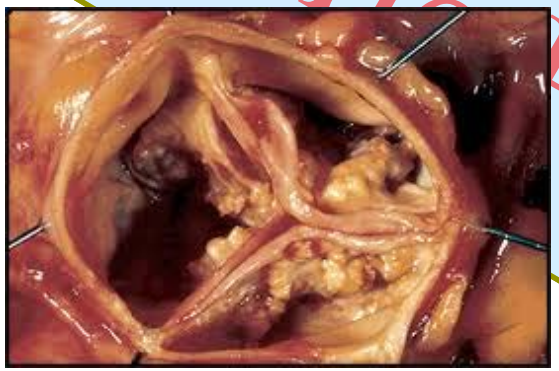
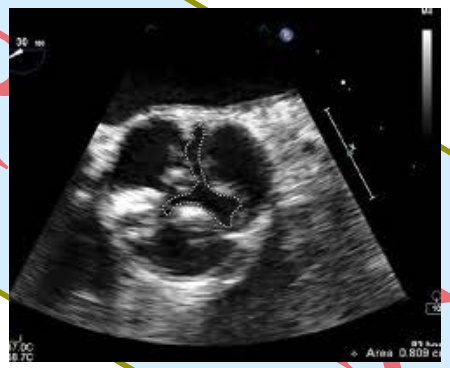
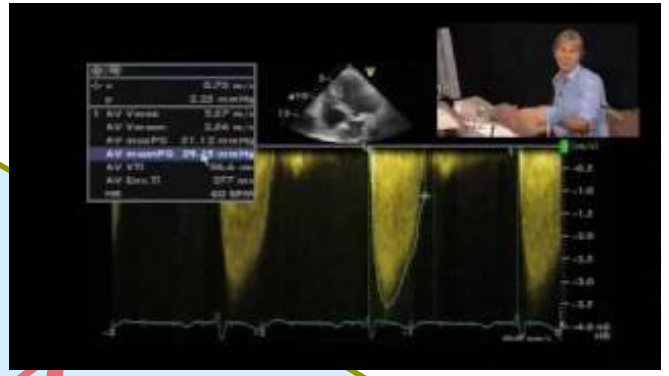
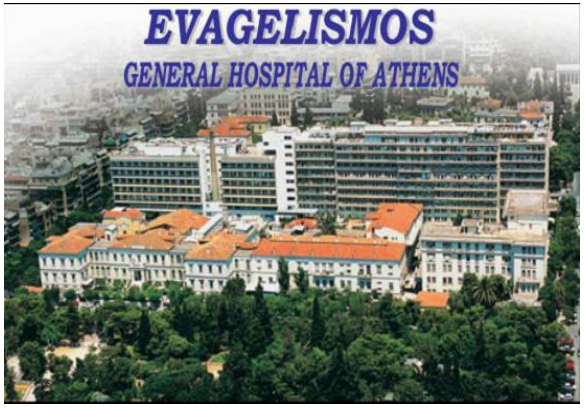
Υπερηχογραφική εκτίμηση ασθενών με Στένωση Αορτής







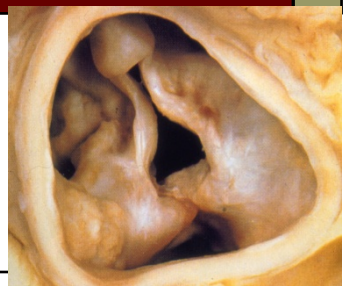


ΕΦΗ Γ. ΡΟΥΣΚΑ

Καρδιολογικό Τμήμα Γ.Ν.Α. ΕΥΑΓΓΕΛΙΣΜΟΣ
Συντονιστής Διευθυντής: ***Καθηγητής Αντ. Μανώλης***

Grand Rounds Καρδιολογίας 2013-2014

Aortic stenosis



In western populations : the most frequent valvular heart disease

- 25% of people aged over 65 have AoV thickening
- 3% aged over 75 have severe stenosis

Around 16% of pts with sclerosis progress to stenosis within 7 yrs

Severe AS remains asymptomatic for many years

Once spontaneous symptoms develop, mortality rises sharply

and the median survival is : 4,5 yrs with exertional chest pain

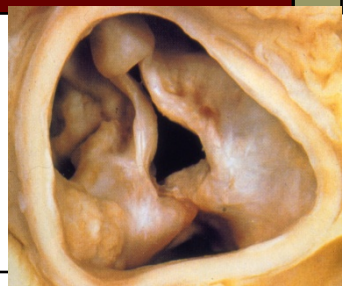
2,6 yrs with exertional dizziness

1 yr with overt heart failure

Circulation. 2010;121:151-156

European Journal of Echocardiography (2009) **10**, i11–i19

Aortic stenosis



- Rate of progression varies but
  - average reduction in AVA is **0,12cm2 each year**
  - average increase in AV Vmax is **0,32m/sec each year**
  - average increase in AV PG is **7mmHg each year**

- The **mortality** is not linear and is around **10% in the first 6 months after the start of symptoms**

- **Exercise test is increasingly used** to reveal occult symptoms in younger pts at low surgical risk

Heart 2009;**95**:877–884. doi:10.1136/hrt.2008.150011
European Journal of Echocardiography (2009) **10**, i11–i19

The art of assessing aortic stenosis

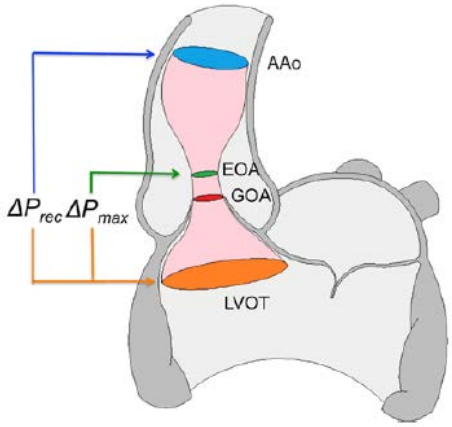
Ronak Rajani, Jane Hancock, John B Chambers

Review

- The **nature of AS has evolved**, pts older – with comorbidities and harder to assess
- Need to assess **ventricle-AoV-aortic coupling** rather than the AoV alone
- Need to assess the **effect of exercise**
- Take account of **biomarkers of cardiac function**, notably BNP
- Trend towards **multi-modality imaging**
  with Echocardiography providing flow data,
  while MDCT gives more accurate anatomical data
  (CMR is not in routine clinical use yet /can provide both anatomical and hemodynamic measurements and full 3-D information)

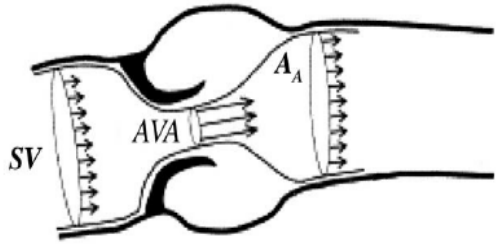
Heart 2012;**98**:iv14–iv22.

Echocardiography remains the mainstay of assessment



The grading of the stenosis and the decision for surgery may often be **influenced by the rest of the heart,**

particularly **the LV** and **the Aorta!**



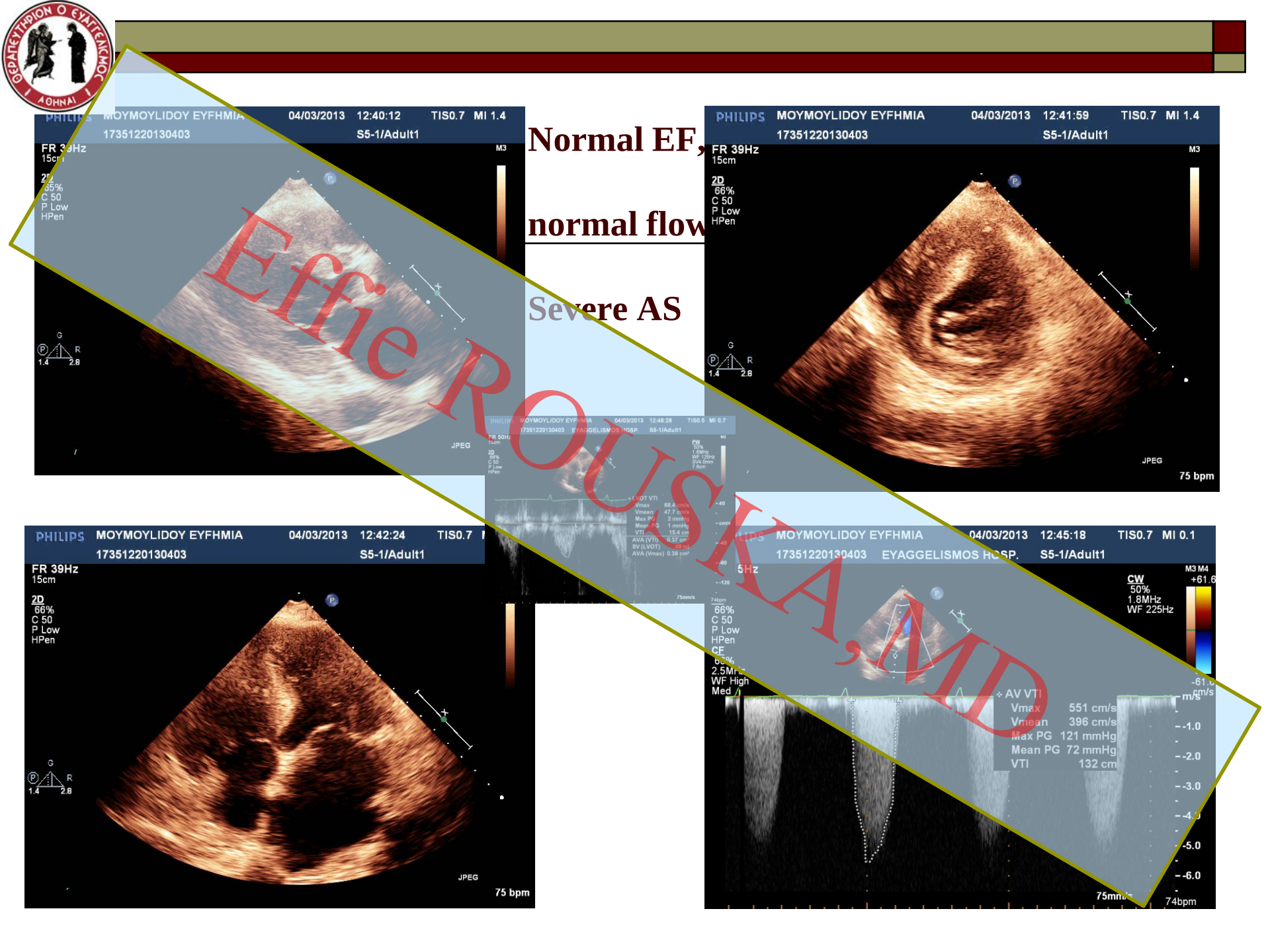
Circulation **2013;127:1149-1156**

Current Cardiology Reports 2008, **10:**91–97

Echocardiographic Criteria for the definition of severe AS

	Aortic Sclerosis	Mild	Moderate	Severe
Aortic jet velocity (m/s)	≤ 2.5 m/s	2.6 -2.9	3.0 - 4	> 4
Mean gradient (mm Hg)		<20[b] <30[a]	20 – 40[b] 30 -50[a]	> 40
AVA (cm^2)		> 1.5	1.0 -1.5	< 1.0
Indexed AVA (cm^2/m^2)		> 0.85	0.60 – 0.85	< 0.6
Velocity ratio		> 0.50	0.25 – 0.50	< 0.25

(a.ESC – b. AHA/ACC)


Normal EF,
normal flow
Severe AS
Effie ROUSKA,MD
PHILIPS MOYMOYLIDOY EYFHMIA 04/03/2013 12:40:12 TIS0.7 MI 1.4
17351220130403 S5-1/Adult1
PHILIPS MOYMOYLIDOY EYFHMIA 04/03/2013 12:41:59 TIS0.7 MI 1.4
17351220130403 S5-1/Adult1
FR 39Hz
15cm
2D
66%
C 50
P Low
HPen
M3
JPEG
75 bpm
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17351220130403 S5-1/Adult1
PHILIPS MOYMOYLIDOY EYFHMIA 04/03/2013 12:45:18 TIS0.7 MI 0.1
17351220130403 EYAGGELISMOS HOSP. S5-1/Adult1
CW
50%
1.8MHz
WF 225Hz
CF
WF High
Med
AV VTI
Vmax 551 cm/s
Vmean 396 cm/s
Max PG 121 mmHg
Mean PG 72 mmHg
VTI 132 cm
75mm/s
74bpm

3-D TEE

European Journal of Echocardiography (2010) **11**, 9–13

Special attention in grading severity of AS

In cases of…..

- AR (mixed AoV disease)
- anemia

Inconsistencies in AS assessment by current guidelines: *is it common?*

Inconsistent grading of aortic valve stenosis by current guidelines: haemodynamic studies in patients with apparently normal left ventricular function

Jan Minners, Martin Allgeier, Christa Gohlke-Baerwolf, Rolf-Peter Kienzle, Franz-Josef Neumann, Nikolaus Jander

Heart 2010;**96**:1463–1468

ORIGINAL ARTICLE

Inconsistent echocardiographic grading of aortic stenosis: is the left ventricular outflow tract important?

Hector I Michelena,[1] Edit Margaryan,[1] Fletcher A Miller,[1] Mackram Eleid,[1] Joseph Maalouf,[1] Rakesh Suri,[2] David Messika-Zeitoun,[3] Patricia A Pellikka,[1] Maurice Enriquez-Sarano[1]

Michelena HI, *et al. Heart* 2013;**99**:921–931

Echocardiographic severity grading in aortic stenosis:

Editorial

only lessons towards patient individualisation…

Michelena HI, Pibarot P,Enriquez-Sarano M . Heart January **2014** Vol 100 No 1

LGSAS

- 1)**Low gradient, low EF AS**

- **2) Paradoxical low-flow, low-gradient severe AS, despite preserved EF**

LGSAS

- Pressure overload causes
  LV remodelling, then ***hypertrophy*** and ***ultimately cavity dilatation*** develops

- There is a wide variation in LV geometry and function
  in relation to wall stress

- This is an important relationship.
  It means that a low LVEF need not imply a "poor" LV.
  The LV with a low EF is using its energy to overcome the resistance of the AoV
  rather than to eject a normal volume of blood at normal flow rates.
  The EF is expected to return towards normal after AVR.

