVEDV LVESV LV EF Regional wall thickening Color TDI for dyssynchrony	Mitral annulus tenting area Coapation distance	ERO Regurgitant volume

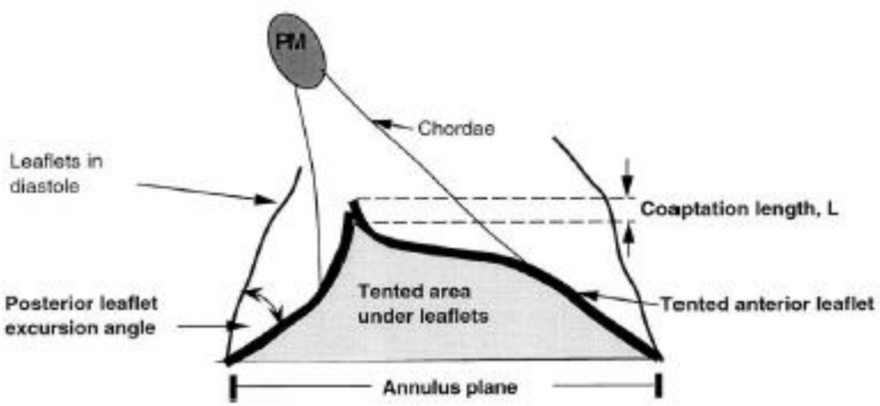
MR ERO changes with exercise correlate with exercise transtricuspid pressure gradient and increased ERO with exercise correlates with MACE in patients with LV dysfunction and mild MR at rest

Exercise echo can unmask severe MR and marked increase in PASP in patients with dyspnea and mild MR . ERO at rest does not correlate with dynamic changes in ERO with exercise