- This condition was first described in 1980 by Carabello et al and
  has been termed "low flow, low-gradient AS".
  A more appropriate term might be **LGSAS**

European Journal of Echocardiography (2009) **10**, i11–i19

JACC: CARDIOVASCULAR IMAGING, VOL. 6, NO. 2, 2013

FEBRUARY 2013:184–95

EAE/ASE Guidelines for the diagnosis of **LGSAS**

	Units	Formula / Method	Cutoff for Severe	Concept	Advantages	Limitations
LV % Stroke Work Loss [27]	%	$\%SWL = \frac{\overline{\Delta P}}{\Delta V \cdot SBP} \cdot 100$	25	Work of the LV wasted each systole for flow to cross the aortic valve, expressed as a % of total systolic work	Very easy to measure. Related to outcome in one longitudinal study.	Flow-dependent. Limited longitudinal data
Recovered Pressure Gradient [13, 32]	mm Hg	$P_{distal} - P_{vc} = 4 \cdot v^2 \cdot 2 \cdot \frac{AVA}{AA} \cdot \left(1 - \frac{AVA}{AA}\right)$	-	Pressure difference between the LV and the aorta, slightly distal to the *vena contracta*, where distal pressure has increased.	Closer to the global hemodynamic burden caused by AS in terms of adaptation of the cardiovascular system. Relevant at high flow states and in patients with small ascending aorta.	Introduces complexity and variability related to the measurement of the ascending aorta. No prospective studies showing real advantages over established methods.
Energy Loss Index [35]	cm^2/m^2	$ELI = \frac{AVA \cdot AA}{AA - AVA} \Big/ BSA$	0.5	Equivalent to the concept of AVA, but correcting for distal recovered pressure in the ascending aorta	(As above) Most exact measurement of AS in terms of flow-dynamics. Increased prognostic value in one longitudinal study.	Introduces complexity and variability related to the measurement of the ascending aorta.
Valvulo-Arterial Impedance [31]	mm Hg/ml/m^2	$Z_{VA} = \frac{\overline{\Delta P_{net}} + SBP}{SVI}$	5	Global systolic load imposed to the LV, where the numerator represents an accurate estimation of total LV pressure	Integrates information on arterial bead to the hemodynamic burden of AS, and systemic hypertension is a frequent finding in calcific-degenerative disease.	Although named "impedance", only the steady-flow component (i.e. mean resistance) is considered. No longitudinal prospective study available.
Aortic Valve Resistance [28, 29]	dynes/s/cm [5]	$AVR = \frac{\overline{\Delta P}}{Q} = \frac{\overline{4 \cdot v^2}}{\cdot r_{LVOT}^2 \cdot \overline{v_{LVOT}}} \cdot 1333$	280	Resistance to flow caused by AS, assuming the hydrodynamics of a tubular (non flat) stenosis.	Initially suggested to be less flow-dependent in low-flow AS, but subsequently shown to not be true.	Flow dependence. Limited prognostic value. Unrealistic mathematic modelling of flow-dynamics of AS.
Projected Valve Area at Normal Flow Rate [30]	cm^2	$AVA_{proj} = AVA_{rest} + VC \cdot (250 - Q_{rest})$	1.0	Estimation of AVA at normal flow rate by plotting AVA vs. flow and calculating the slope of regression (DSE)	Accounts for the variable changes in flow during DSE in low flow low gradient AS, provides improved interpretation of AVA changes	Clinical impact still to be shown. Outcome of low-flow AS appears closer related to the presence / absence of LV contractility reserve.

Journal of the American Society of Echocardiography
January 2009

LGSAS

- 1)**Low gradient, low EF AS**
- 2) Paradoxical low-flow, low-gradient severe AS, despite preserved EF

1)Low gradient, low EF AS

- Low gradient, low EF AS represents about 5-10% of all cases of severe AS and is the most challenging subgroup of pts to manage

- This term is applied to pts with
  an AVmean PG <30 (40)mmHg, AVA<1cm2 and LVEF < 35(40)%

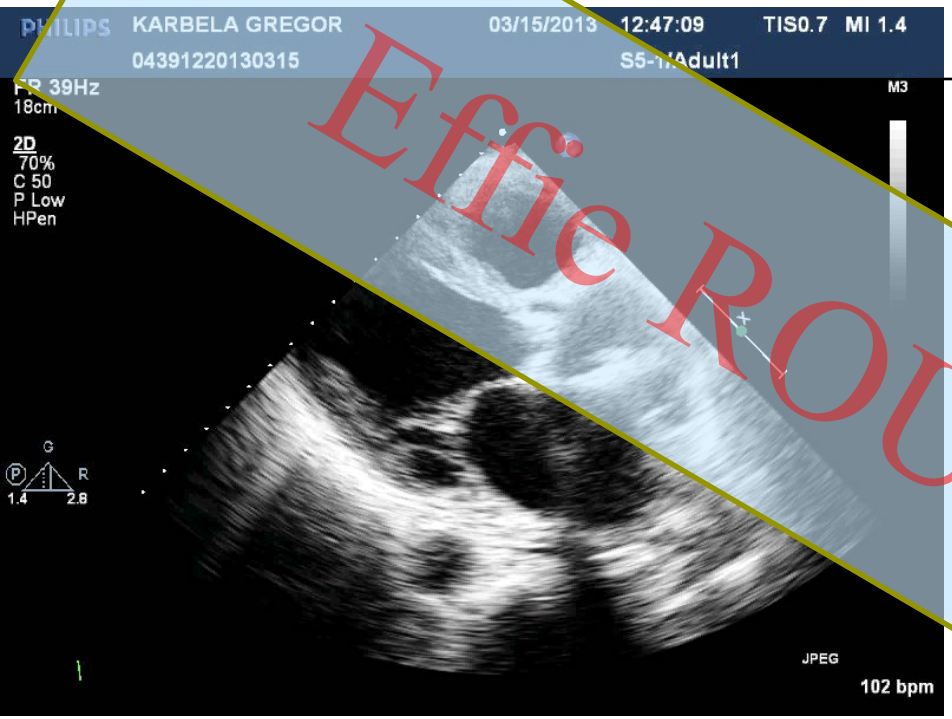
- The essential difficulty for clinicians is to distinguish
  true severe low flow AS, responsible for EF,
  from pseudo-severe AS comprising mild-to-moderate AS
  associated with another cause of LV dysfunction.

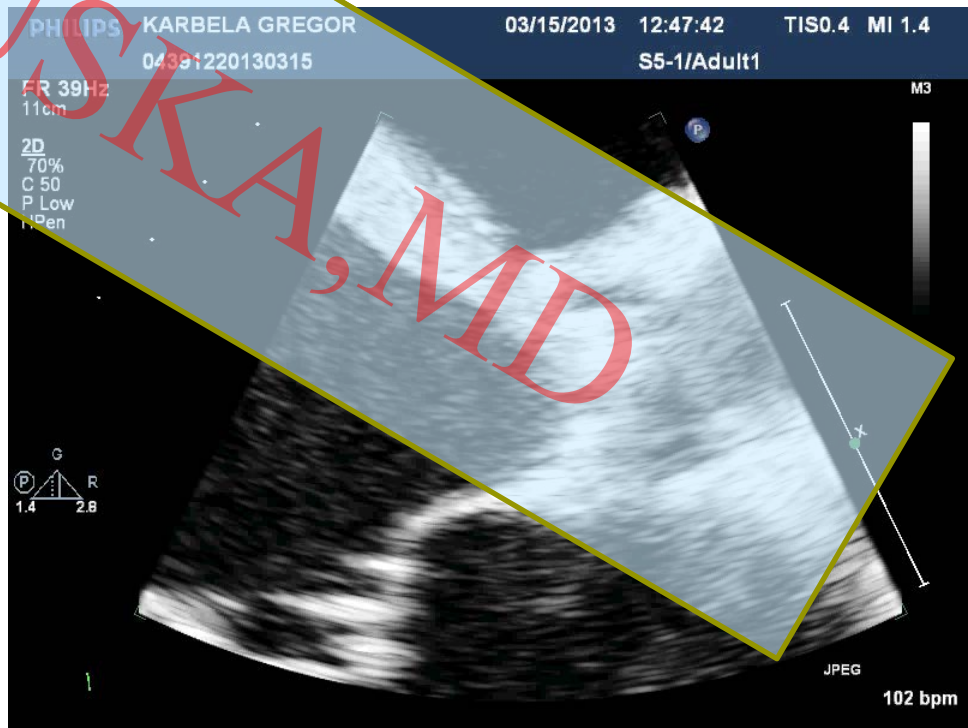
- The two main questions are:
  -How severe is AS?
  -Which pts can benefit from surgery?

Heart.2008;94(12):1526

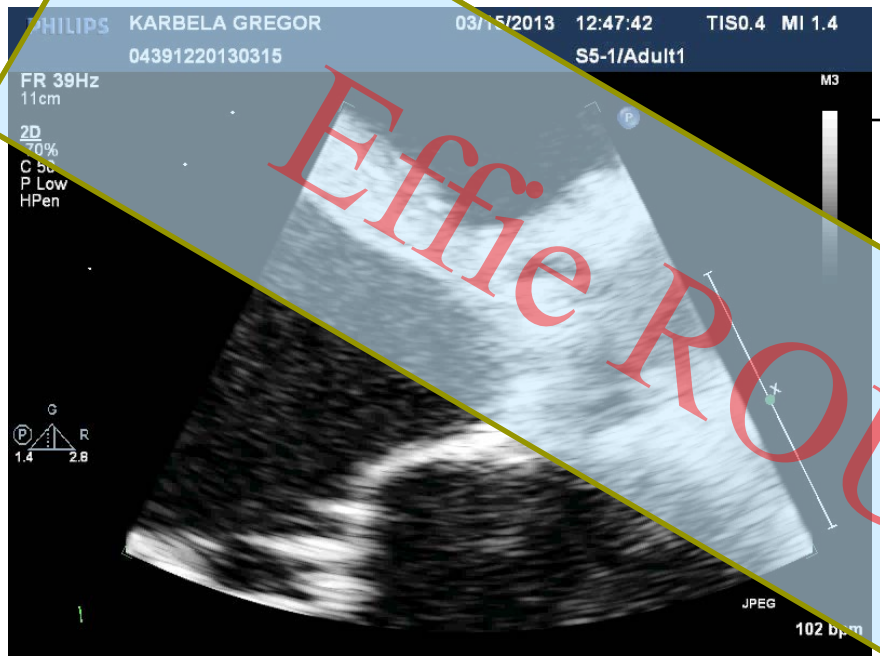
Our patient

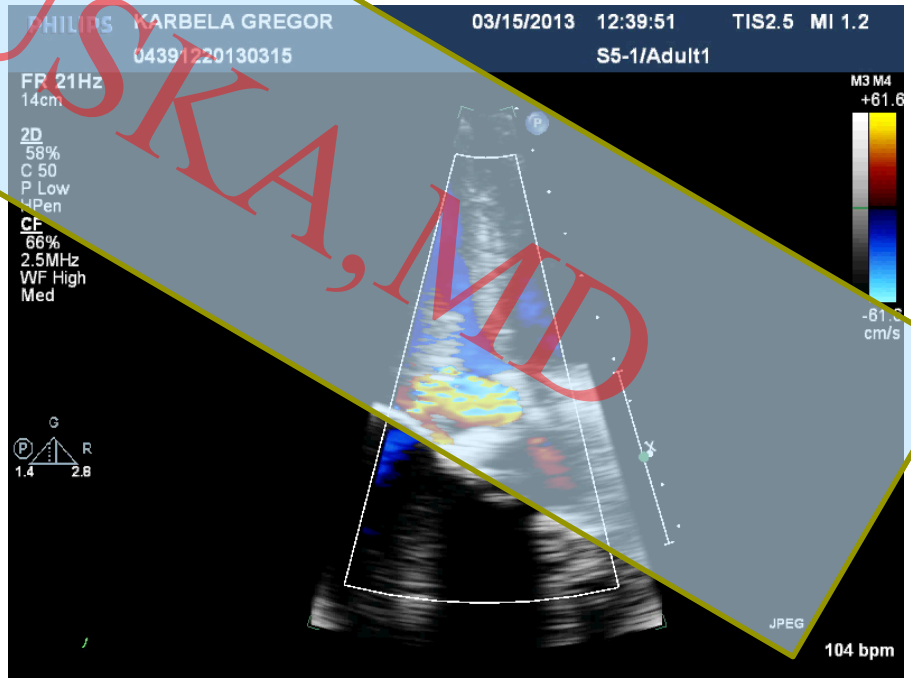
TTE – PLAX

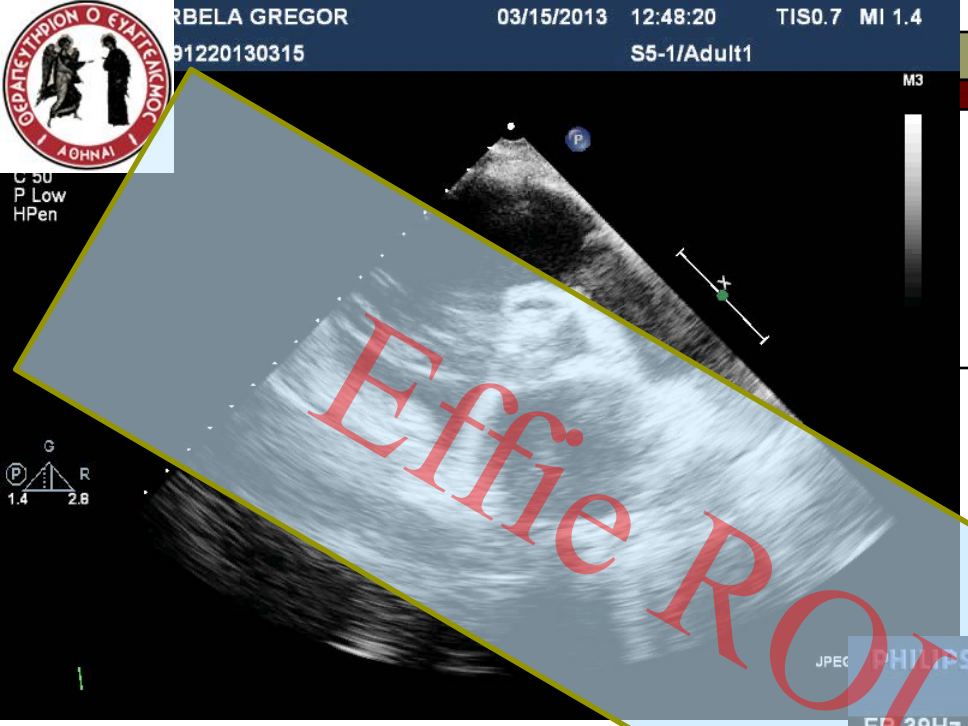


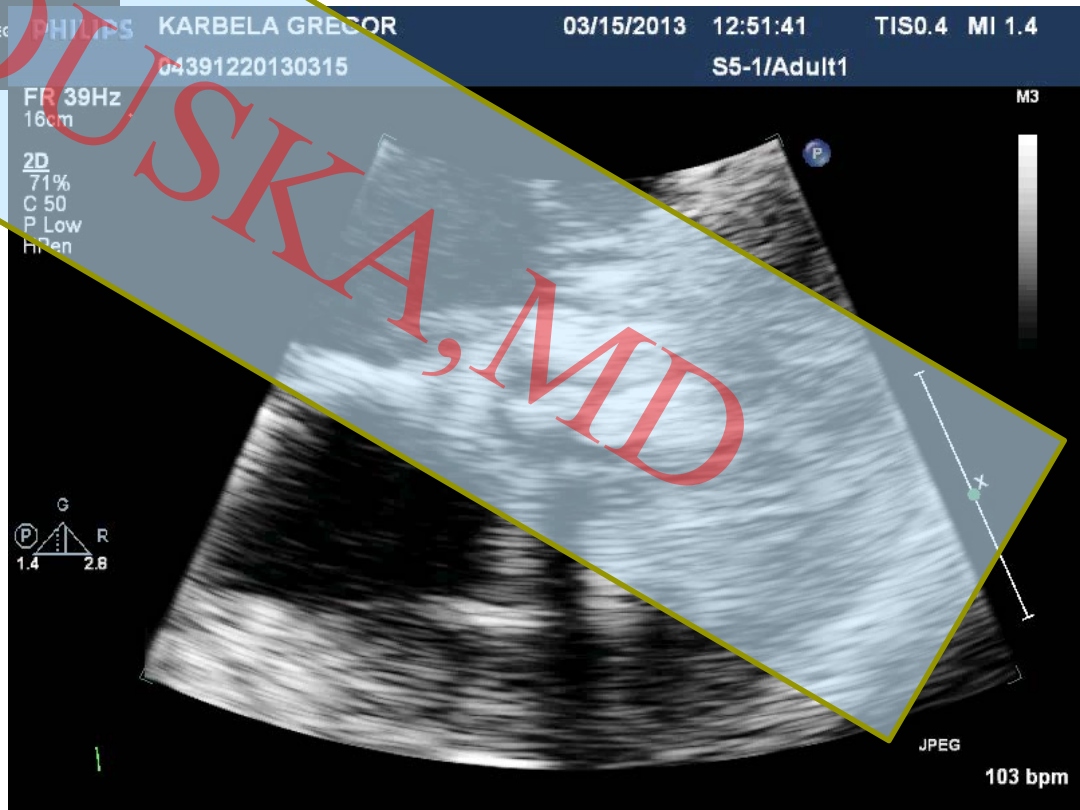


Mixed AoV disease!

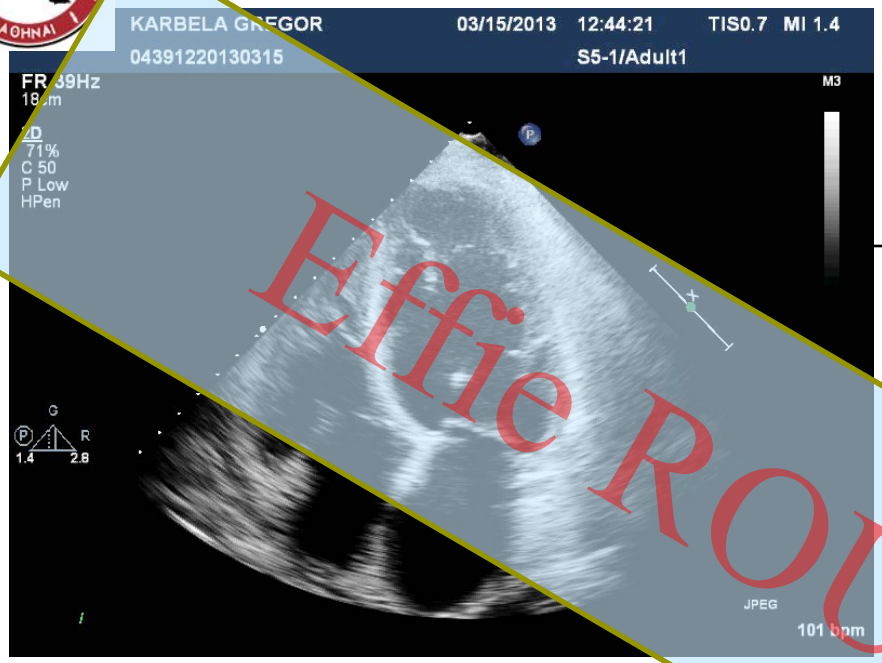


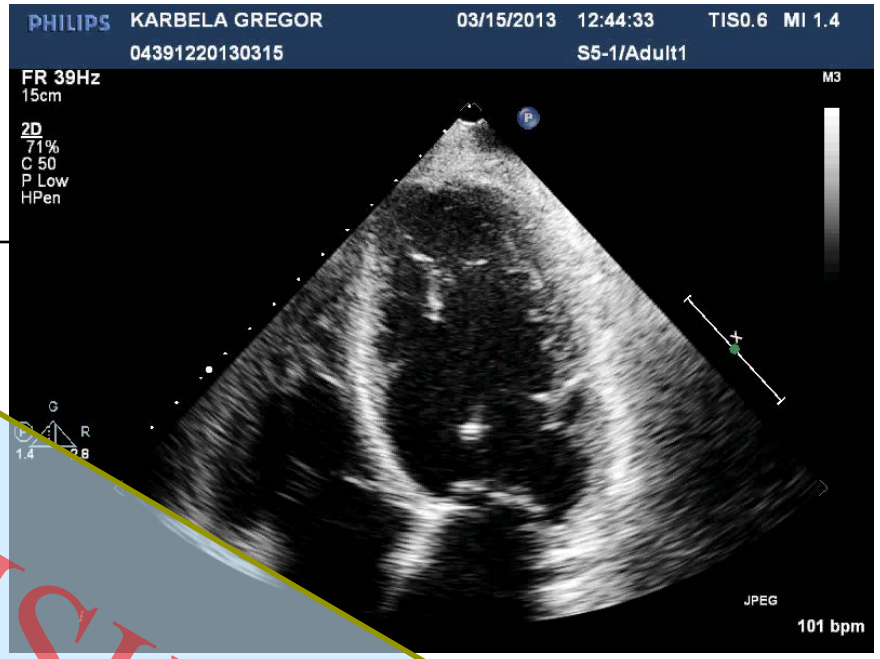


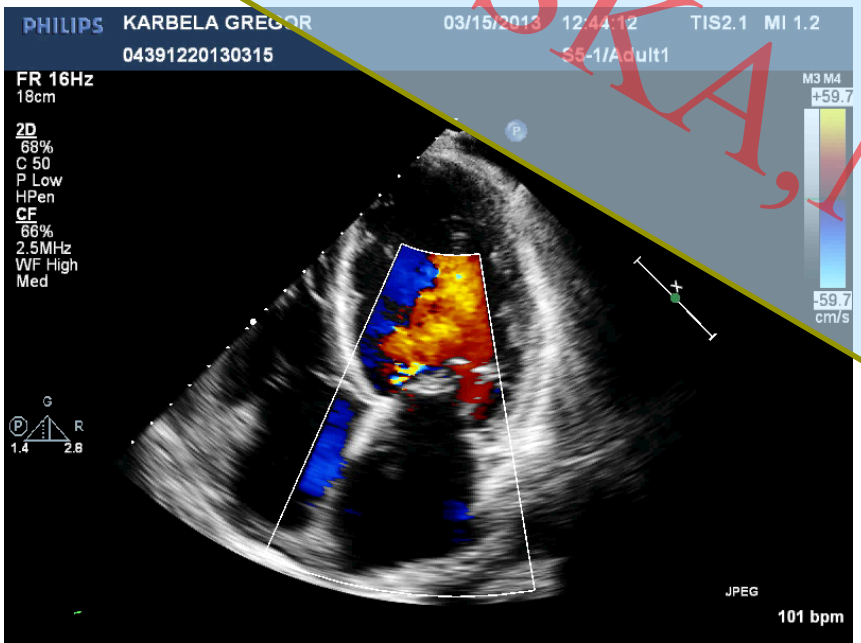




TTE – SAX

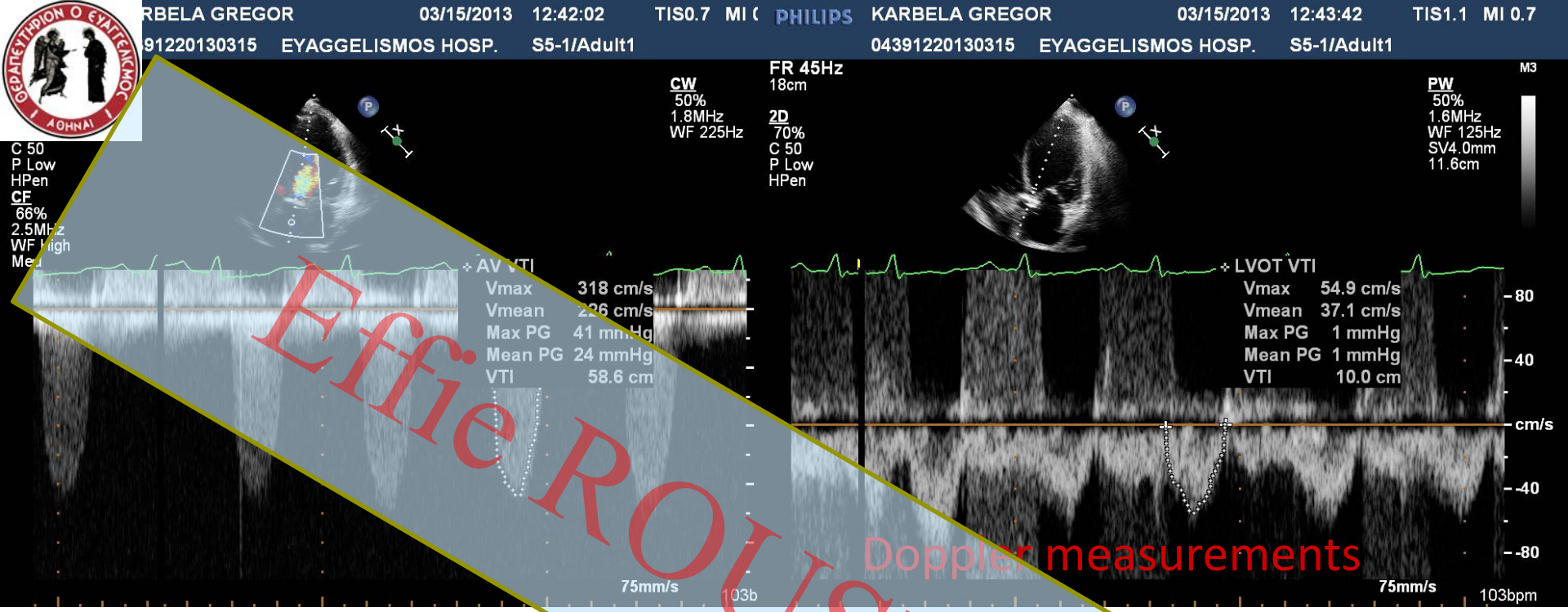




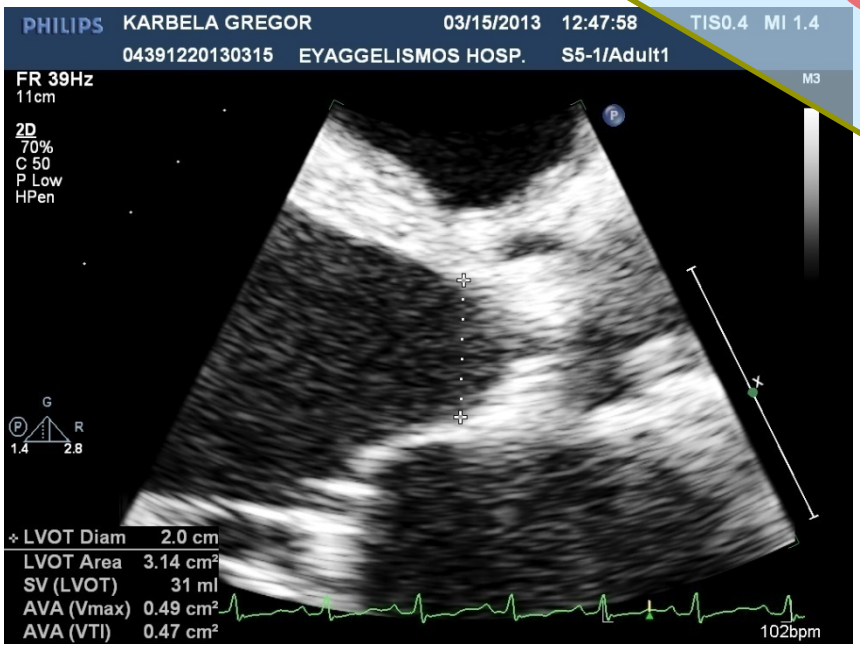


TTE

4-ch view



Doppler measurements

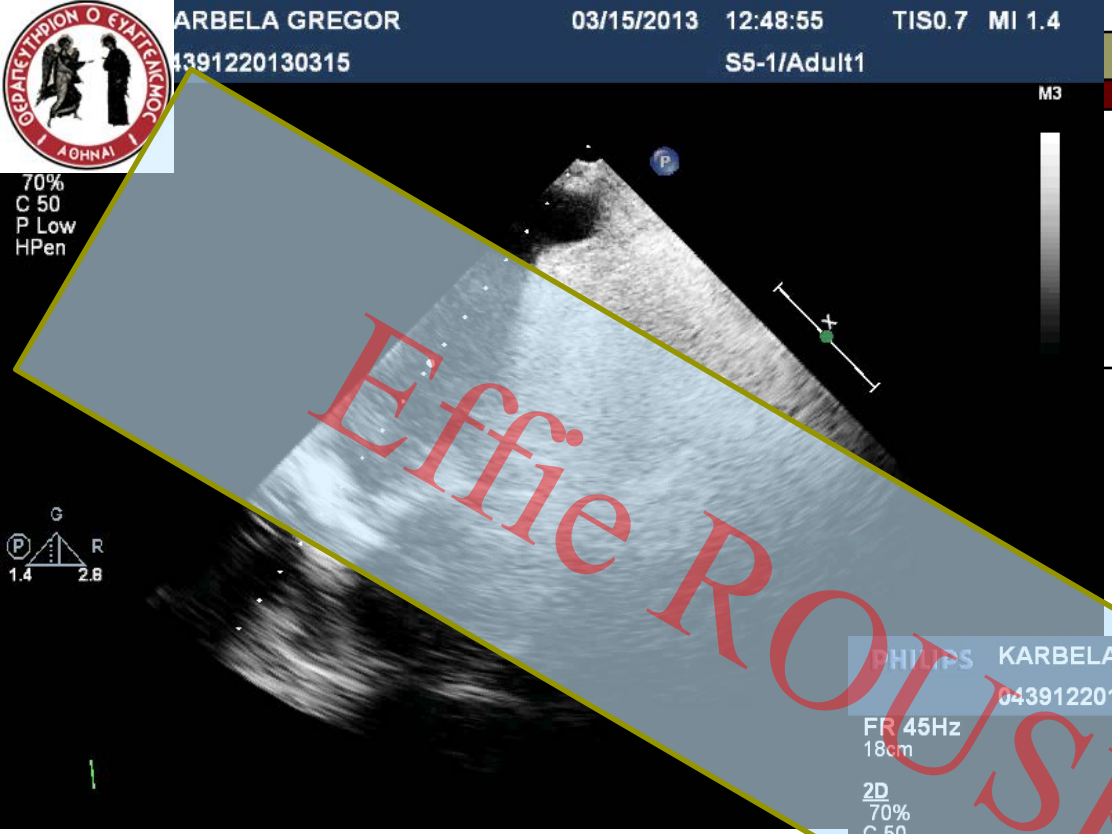


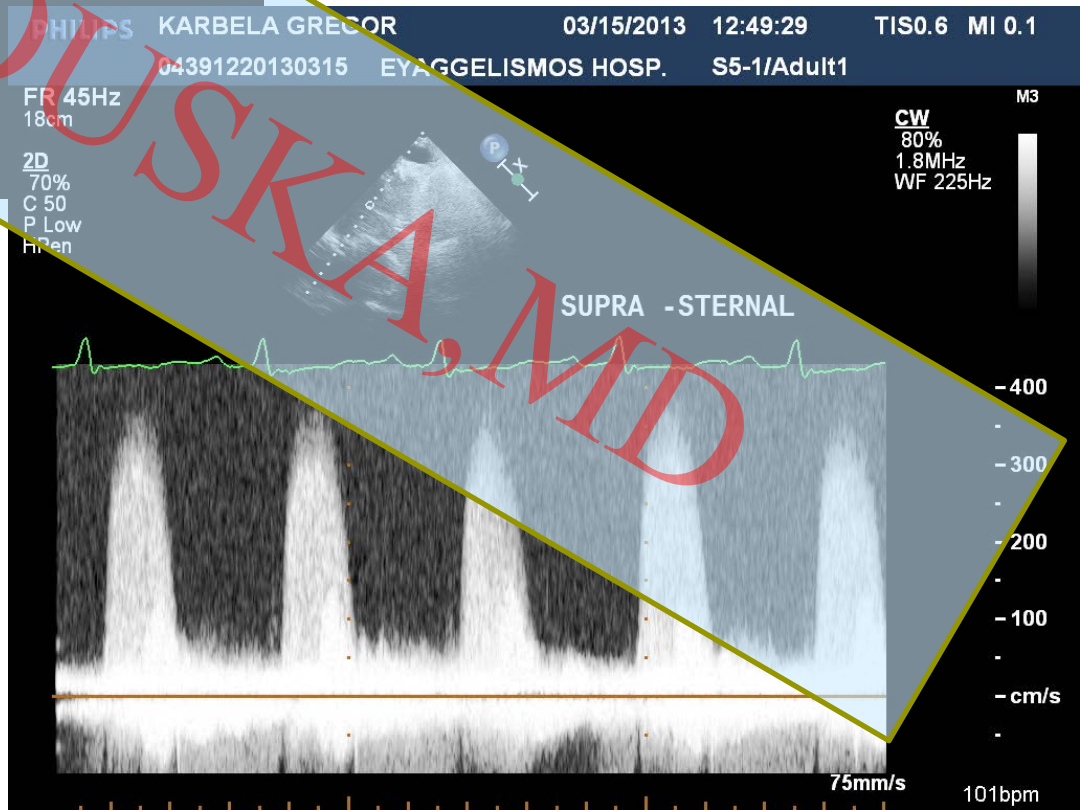
- DVI= 0,17

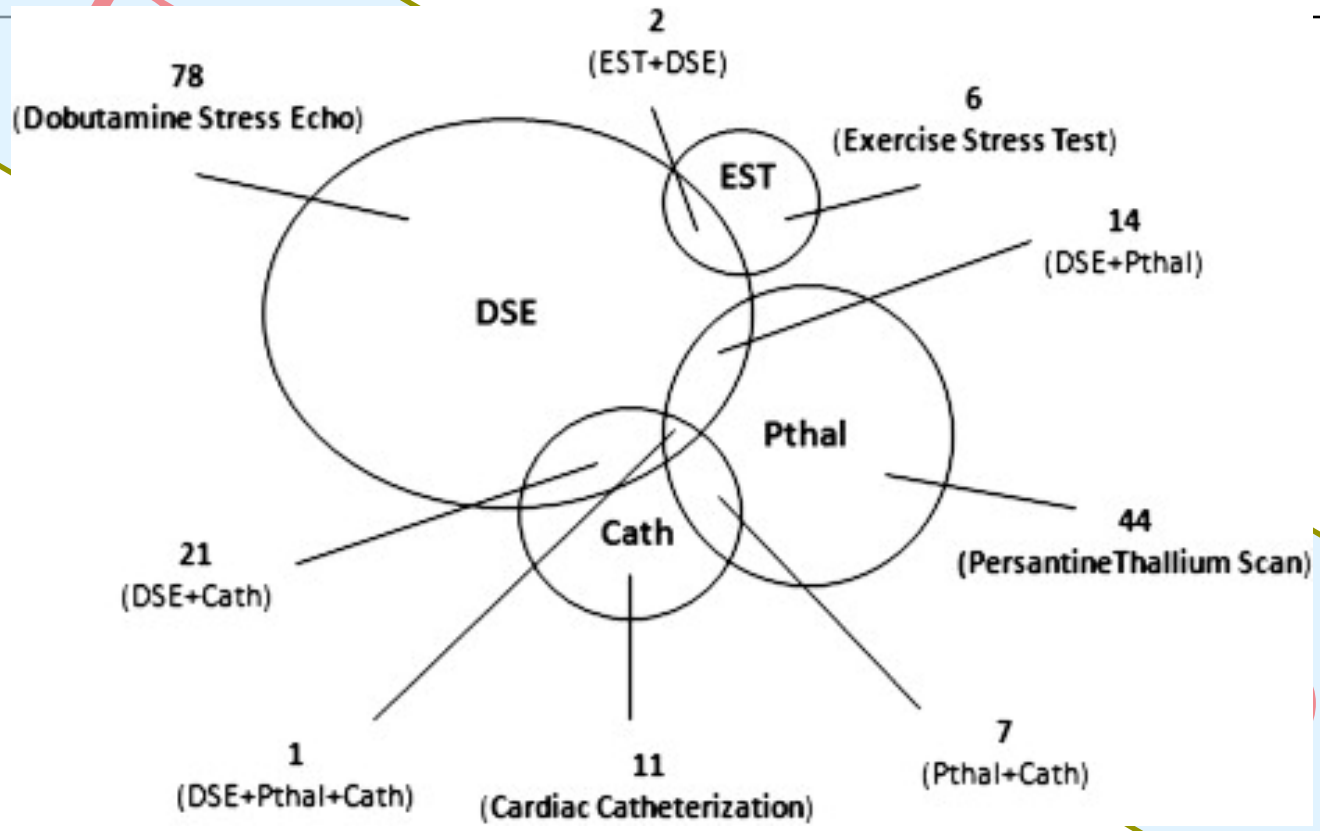
(LVOT Vmax/AoV Vmax)

- Calculation of AVA by CE=0,50cm2

Supra-sternal view



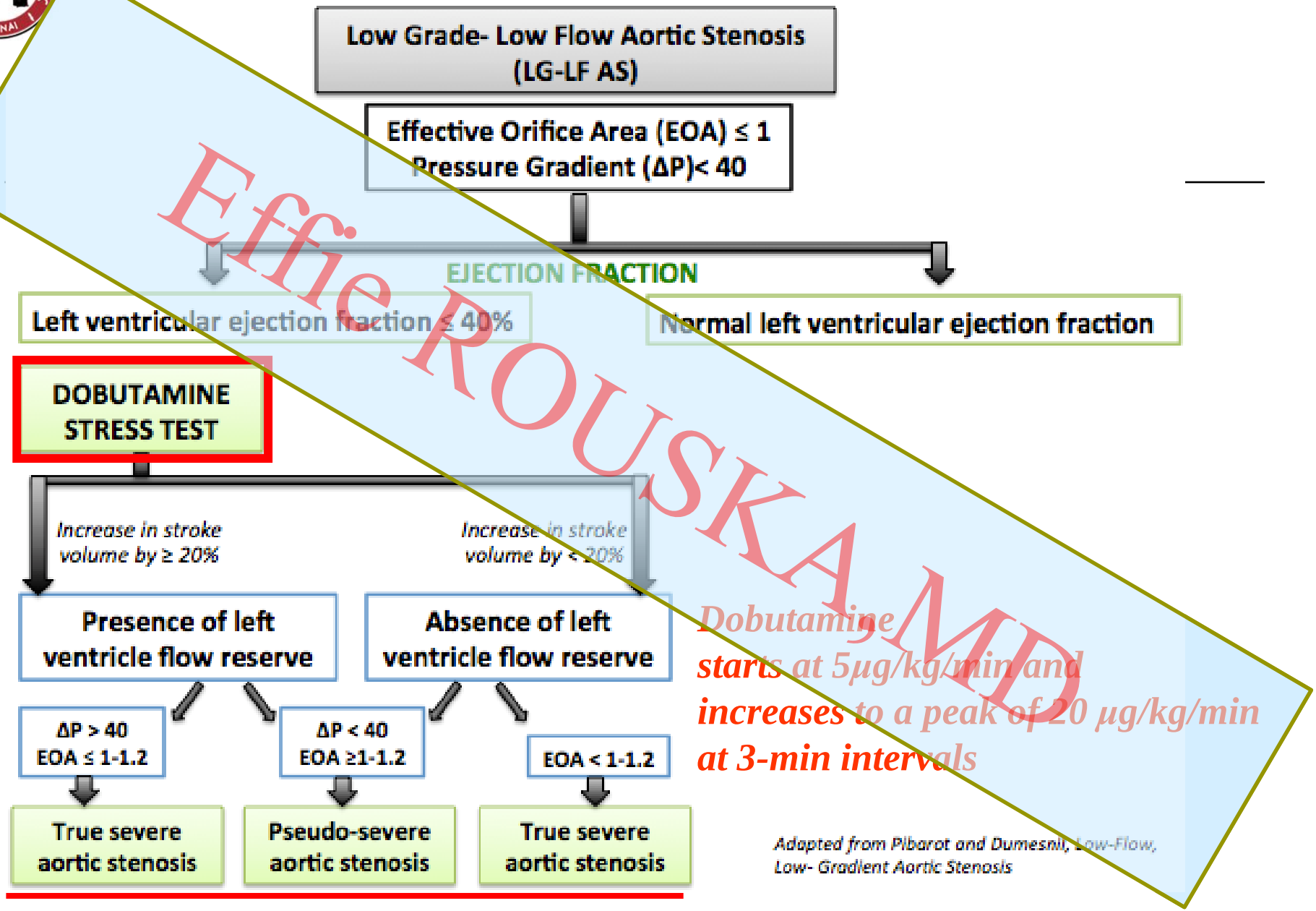



2
(EST+DSE)
78
(Dobutamine Stress Echo)
6
(Exercise Stress Test)
EST
14
(DSE+Pthal)
DSE
Pthal
Cath
21
(DSE+Cath)
44
(PersantineThallium Scan)
1
(DSE+Pthal+Cath)
11
(Cardiac Catheterization)
7
(Pthal+Cath)

DSE

- A low dose starting at 2.5 or 5 μg/kg/min
  with an incremental increase in the infusion
  every 3–5 min
  to a maximum dose of 10–20 μg/kg/min

- The infusion should be stopped as soon as
  - Positive result is obtained
  - Arrhythmias
  - Hemodynamic instability



In patients with fixed AS, dobutamine induced an increase in peak velocity, mean transvalvular pressure gradient, and valve resistance and no change in valve area. In contrast, in those with pseudo-AS, dobutamine caused a considerable increase in valve area ($\geq$0.3 cm^2) without a substantial change in peak velocity, mean transvalvular pressure gradient, or valve resistance. Therefore, DSE