Lebrun F et al JACC 2001

Determinants of MV Dynamics

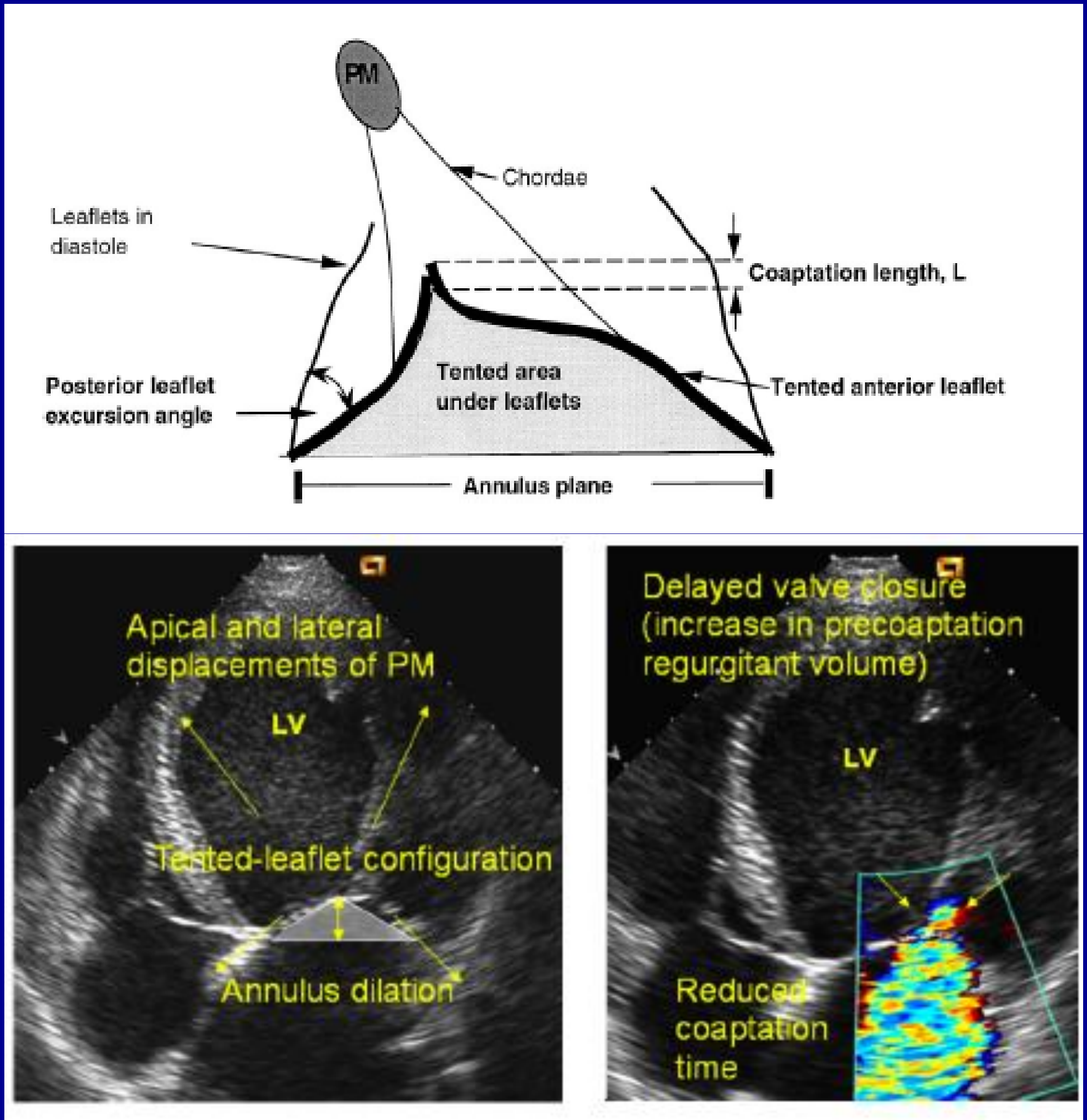


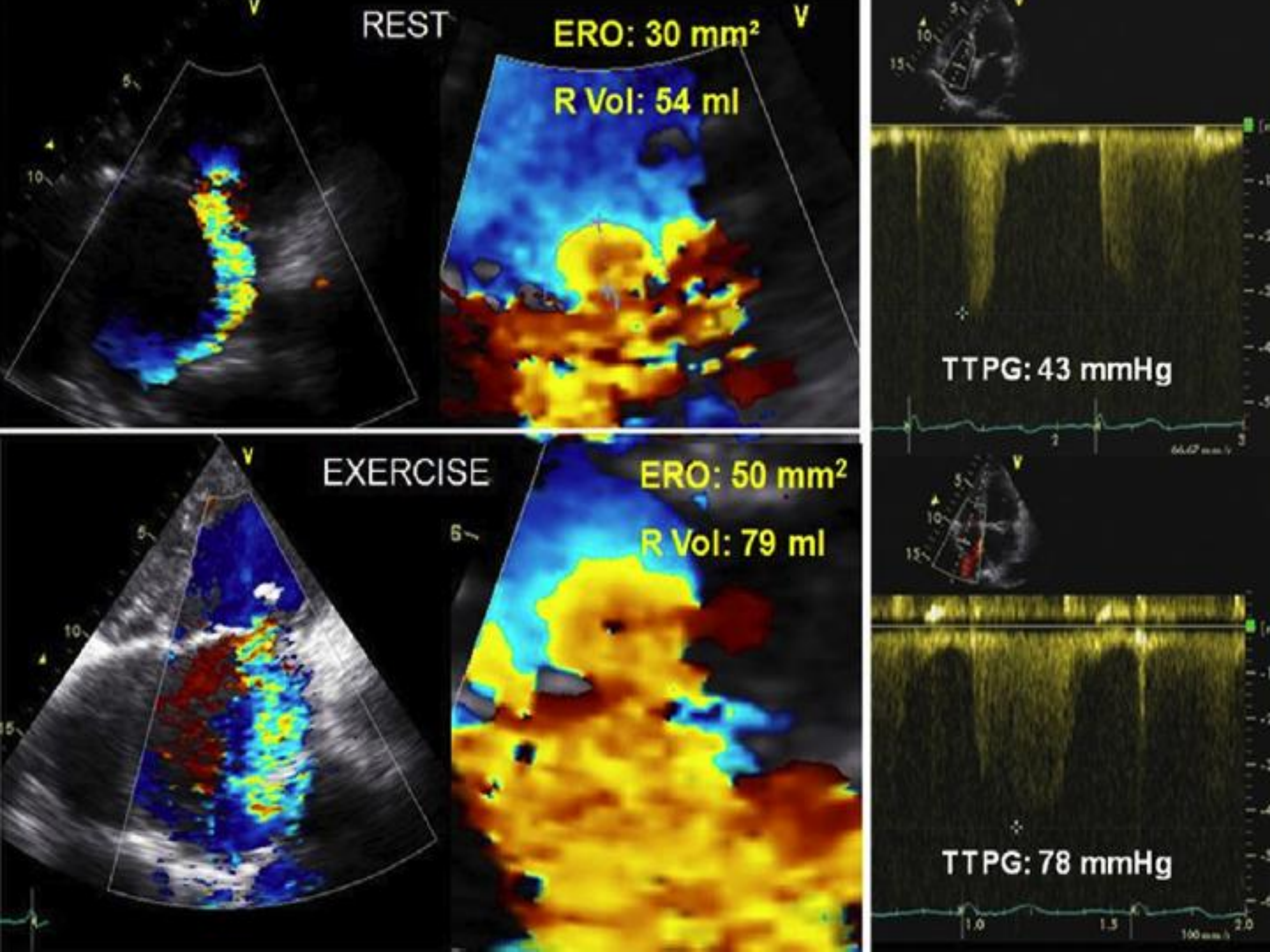


Characteristics of Exercise Induced Functional MR (FMR)

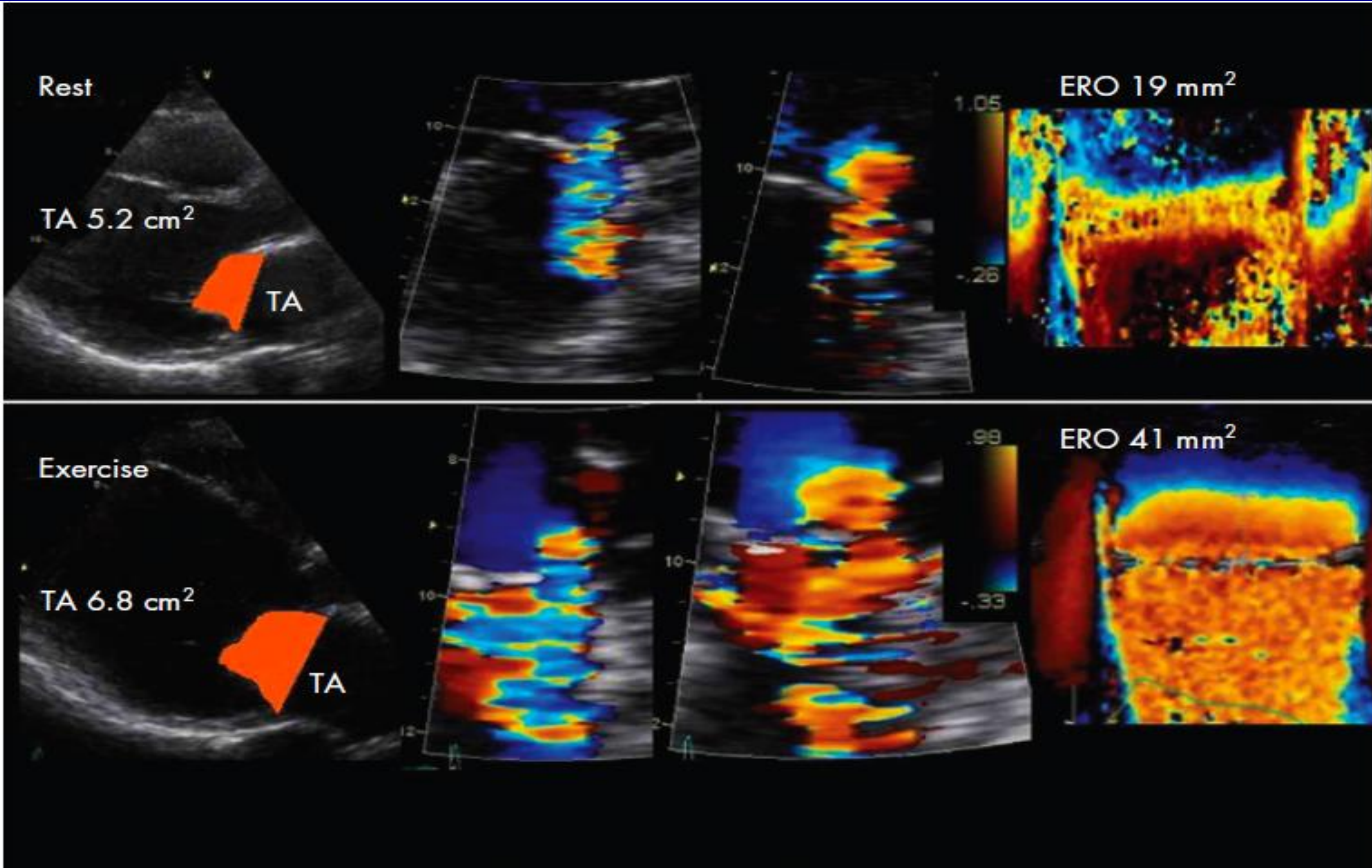
1. Greatly varies among patients
2. Des not correlated with FMR at rest
3. Does not correlate with LV dysfunction
4. Mainly correlates with changes in mitral valve deformation
5. Affected by local rather than global LV function and remodelling
6. Favorably affected by recruitable contractile reserve