clearly can help to differentiate patients with fixed low-gradient AS (who will benefit from valve replacement surgery) from those with pseudo-AS (in whom valve replacement surgery is not indicated).

(*Circulation*. 2006;113:1718-1720.)

Presence of Contractile Reserve is defined as:

- increase in peak velocity of > 0.6m/sec
- increase in stroke volume of >20%
- increase in MPG > 10mmHg, *with Dobutamine*

The most recent guidelines indicate that:

- True AS is characterised by

- <0,2cm^2 in AVA, *while still <1cm^2*

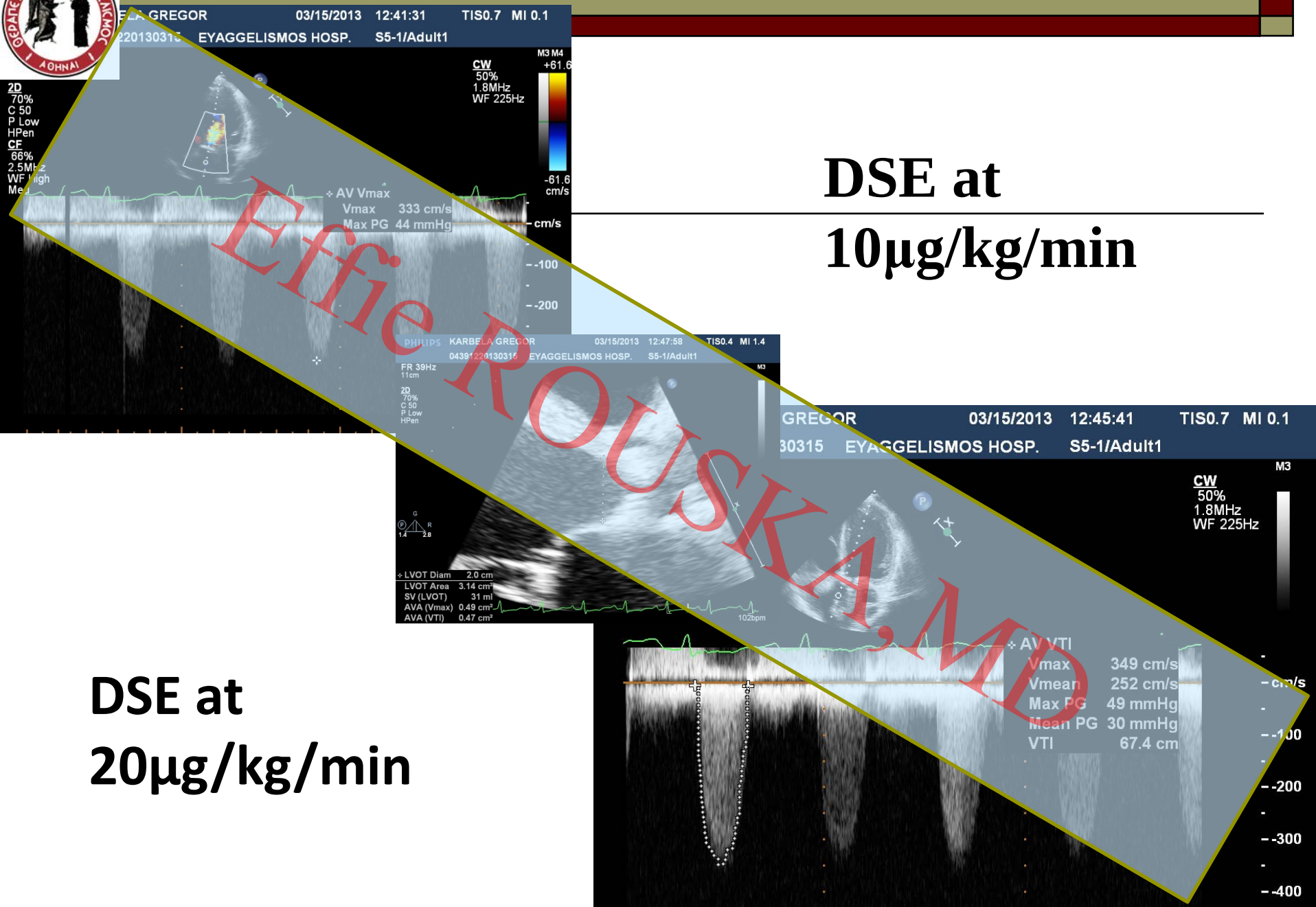
- with an increase in MPG to >40mmHg

- Conversely, pseudo-AS has

- a marked increase in valve area

- but only minor changes in gradients

DSE at 10µg/kg/min



DSE at 20µg/kg/min

In absence of contractile reserve

- Absence of contractile reserve does not help differentiate between true AS or pseudo-AS
  because there is no change in forward stroke volume

- Other imaging modalities like multislice CT (calcium score>1,651),
  cine MRI (AVA by CE using phase velocity),
  PET (smaller resting myocardial flow reserve in pts with true stenosis),
  fluoroscopy

- Quere et al showed that in those pts who had no contractile reserve
  on pre-operative DE, but survived the peri-operative period,
  90% had an improvement in their functional class and
  65% showed a post-operative increase in LVEF by at least 10%.

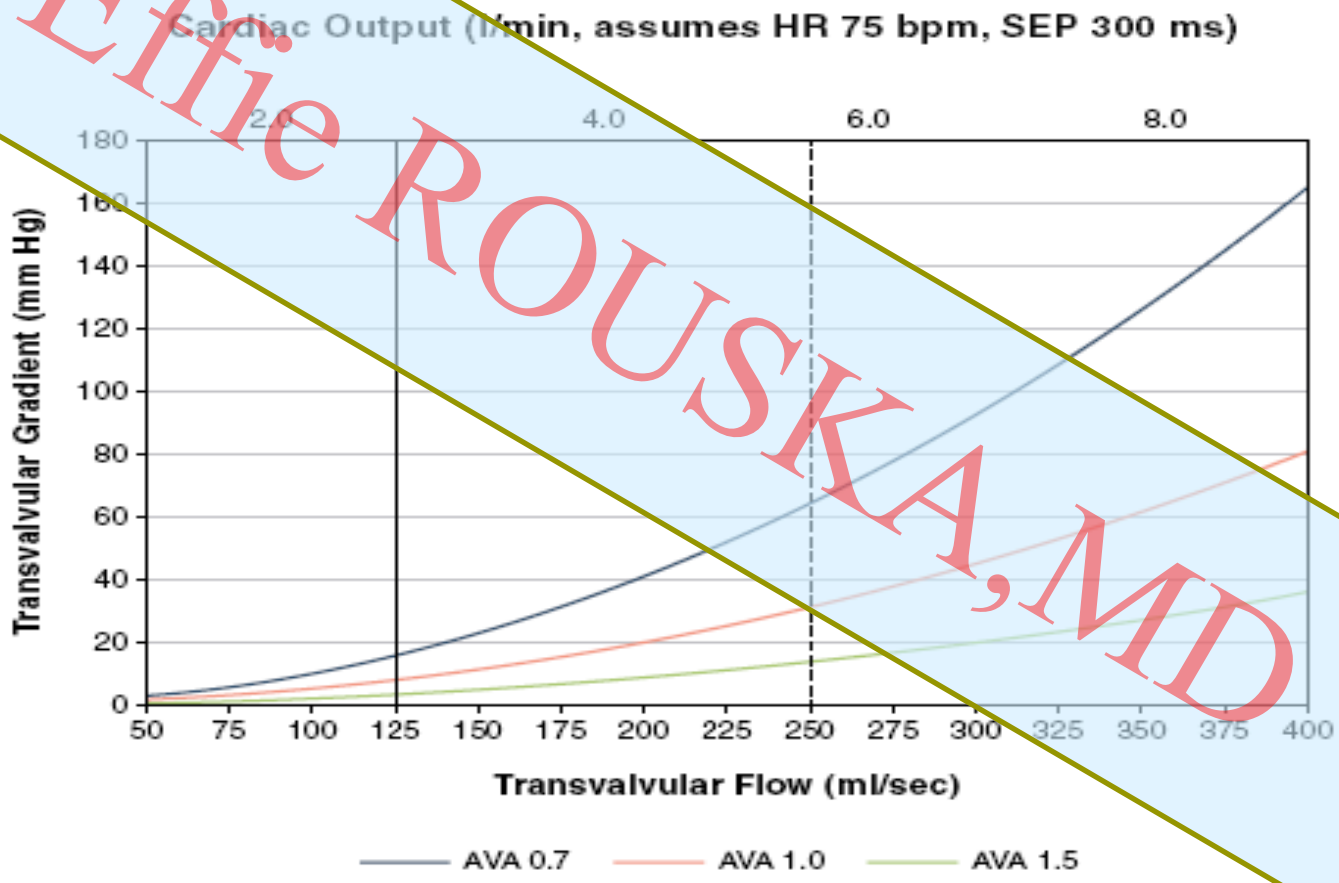
- Absence of contractile reserve should not preclude AVR, even though it clearly portends a higher operative mortality.

Circulation 2006;113:1738–44.

J Am Coll Cardiol 2009;53:1865–73

One of the limitations of DE

is the different transvalvular flow rates achieved in different pts



JACC: CARDIOVASCULAR IMAGING, VOL. 6, NO. 2, 2013
FEBRUARY 2013:184–95

Circulation. 2006;113:711-721

The additional value of a New Index

derived from Dobutamine Echocardiography

the projected effective AVA

at a normal transvalvular flow rate of 250ml/s,

has been proposed to distinguish
pts with true severe low-gradient, low EF AS
from pts with pseudo-severe disease

Circulation. 2006;113:711-721

JACC: CARDIOVASCULAR IMAGING, VOL. 6, NO. 2, 2013
FEBRUARY 2013:184–95

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

For each pt,

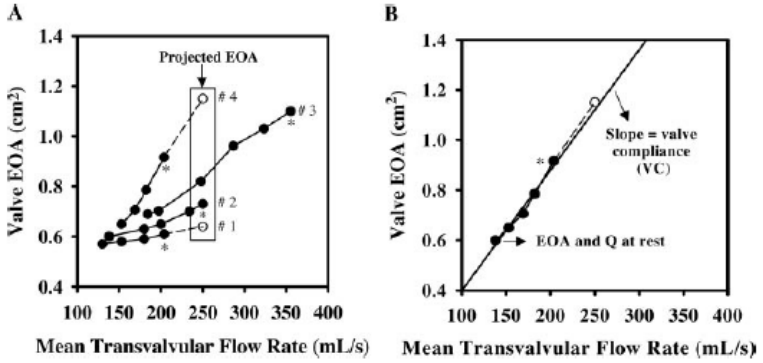
EOA is plotted against transvalvular flow (Q)

at each dobutamine stage,

and the EOA at a standardised of flow rate of 250mL/sec

is projected from the equation of the regression line

fitted to the EOA versus Q plot



$$EOA_{proj} = EOA_{rest} + VC \times (250 - Q_{rest})$$

where EOA_{rest} and Q_{rest} are the EOA and Q at rest and VC is the valve compliance corresponding to the slope of the EOA-flow relationship

Circulation. 2006;113:711-721

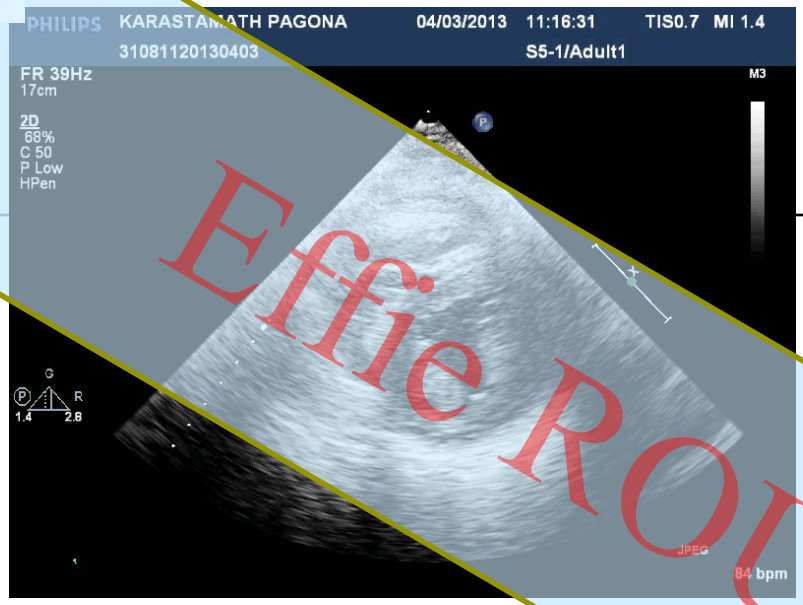
Low gradient, low EF AS
Which pts can benefit from surgery?

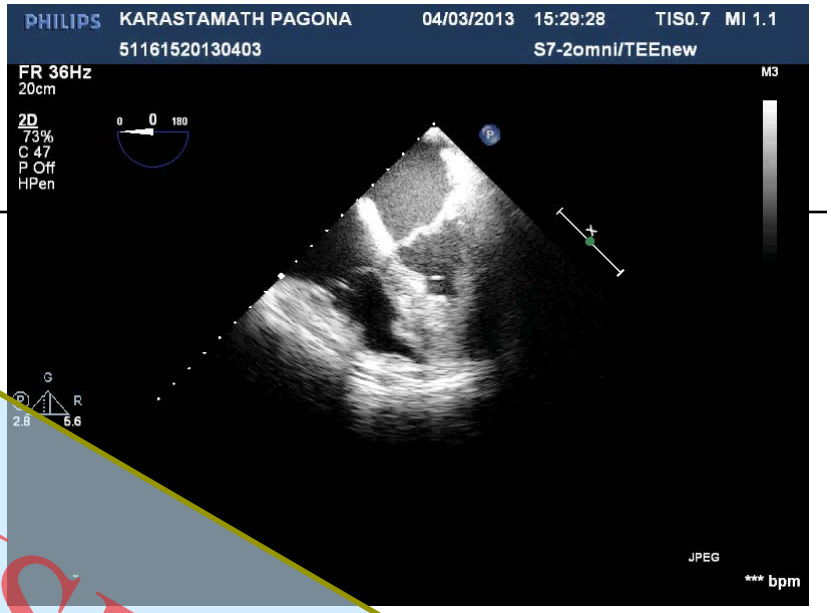
- Perioperative mortality ranges from 8-21%
  in recent publications
- Without CR there is a high operative mortality of 30%
- With CR there is an operative mortality of only 5-8%
- Among pts who survive AVR, an improvement in functional status is usually seen and the EF increases by at least 10%
  in more than 80% of cases.

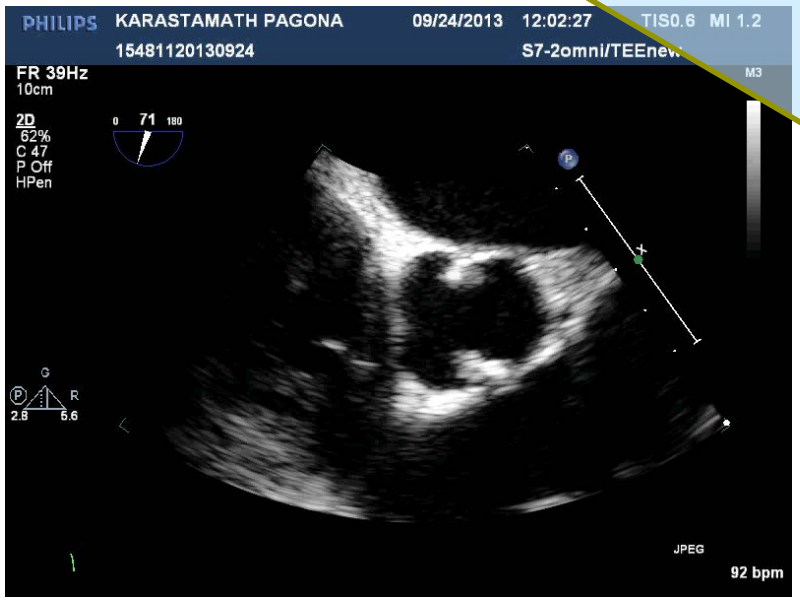
LGSAS

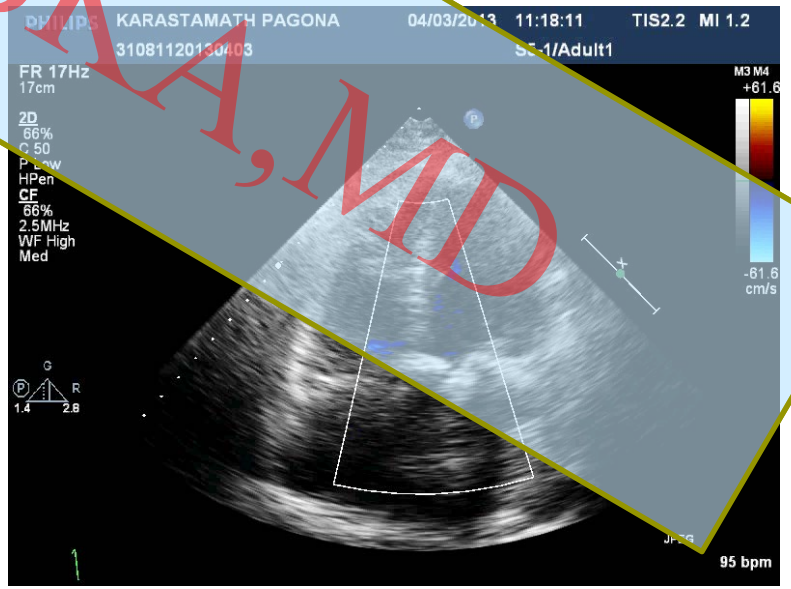
- 1)Low gradient, low EF AS

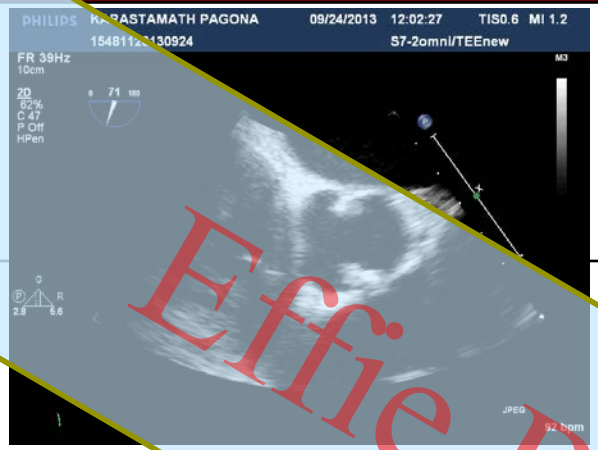
- **2) Paradoxical low-flow, low-gradient severe AS, despite preserved EF**