Functional Mitral Regurgitation : Interplay of Dynamics



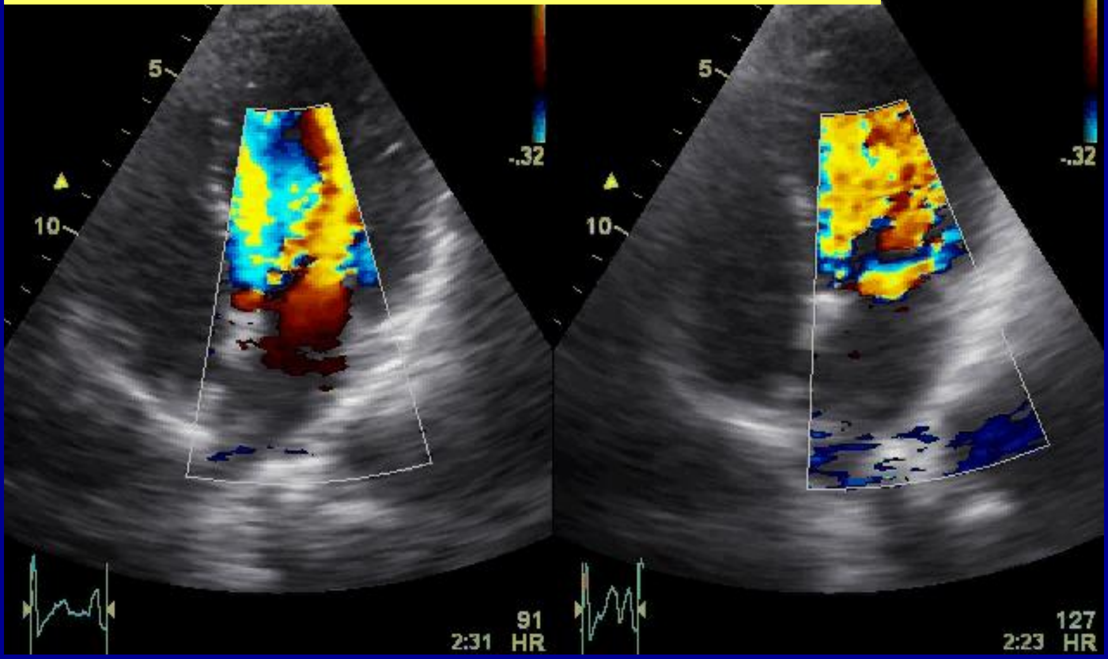

REST
ERO: 30 mm²
R Vol: 54 ml
TTPG: 43 mmHg
EXERCISE
ERO: 50 mm²
R Vol: 79 ml
TTPG: 78 mmHg