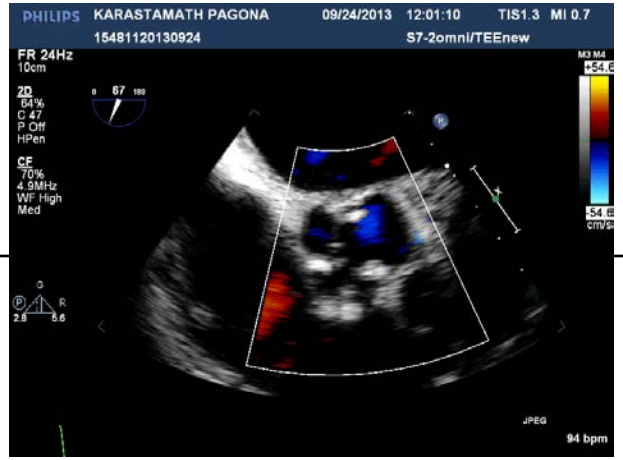


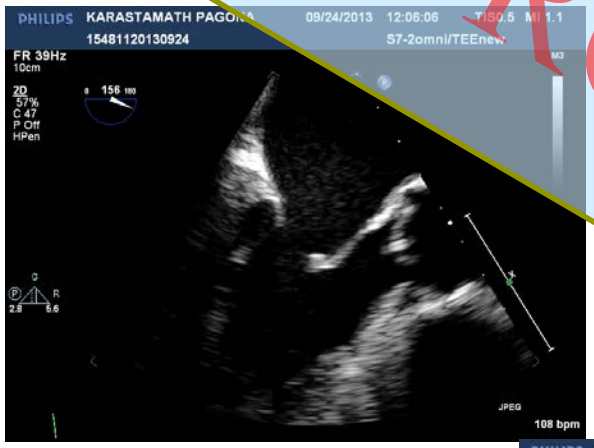


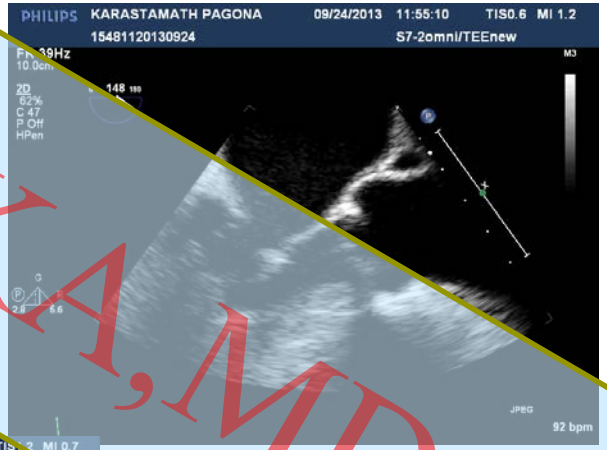


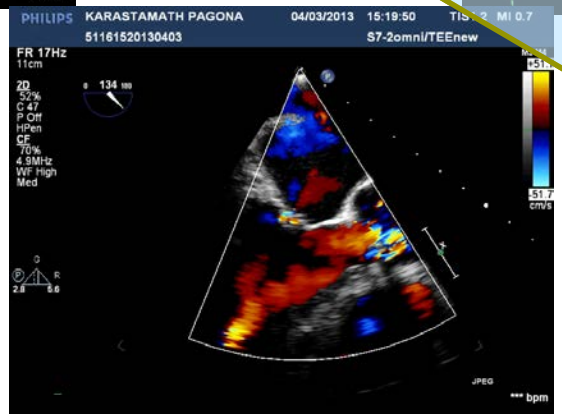


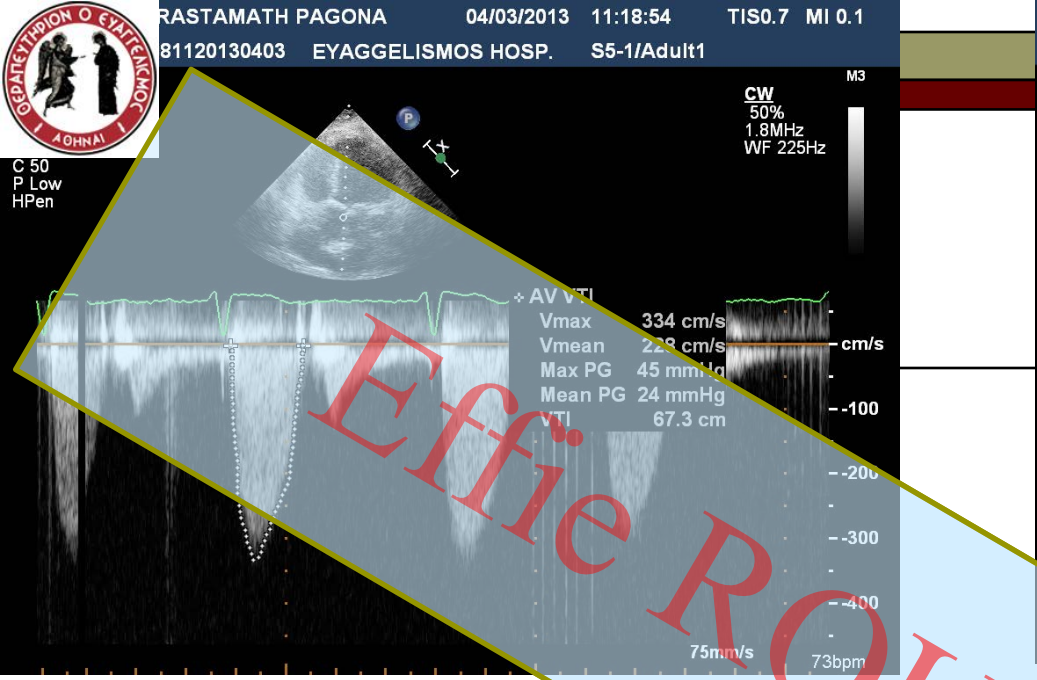


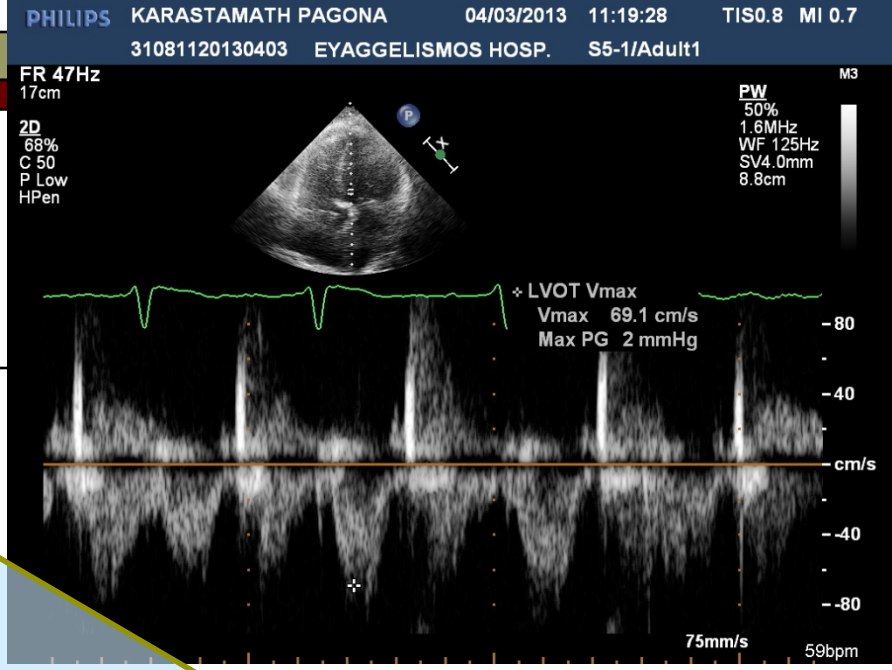


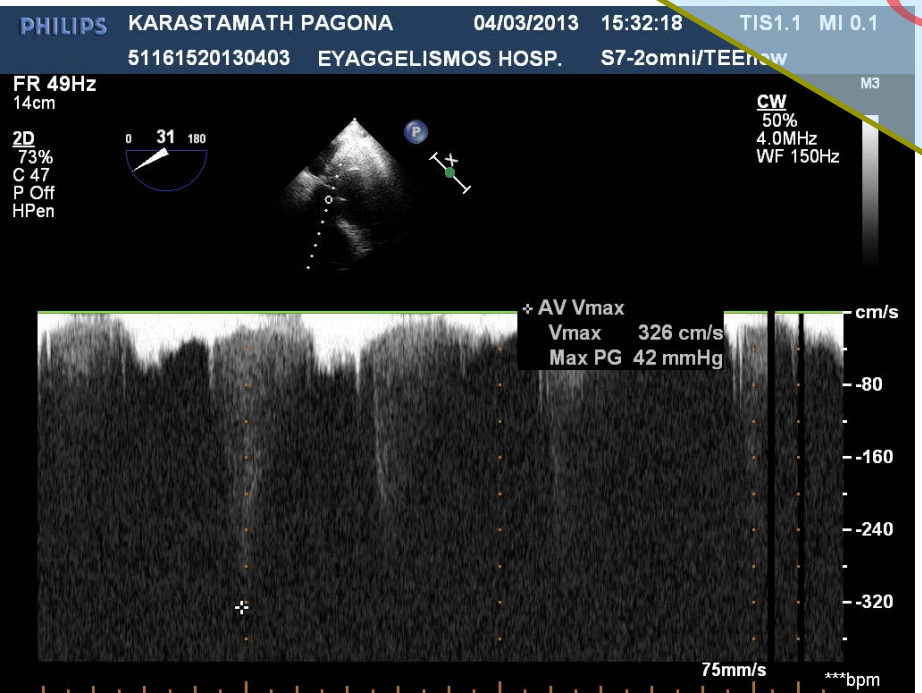


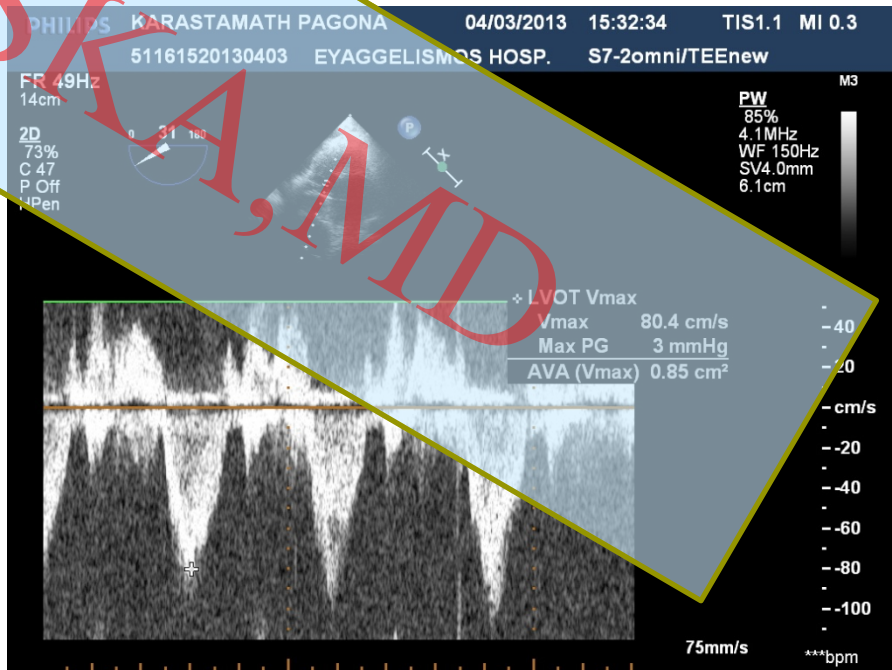


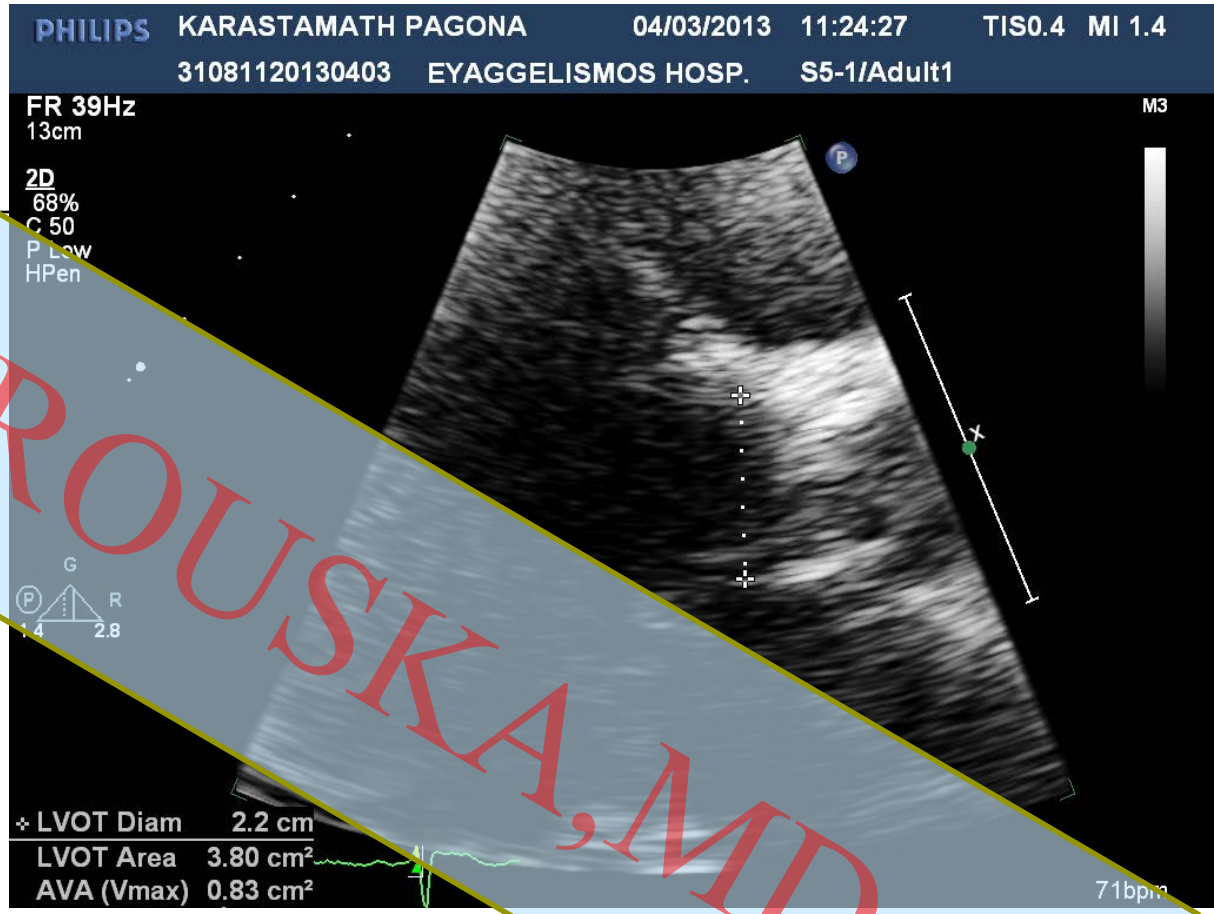












SV=50ml

SVi=28ml/m2

AVA(by CE)=0,8cm2

DVI= (LVOTVmax/AVVMAX)=0,7/3.3 =0.21

Circulation
Cardiovascular Imaging
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association
Learn and Live

Low-Flow, Low-Gradient Severe Aortic Stenosis Despite Normal Ejection Fraction Is Associated with Severe Left Ventricular Dysfunction as Assessed by Speckle-Tracking Echocardiography: A Multicenter Study

Jérôme Adda, Christopher Mielot, Roch Giorgi, Frédéric Cransac, Xavier Zirphile, Erwan Donal, Catherine Sportouch-Dukhan, Patricia Réant, Stéphane Lafitte, Stéphane Cade, Yvan Le Dolley, Franck Thuny, Nathalie Touboul, Cécile Lavoute, Jean-François Avierinos, Patrizio Lancellotti and Gilbert Habib

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Conclusions—LFLG AS is observed in 9% of patients with severe AS and normal EF and is associated with high global afterload and reduced longitudinal systolic function. Patients with NFLG AS are more frequent and present with less severe AS, normal afterload, and less severe longitudinal dysfunction. Severe LV longitudinal dysfunction is a new explanation to the concept of LFLG AS.

2) Paradoxical low-flow, low-gradient severe AS despite preserved EF

Severe AS on the basis of AVA (<1cm2, indexed AVA<0,6cm2/m2) who paradoxically have a low transvalvular flow rate (SVi<35ml/m2) despite the presence of a preserved LVEF >50%

In fact these pts often have a **higher global hemodynamic load** and a more pronounced **impairment of intrinsic myocardial function**, consistent with a more advanced stage of the disease

Represents 25% of the total AS population
(30%of all pts who undergo echocardiographic assessment of AS severity)
Highly challenging subset of pts in terms of diagnosis and clinical decision making, esp if they are symptomatic

Poorer prognosis

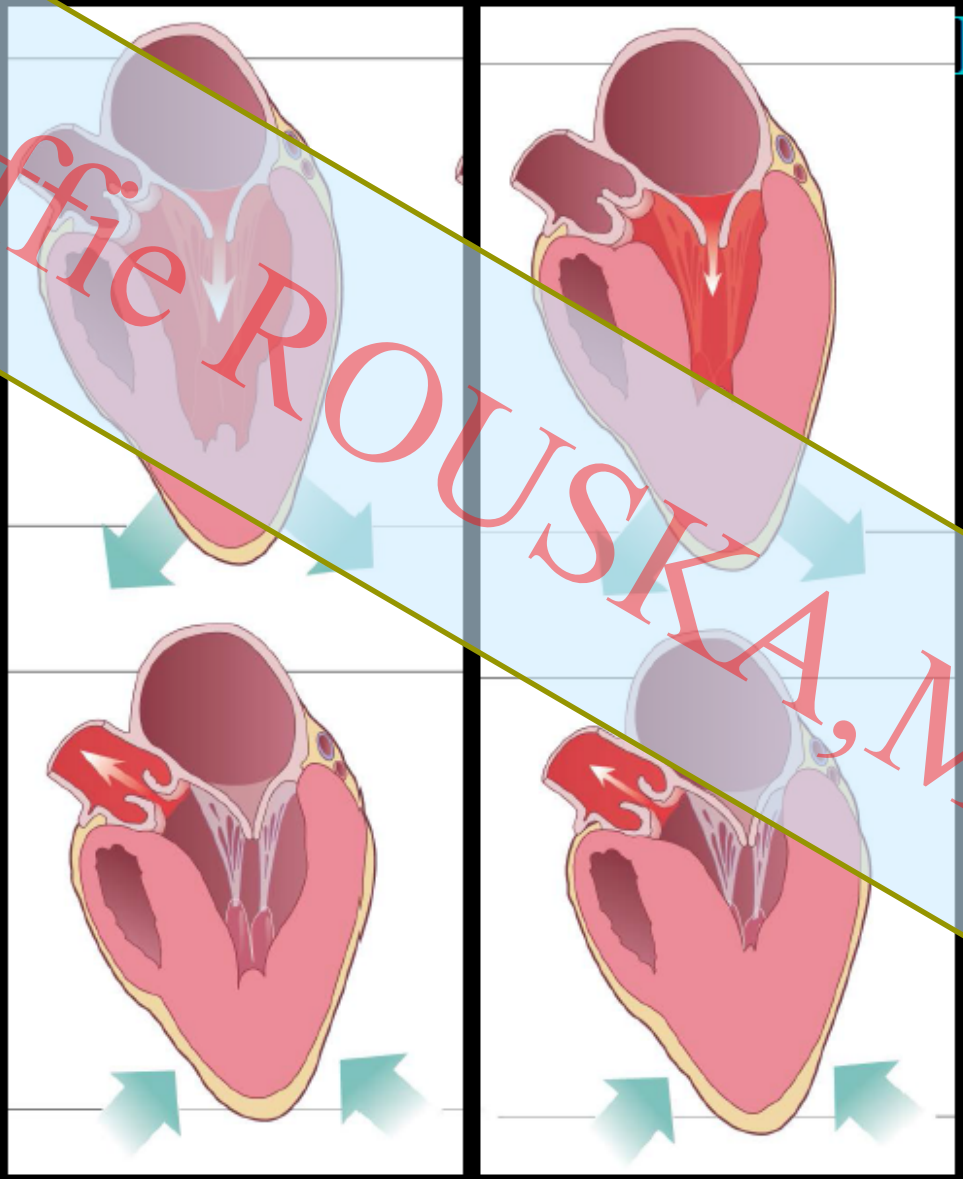
Curr Cardiol Rep(2010) 12:108-115

Normal Flow AS

LVEDV: 115 ml

LVEF: 60%

SV: 70 ml
AVA: 0.7 cm²
ΔP: 45 mmHg



«Paradoxical» Low-Flow AS

↑Age
Women
Hypertension
MetS - Diabetes

LVEDV: 85 ml

LVEF: 60%

SV: 50 ml
AVA: 0.7 cm²
ΔP: 25 mmHg

Pibarot & Dumesnil
iJACC; 2:400-3, 2009

New approaches in **LGSAS**

- Degenerative AS cannot be viewed as an isolated disease strictly limited to the valve
- Rather it is often part of a continum, which includes increased rigidity of the aortic wall due to atherosclerosis and alterations of LV function secondary to CAD and HTN
- Recent studies suggest that ***reduced systemic arterial compliance*** and/or ***LV dysfunction*** are frequently associated with AS, rendering the evaluation of its severity and the choice of appropriate therapy much more complicated
- The new approaches to quantify AS severity take into account the inter-relation between the different variables that may be responsible for symptom appearance or poorer prognosis in these pts

New approaches in **LGSAS**

- The chronic exposure to a high level of afterload
  (due to the combination of severe AS and reduced arterial compliance) eventually exceeds the limit of LV compensatory mechanisms and leads to an intrisic impairment of myocardial function and
  a decrease in cardiac output.

- This results in pseudo-normalization of transvalvular gradients and peripheral BP

- This situation is highly insidious because AS and HTN may appear less severe on the basis of gradient and BP,
  whereas these pts are at a more advanced stage of their disease.

- They need a more comprehensive evaluation of AS severity going beyond the classical measurements to include indices that are less flow-dependent

Low flow- Low gradient severe AS

- Higher prevalence in ***women, older age*, higher degree of LV concentric remodelling**, higher degree of myocardial fibrosis, impaired LV filling, smaller end-diastolic volume, and reduced mid-wall and longitudinal shortening.
  The LV systolic function is in fact reduced

- AS pts with ***metabolic syndrome or type 2 diabetes*** might be at higher risk to develop a paradoxical low-flow pattern

- This entity shares many pathophysiologic and clinical similarities with normal LVEF heart failure. Both entities are characterised by a restrictive physiology , in which the LV pump function and thus the stroke volume, are markedly reduced despite preserved LVEF

Curr Cardiol Rep(2010) 12:108-115

LGSAS

Combining

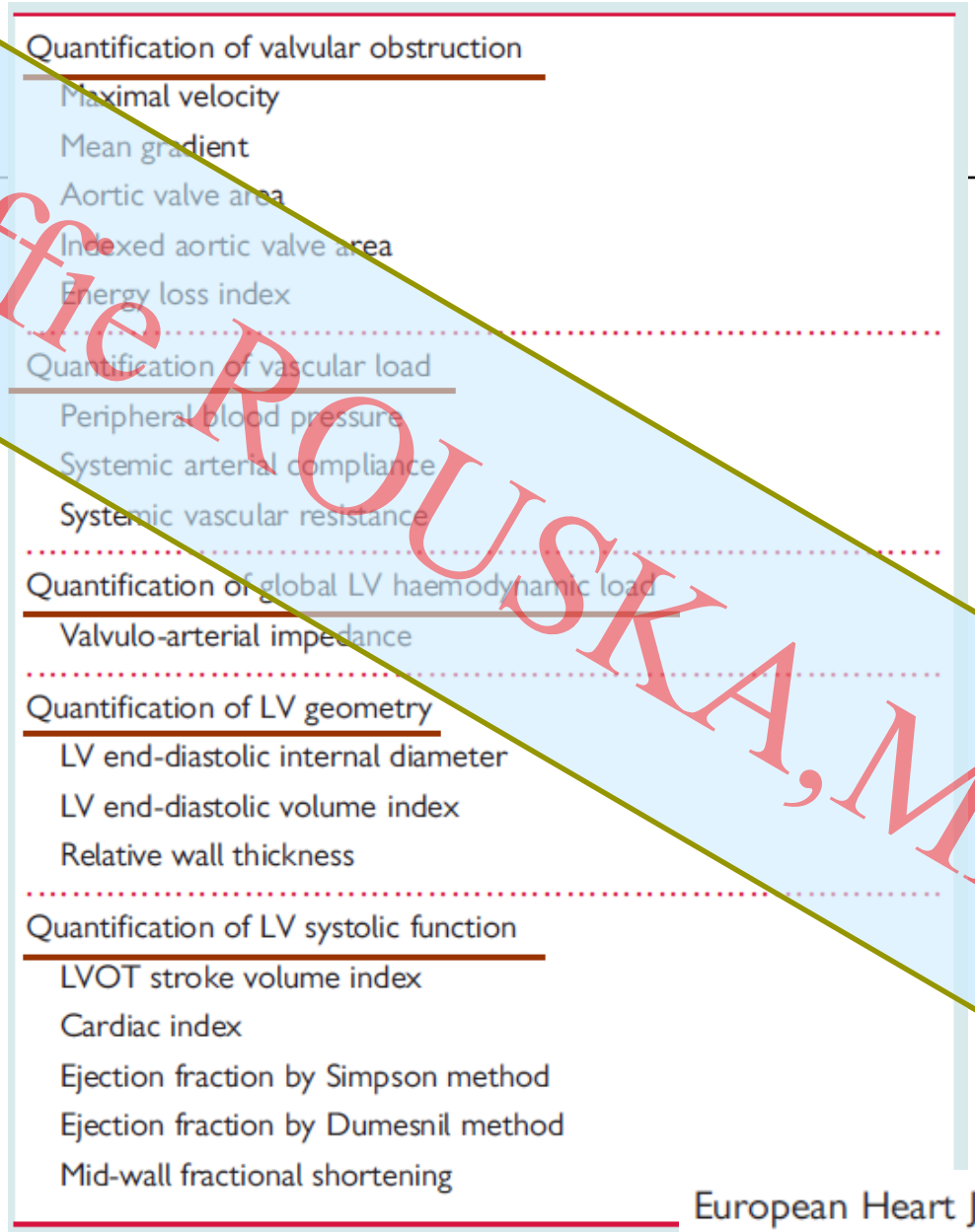
- Clinical data
- Systemic Arterial Hemodynamics
- Doppler Echocardiographic Data

paradoxical low-flow aortic stenosis with preserved LV ejection fraction

Clinical/Doppler/echocardiographic feature	Variable	Suggested criteria
More prevalent in women		
More prevalent in elderly people		
Frequently associated with hypertension	Systolic blood pressure	>135 mm Hg
	Systemic arterial compliance	<0.6 mL/mm Hg/m^2
	Systemic vascular resistance	>2000 dyne/s/cm^2
Pronounced LV concentric remodeling	Relative wall-thickness ratio	>0.45
Small LV cavity size	LV end-diastolic diameter	<50 mm
	LV end-diastolic volume index	<60 mL/m^2
Impaired LV filling	Diastolic dysfunction	Moderate-severe
Preserved LV ejection fraction	LV ejection fraction	>50%
Altered myocardial systolic function	LV longitudinal shortening	<18%
	LV mid-wall shortening	<20%
Reduced stroke volume	Stroke volume index	<35 mL/m^2
Thickened calcified valve	Calcification score (echo)	≥2
	Calcification score (CT)	>1500 Agatston units
Small aortic valve area	Aortic valve area	<1.0 cm^2
	Indexed aortic valve area	<0.6 cm^2/m^2
Often low transvalvular gradient	Mean gradient	<40 mm Hg
Increased global hemodynamic load	Valvuloarterial impedance	>4.5 mm Hg/mL·m^{-2}

Curr Cardiol Rep (2010) 12:108–115

Comprehensive Doppler-Echocardiographic examination of AS



European Heart Journal (2010) **31**, 281–289

Various Hemodynamic Metrics used for assessment of AS and their cutoff values for severe AS

AS jet velocity*	m/s	Direct measure	> 4.0
Mean pressure gradient*	mm Hg	Direct measure (Cath) Bernoulli equation (Echo)	> 40
EOA*	cm^2	Gorlin equation (Cath) Continuity equation (Echo)	< 1.0
Indexed EOA*	cm^2/m^2	EOA normalized by BSA	< 0.6
Dimensionless index (DI)*	None	Ratio of LVOT velocity and VC velocity	< 0.25
Energy loss index	cm^2/m^2	Indexed EOA accounting for ascending aorta size	< 0.5–0.6
Valvuloarterial impedance	$mm\,Hg \cdot mL^{-1} \cdot m^{-2}$	Global systolic LV load, including arterial pressure	4.5–5
AV resistance	$dynes \cdot s^{-1} \cdot cm^{-5}$	Resistance of AV to flow	> 280
Projected valve area at normal flow	cm^2	Estimated EOA at normal flow	< 1.0
Calcium score	AU	Measured from CT data	> 1651

Circulation January 14, 2014

A)Quantifying Valvular Obstruction

	Criteria for "severe"	Advantages	Limitations
Quantification of valvular obstruction			
Mean gradient, *mm Hg*	>40	Easy to measure	Highly flow-dependent Overestimates LV energy loss in patients with small aortas May under- or overestimate stenosis severity in presence of HPT Underestimates stenosis severity in low-flow states
Valve EOA, cm^2 *(indexed: cm^2/m^2)*	≤ 1.0 Indexed: ≤ 0.6	Less flow-dependent than gradient Reflects the intrinsic severity of valvular obstruction	Overestimates LV energy loss in patients with small aortas May under- or overestimate stenosis severity in presence of HPT May overestimate stenosis severity in low-flow states
Energy loss index, cm^2/m^2	≤ 0.55	Less flow-dependent than gradient Reflects the true LV energy loss caused by the stenosis	May under- or overestimate stenosis severity in presence of HPT May overestimate stenosis severity in low-flow states
Projected EOA, cm^2 *(indexed: cm^2/m^2)*	≤ 1.0 Indexed: ≤ 0.55	Not flow-dependent Accurately estimates stenosis severity in low-flow states	Overestimates LV energy loss in patients with small aortas May under- or overestimate severity in presence of HPT

European Heart Journal (2010) **31**, 281–289

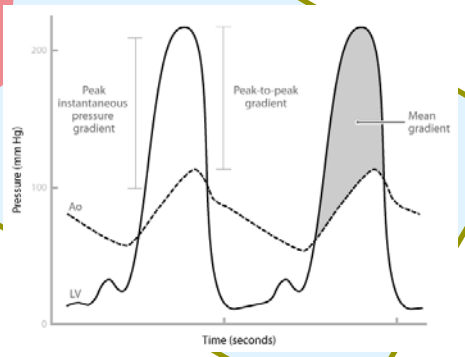
Indexing AVA by BSA

Indexing AVA by BSA and applying the current partition value of AVA_{index} <0.6 cm^2/m^2 for severe stenosis increases the prevalence of severe aortic valve stenosis compared to unindexed AVA by including individuals with a milder degree of disease without improving the predictive accuracy for clinical events.

Jander N, *et al*. *Heart* 2014;100:28–33

Pressure Recovery and Energy Loss coefficient

- The guidelines make no distinction between cathetirization and echo measurements.
- However, as blood flow velocity decelerates between the valve and the ascending aorta, part of the kinetic energy is reconverted to static energy due to pressure recovery phenomenon.
- The extend of PR is determined by the ratio between EOA and the area of the Asc Ao,
  a situation that can be clinically important in pts with smaller aortas (d<30mm)
- In these pts it becomes appropriate to account for PR and calculate the **energy loss coefficient**
- **The severity of AS is frequently overestimated if correction for pressure recovery is not performed**



For accurate assessment of AS severity, pressure recovery adjustment of AVA must be routinely performed

$$iPR = 0 + 2 \times \frac{AVA}{AA} - 2 \times \frac{AVA^2}{AA^2}$$

$$cAVA = \left(\frac{1}{2} - \frac{\sqrt{4 - 8 \times iPR}}{4} \right) \times AA$$

The severity of AS is frequently overestimated if correction for pressure recovery is not performed. For accurate assessment of AS severity, pressure recovery adjustment of AVA must be routinely performed.