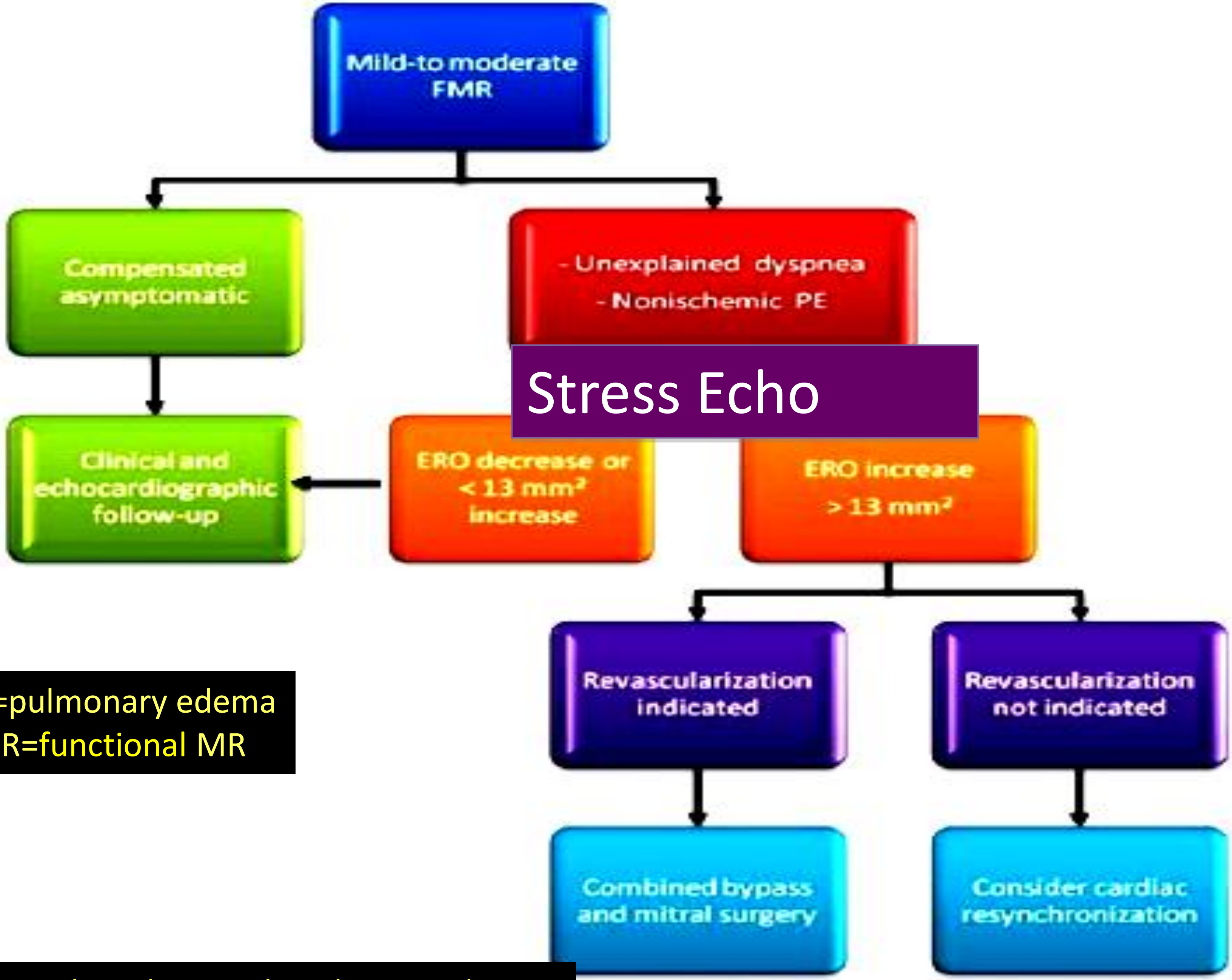
Exercise echo in Functional MR



Rest Stress Rest Stress

Rest Stress





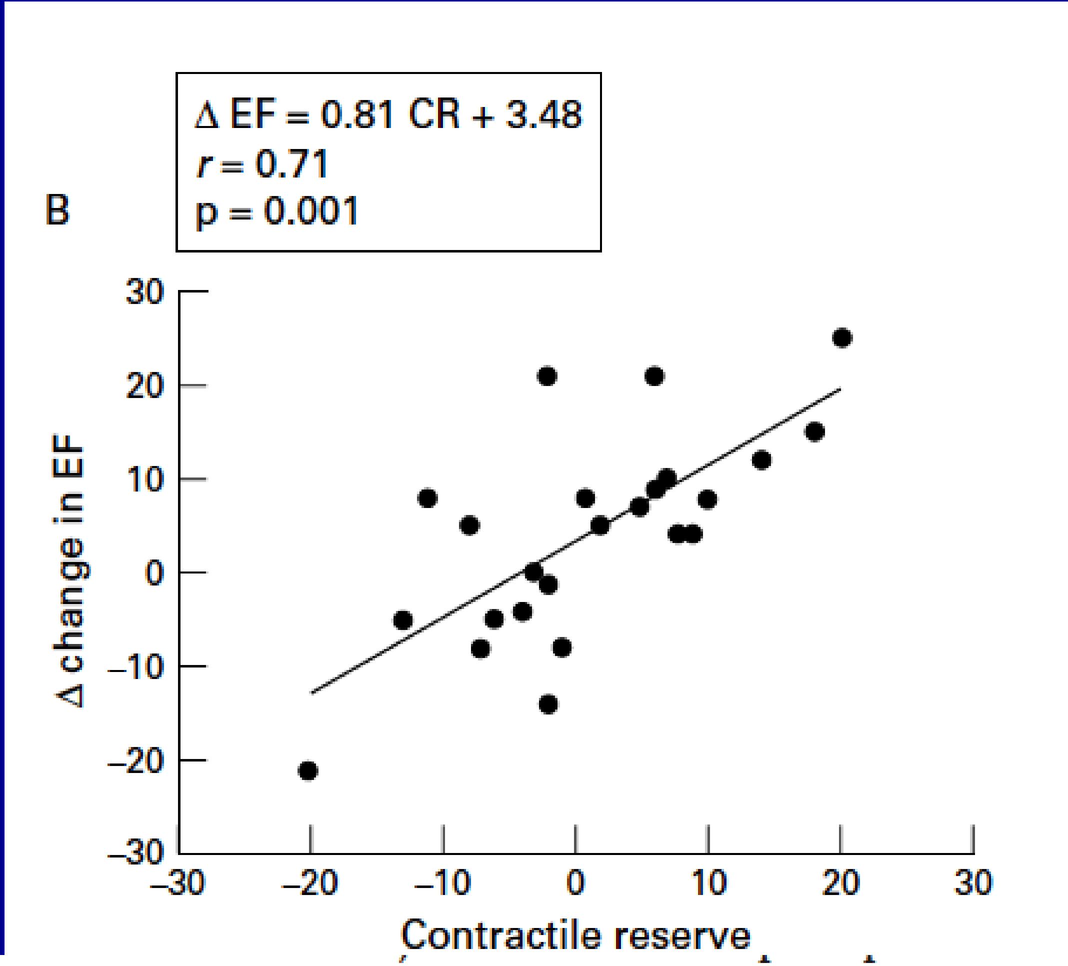
PE=pulmonary edema
FMR=functional MR

Bigi et al Cardiovascular Ultrasound 2009

Heart 2000;84:606–614

Exercise echocardiography predicts development of left ventricular dysfunction in medically and surgically treated patients with asymptomatic severe aortic regurgitation

S Wahi, B Haluska, A Pasquet, C Case, C M Rimmerman, T H Marwick



Conclusions—Contractile reserve on exercise echocardiography is a better predictor of left ventricular decompensation than resting indices in asymptomatic patients with aortic regurgitation. In patients undergoing aortic valve replacement, contractile reserve had a better correlation with resting ejection fraction on postoperative follow up. Measurement of contractile reserve may be useful to monitor the early development of myocardial dysfunction in asymptomatic patients with aortic regurgitation, and may help to optimise the timing of surgery.

(*Heart* 2000;84:606–614)

Stress Echo in AI

Predictors of LV Decompensation by Stress Echocardiography in Patients With Asymptomatic Severe AI and Normal LV Function*

	Measurements	P Value
Ejection fraction post exercise	Decrease >2%	0.001
FS post exercise	<48%	0.02
LV WS rest	>103 g/cm^2	0.02
LV WS post exercise	>88 g/cm^2	0.02

Stress Echo And Prosthetic Valves

Normal prosthetic valves inherently stenotic due to small EOA

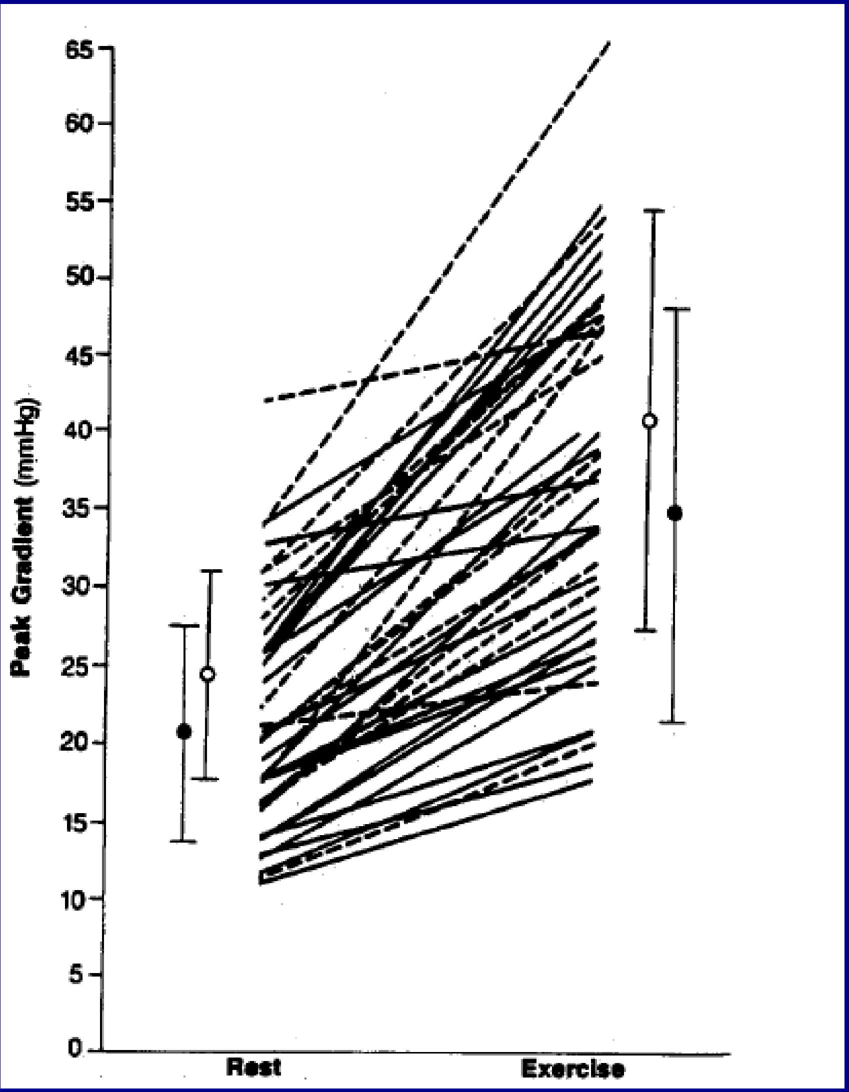
Type of prosthesis : mechanical versus bioprosthetic /stentless location and annulus size (aortic) determine gradients

Resting gradients tend to overlap for normal and abnormal functioning prosthesis many times

In general gradients across prosthetic valves will increase depending on transvalvular flow rate

The exaggerated /absolute percentage of increase maybe the most important factor provided by stress echo

Evaluation of St Jude and Medtronic Hall Prosthesis By Stress Echo



Small size of aortic prosthesis

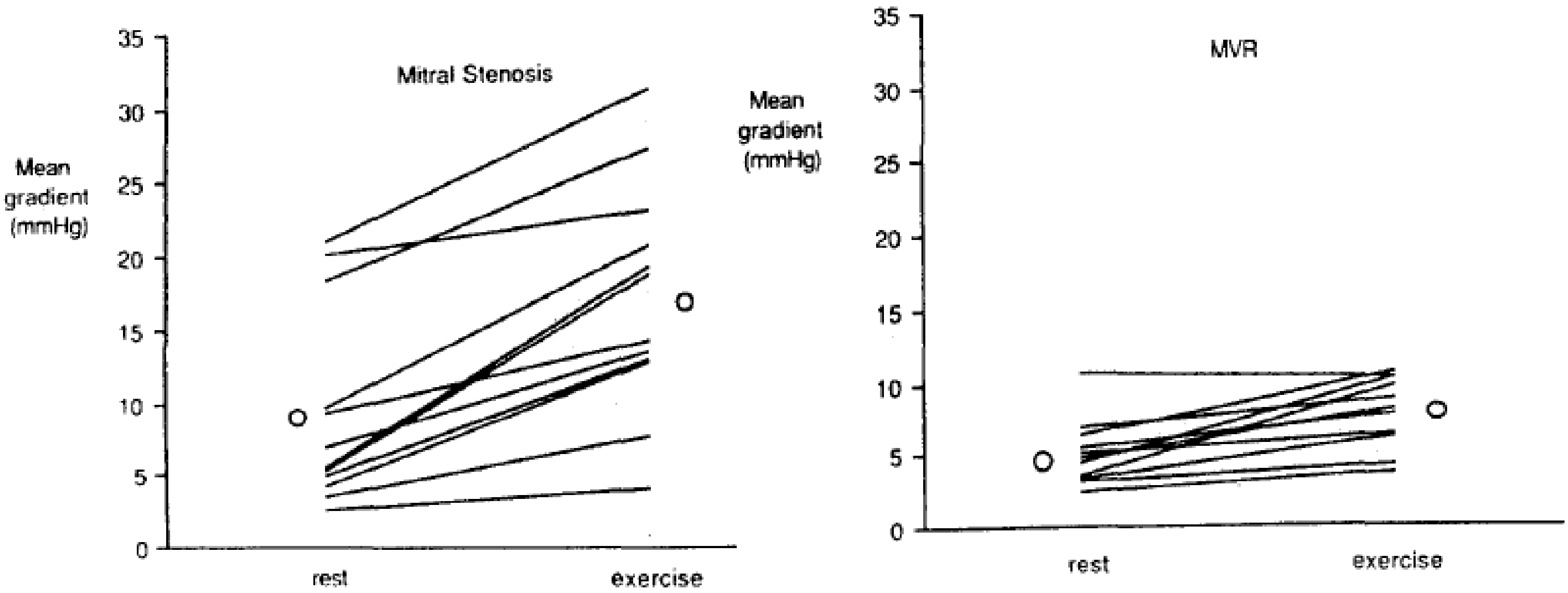
technical factors contributing to increased gradients across aortic prosthesis

Note that normal functioning aortic prosthesis can have substantial increases in gradient with exercise

Circulation 1989; 80;116-23

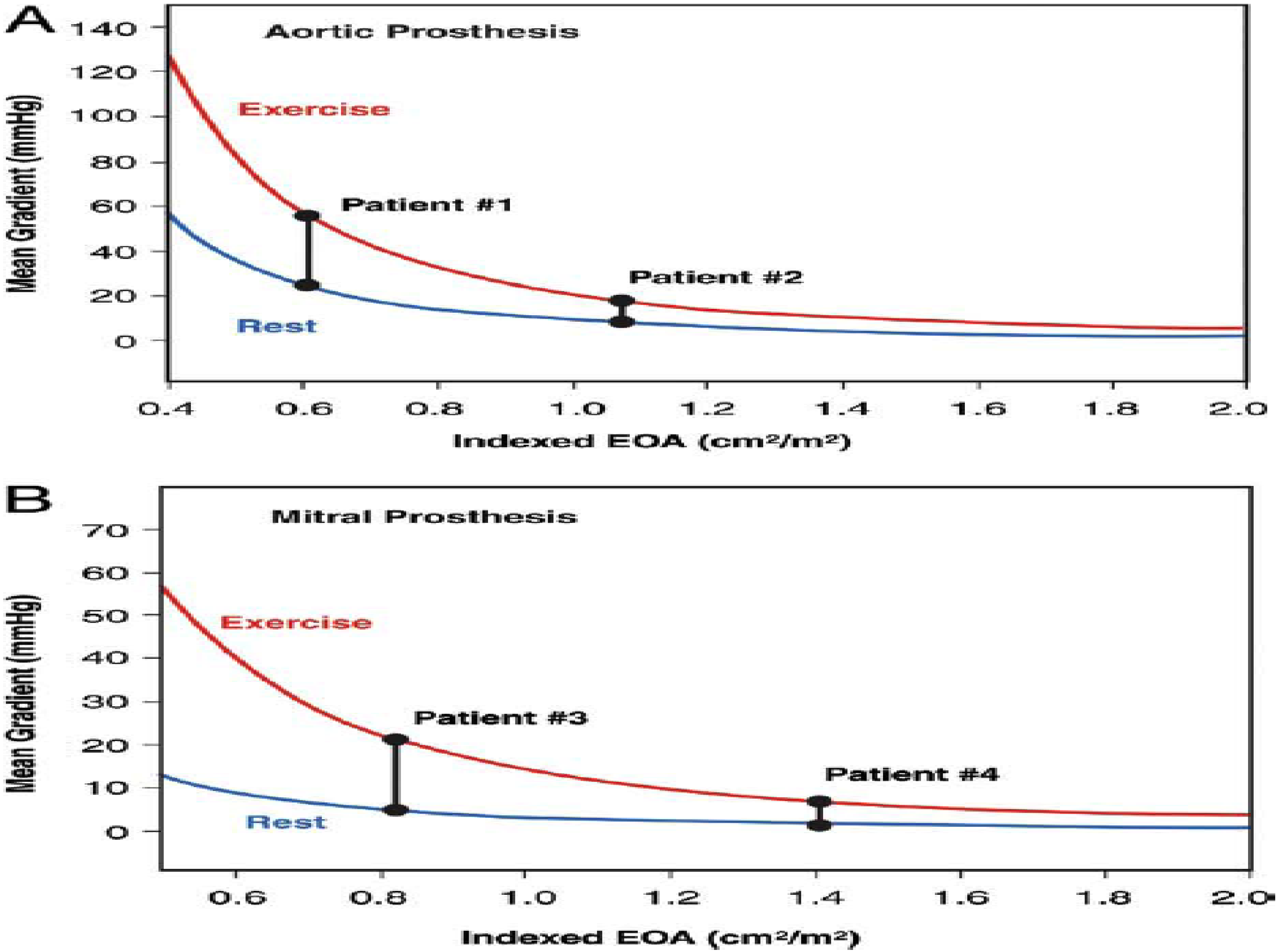
Exercise Gradients in MS and Post MVR with Normal Prosthetic function

JACC 1991;17;1520-26

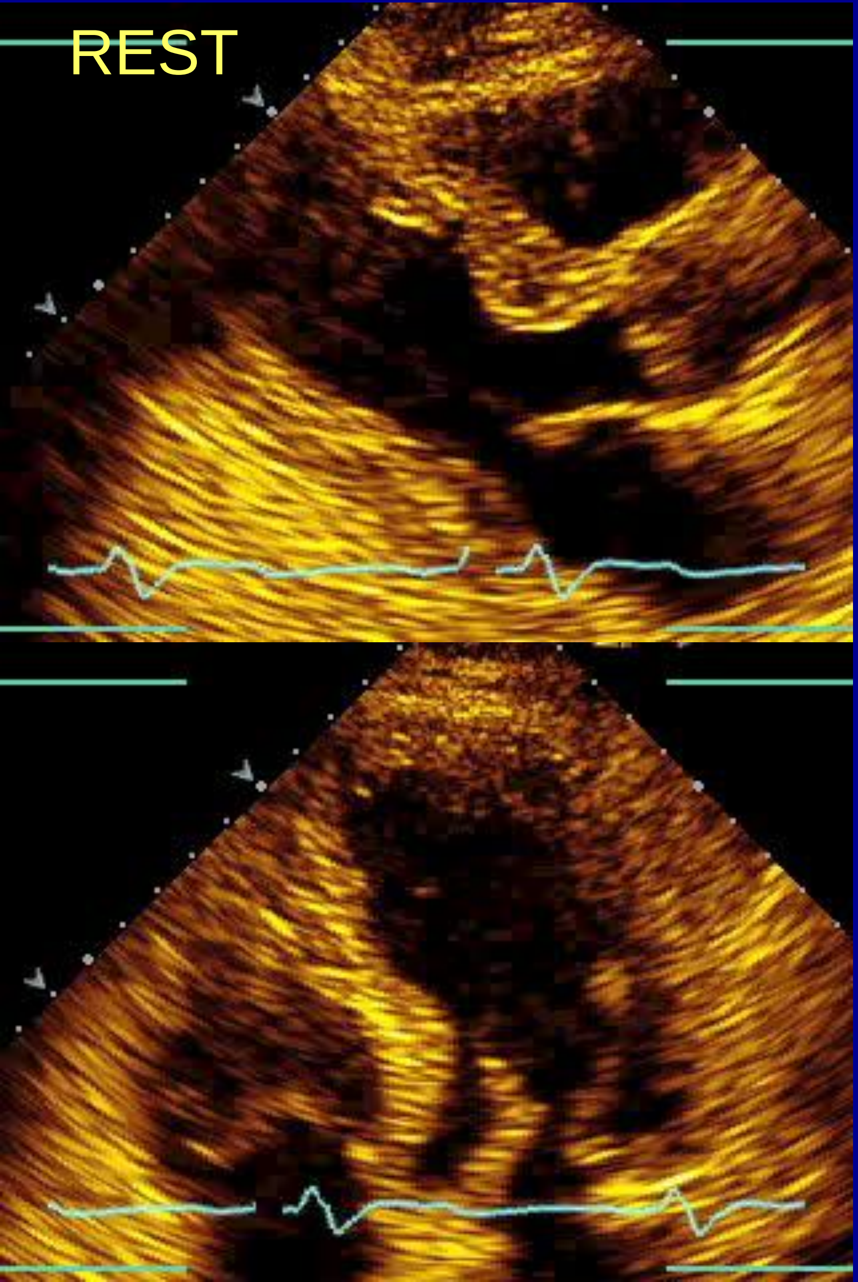


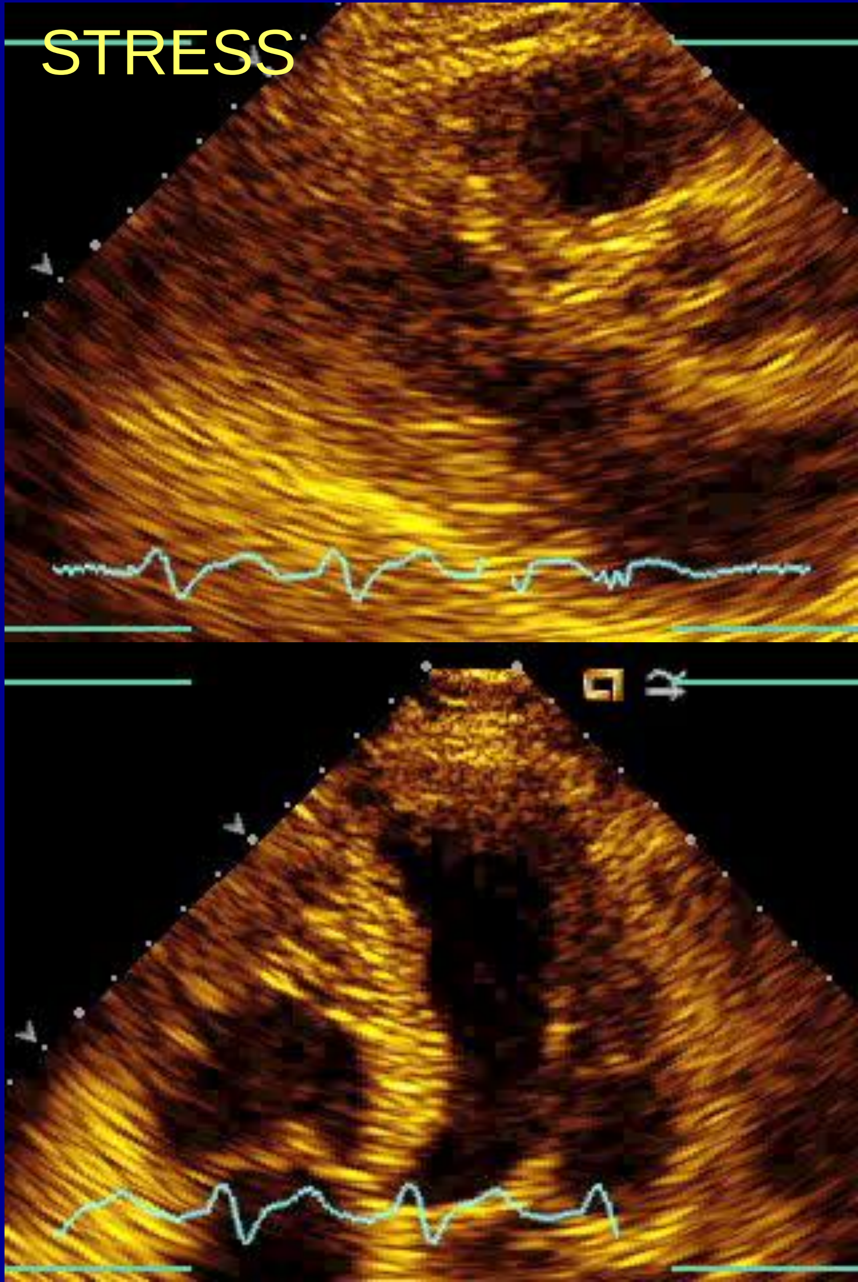
Normal increase of TMG is mild with no or mild increase in EOA by P1/2 time. A 100% or greater increase is likely pathological

van de Brink et al Am J Cardiol 1992


A
Aortic Prosthesis
Exercise
Patient #1
Patient #2
Rest
Mean Gradient (mmHg)
140
120
100
80
60
40
20
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Indexed EOA (cm²/m²)
B
Mitral Prosthesis
Exercise
Patient #3
Patient #4
Rest
Mean Gradient (mmHg)
70
60
50
40
30
20
10
0
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Indexed EOA (cm²/m²)

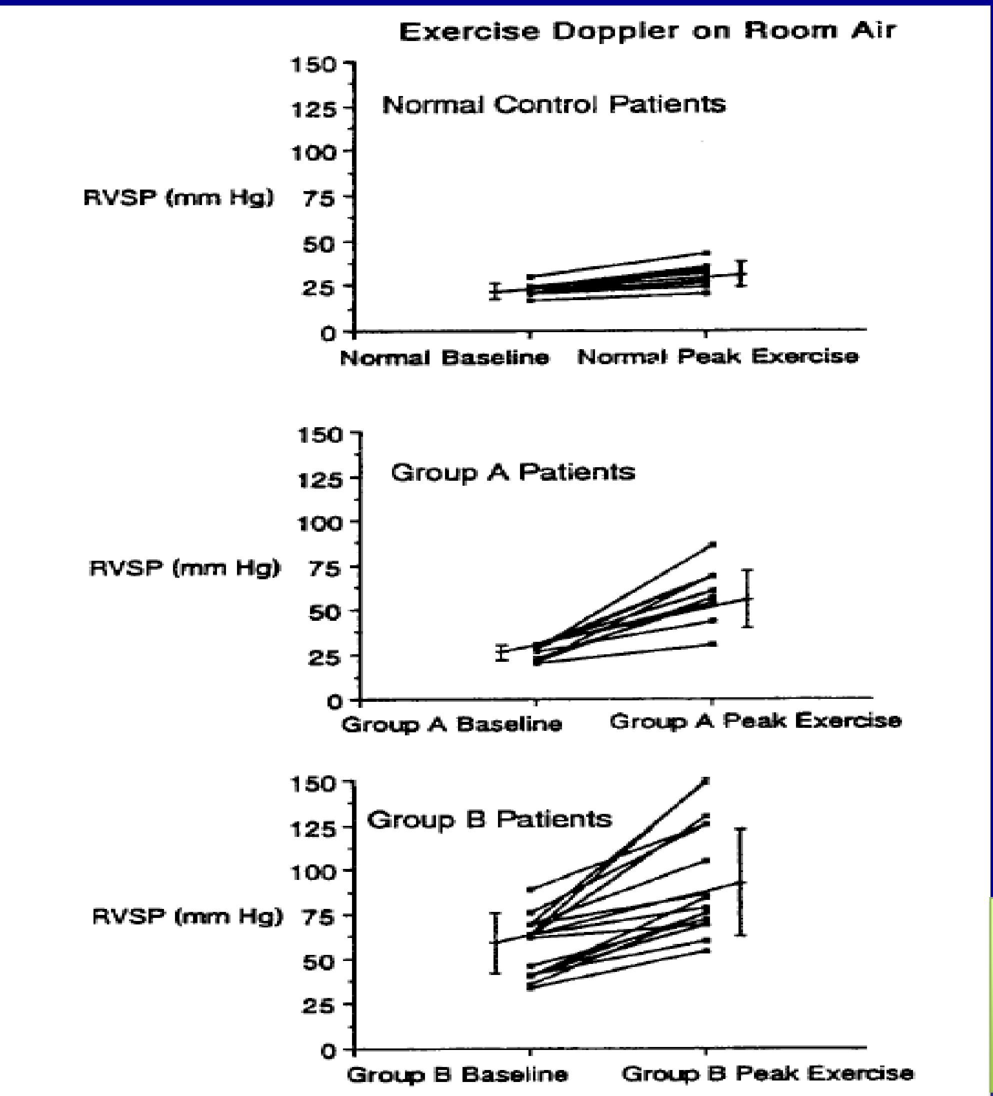
Stress Echo in HOCM





Kay Role of Stress Echo in HCM: provocation, hemodynamics, arrhythmias, worsening MR

Exercise Echo and Dyspnea Evaluation In Chronic Lung Disease



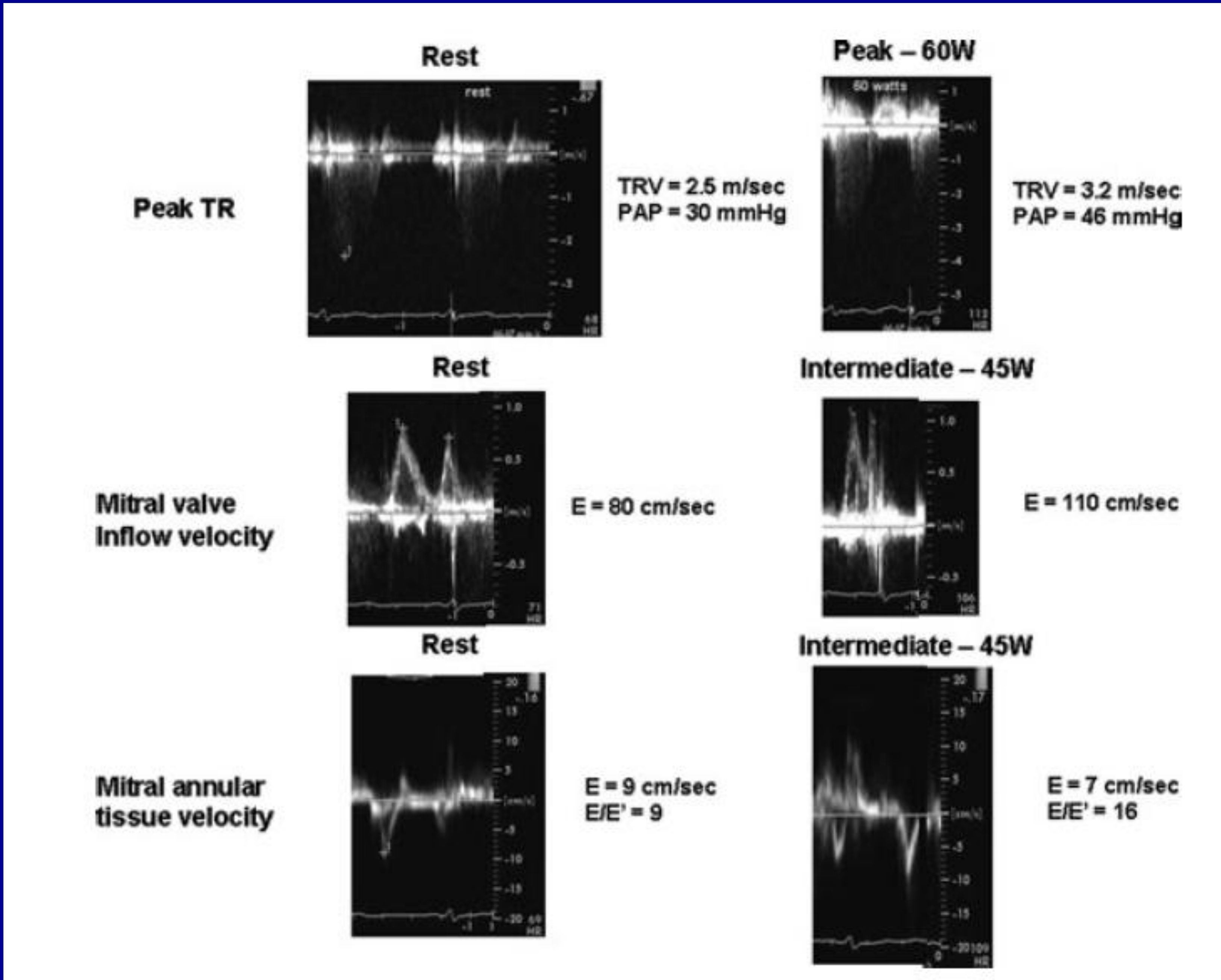
normal patients

chronic lung disease and normal resting PA pressures

chronic lung disease and abnormal resting PA pressures

Imp : regardless of PASP pts with chronic lung disease have exercise induced increase in PASP reflecting abnormal PVR

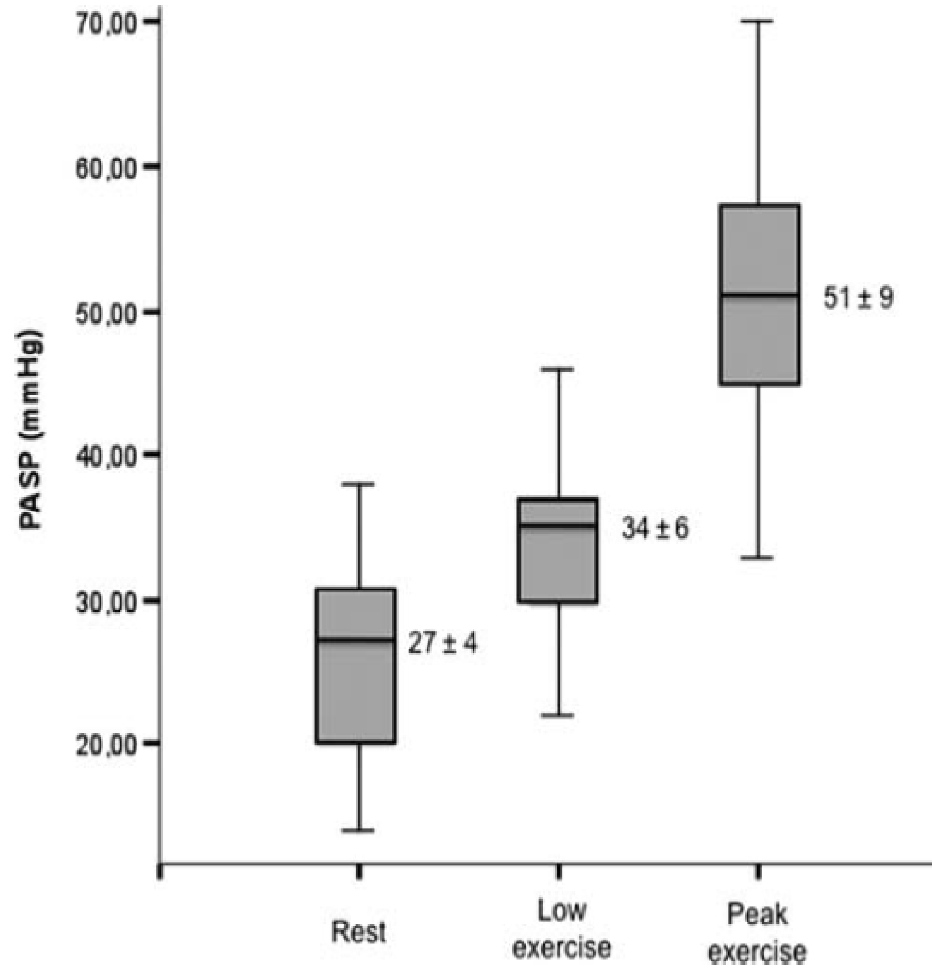
Exercise Echo in Dyspnea Evaluation



Effects of age on pulmonary artery systolic pressure at rest and during exercise in normal adults

Haïfa Mahjoub[1], Franck Levy[1], Mélanie Cassol[1], Patrick Meimoun[2], Marcel Peltier[1], Dan Rusinaru[1], and Christophe Tribouilloy[1]*

[1]*University Hospital, Cardiology Unit, 80054 Amiens Cedex, France; and* [2]*Department of Cardiology and Intensive Care Unit, Compiègne Hospital, 8 rue Henri Adnot, 60200 Compiègne, France*



Conclusion Pulmonary artery systolic pressure at peak exercise can reach values ≥60 mmHg in many healthy individuals older than 60 with good exercise capacity. However, high levels of PASP > 60 mmHg for low level of exercise should be considered abnormal.

European Journal of Echocardiography (2009) 10, 635–640

Dynamic Diastology
with Exercise

	E	E’	E/E’
Normal	⇧	⇧	⇔
⇧ **DFP**	⇧	⇔	⇧

DFP ***diastolic filling pressure***

THANK YOU

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