JACC: CARDIOVASCULAR IMAGING, VOL. 3, NO. 6, 2010
JUNE 2010:555–62

Estimation of pressure recovery at the sinotubular junction is suggested

$$PR = P(\text{V} - \text{X}) - P(\text{V-A})$$

Table 5. Estimation of Pressure Recovery and ELI at Different Levels of the Aorta

Variables	Sinus	Junctional	Supracoronary
Aortic diameter, cm	3.08 ± 0.44*†	2.82 ± 0.42†	3.11 ± 0.47
Pressure recovery, mm Hg	5.14 ± 1.97*	5.88 ± 2.27†	5.07 ± 1.98
ELI, cm^2/m^2	0.84 ± 0.38*	0.89 ± 0.45†	0.84 ± 0.38
Severe AS, %	19.7*	17.2†	20.0

*p < 0.001 versus junctional level; †p ≤ 0.001 versus supracoronary level.
AS = aortic stenosis; other abbreviations as in Table 2.

JACC: CARDIOVASCULAR IMAGING, VOL. 3, NO. 6, 2010
JUNE 2010:555–62

Eur Heart J, Vol. 20, issue 18, September 1999

Energy Loss Index (ELI)

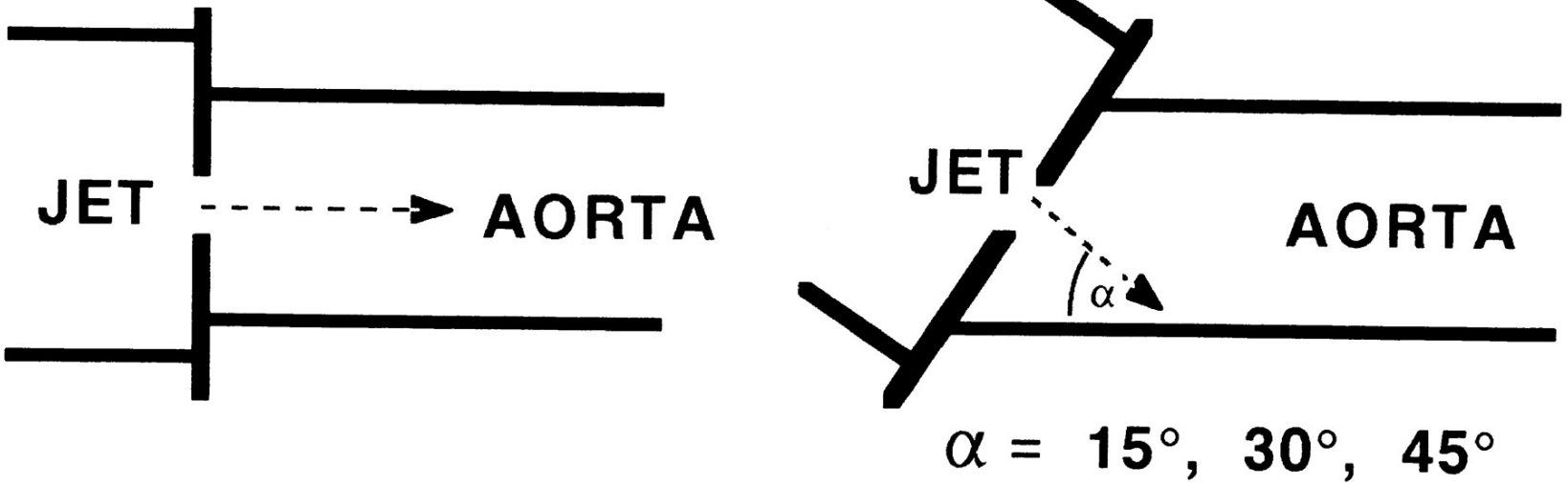
$$ELI = \frac{AVA \times A_A / A_A - AVA}{BSA}$$

where AVA is the valve effective orifice area, A_A is the aortic cross-sectional area, and BSA is body surface area.

ELI<0,55cm²/m² suggested for severe AS

Circulation. 2007;115:2856-2864

Straight aorta with centrally entering stenotic jet (left) and the angled aortas (right) designed to study jets with 15°, 30°, and 45° eccentricity.



Niederberger J et al. Circulation 1996;94:1934-1940

Valvular Resistance (RES) (flow correction)

$$RES = \frac{(1333 \times MG)}{Q_{mean}}$$

where MG is the mean gradient and Q_{mean} is the mean transvalvular flow rate (ie, the stroke volume divided by LV ejection time).

RES>280 $dynes \cdot s^{-1} \cdot cm^{-5}$ ***suggested for severe AS***

Circulation. 2007;115:2856-2864

B)Quantifying Vascular Load

	Criteria for "severe"	Advantages	Limitations
Quantification of vascular load			
Systemic arterial pressure, *mm Hg*	> 140/90	Easy to measure	Highly flow-dependent Often pseudo-normalized in AS patients Underestimates HPT severity in low-flow states
Systemic arterial compliance, *mL/mm Hg^{-1}/m^{-2}*	≤ 0.6	Can be measured by Doppler echocardiography Most common cause of increased vascular load in AS patients Can unmask HPT in patients with pseudo-normalized blood pressure	
Systemic vascular resistance, *dyne/s/cm^{-2}*	> 2000	Can be evaluated by Doppler echocardiography Can unmask HPT in patients with pseudo-normalized blood pressure	

European Heart Journal (2010) **31**, 281–289

Systemic Arterial Compliance

$$SAC = \frac{SVI}{PP}.$$

Systemic arterial pressure was measured with the use of an arm-cuff sphygmomanometer at the same time as the Doppler measurement of stroke volume measured in the left ventricular outflow tract (LVOT stroke volume). The ratio of SVI to brachial pulse pressure (PP) was used as an indirect measure of total systemic arterial compliance.[1]

A value of less than 0.6mL/mmHg^{-1}/m^{-2} is considered consistent with decreased SAC

Circulation. 2007;115:2856-2864

Systemic Vascular Resistance

$$SVR = \frac{80 \times MAP}{CO}$$

where MAP is the mean arterial pressure defined as diastolic pressure plus one third of brachial pulse pressure and CO is the cardiac output.

A value of more than 2000 dyne/s/cm^{-2} is suggested for severeAS

Circulation. 2007;115:2856-2864

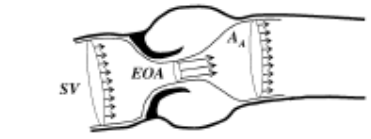
C) Quantifying Global LV Afterload

	Criteria for "severe"	Advantages	Limitations
Quantification of global LV afterload			
Valvulo-arterial impedance, *mm Hg/mL^{-1}/m^{-2}*	> 4.5	Can be measured by Doppler echocardiography Reflects the global afterload imposed on the LV Potentially superior in predicting occurrence of symptoms and events	Does not permit discrimination of the valvular vs the vascular contribution to the global afterload

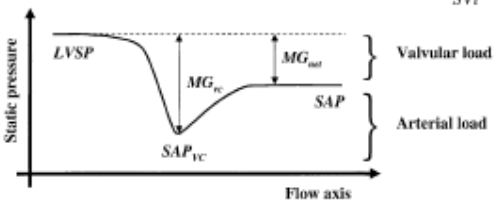
$$Z_{va} = \frac{SAP + MG_{net}}{SVi}$$

Circulation. 2007;115:2856-2864

Valvuloarterial impendance (Z_{va})



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



- This pseudo-normalization phenomenon observed for the gradient also applies to BP, which is often whithin normal range despite the presence of increased arterial rigidity.

- These pts have a markedly higher level of global LV hemodynamic load as reflected by a higher valvuloarterial impendance **(Zva)**

- One of the main advantages of **Zva** is to allow the clinician to unmask the pseudo-normalization of gradient and BP and thereby to better identify the pts with paradoxical low-flow AS.

Curr Cardiol Rep(2010) 12:108-115

LV Geometry

- LVIDd, IVSd, LVPWd / LVIDs, IVSs, LVPWs
- LV mass → Left ventricular mass was calculated with the corrected formula of the American Society of Echocardiography and indexed for body surface area
- RWT → $RWT = 200 \times \frac{PWTd}{LVIDd}$

and LV hypertrophy was defined as LV mass index >115 g · m^{-2} in men and >95 g · m^{-2} in women as recommended in the 2005 report of the American Society of Echocardiography.

Circulation. 2007;115:2856-2864

LV Diastolic Function

Πέρα από τους συμβατικούς δείκτες
και τη σταδιοποίηση της διαστολικής δυσλειτουργίας :

Independent Predictors of LV Diastolic Dysfunction

Variable	Model Without Z_{va} Odd Ratio (95% CI)	p Value	Model With Z_{va} Odd Ratio (95% CI)	p Value
ELI ≤0.60 cm^2/m^2	2.9 (1.5–5.8)	0.003	—	—
SVi/PP ≤0.60 $ml/m^2/mm\ Hg$	3.1 (1.5–6.7)	0.003	—	—
Z_{va} ≥4.5 $mm\ Hg/ml/m^2$	N/A	N/A	5.4 (2.0–14.3)	<0.001

The output of the model was 0 for normal diastolic function and 1 for diastolic dysfunction.
CI = confidence interval; other abbreviations as in Table 2.

JACC Vol. 46, No. 2, 2005

Patients with paradoxical low-flow AS have abnormal myocardial systolic function

Potential Mechanisms of Low-Flow AS in Patients With Normal EF

The combination of a higher global afterload and a decreased output in the PLF group is suggestive of a decrease in cardiac reserve whereby the chronic exposure to a high level of afterload eventually exceeds the limit of LV compensatory mechanisms and leads to an intrinsic impairment of myocardial function and a decrease in cardiac output. This concept is further illustrated by the results of our recent study in which a value of the valvulo-arterial impedance ≥ 5 mm Hg $\cdot$ mL^{-1} $\cdot$ m^{-2} was independently associated with a 4-fold increase in the risk of LV systolic dysfunction defined as a LVEF $<50\%$.[1] However, the apparent discrepancy in the present study is that the PLF patients all had a LVEF $\geq 50\%$ and on this basis could be presumed to have normal LV function. Nonetheless, the same patients also had significantly lower mid-wall fractional shortening and stroke work index, suggesting a significant impairment in intrinsic myocardial function.

Hachicha Z et al., Circulation. 115:2856-2864, 2007

LV Systolic Function

- ***LVEF*** (Simpson bi-plane method)
- ***LV stroke volume***
- ***MWFS***

$$MWFS = 100 \times \frac{(LVIDd/2 + PWTd/2) - (LVIDs/2 + PWTs/2)}{LVIDd/2 + PWTd/2}$$

- ***LV cardiac output***

The LV cardiac output was calculated as the product of heart rate and stroke volume and was indexed for body surface area.

- ***LV SW***

$$SW = (MAP + MG) \times SV \times 0.0136,$$

where MAP is the mean arterial pressure, MG is the mean transvalvular pressure gradiant, and SV is the stroke volume measured in the LVOT. The SW was also indexed to LV mass.

Circulation. 2007;115:2856-2864

Indices more sensitive to detect alterations of intrinsic myocardial systolic function

Longitudinal shortening, velocity, strain

Myocardial deformation

(TDI / 2-D strain / speckle tracking echocardiography / 3-D)

European Heart Journal (2013) **34**, 1906–1914

Circ Cardiovasc Imaging. 2012;5:27-35.

The British Journal of Radiology, 84 (2011), S237–S244

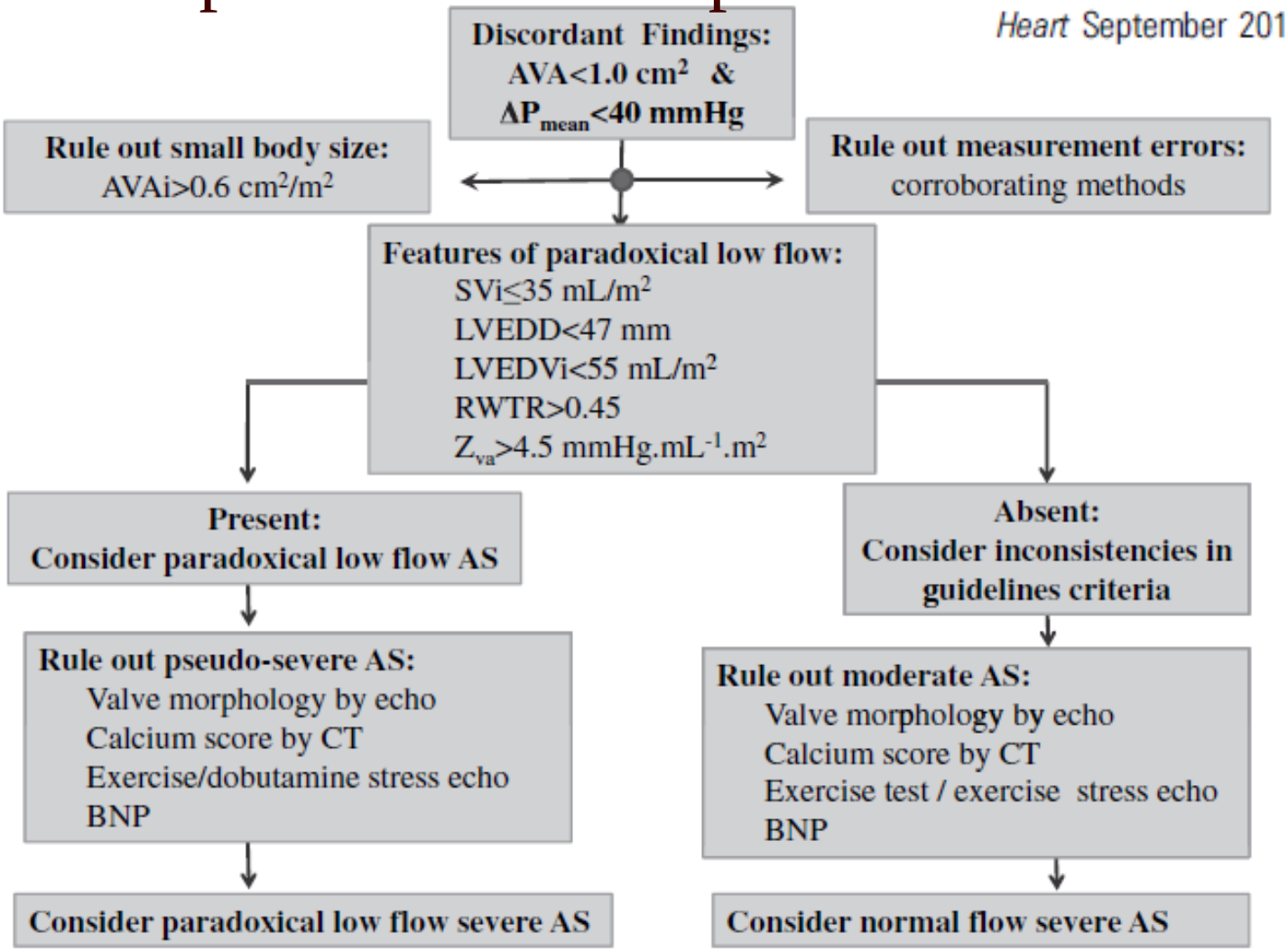
Independent Predictors of LV Systolic Dysfunction Defined as an LV Ejection Fraction <50%

	Model Without Z_{va}		Model With Z_{va}	
Variable	Odds Ratio (95% CI)	p Value	Odds Ratio (95% CI)	p Value
Female gender	—	—	3.5 (1.2–10.3)	0.025
Coronary artery disease	25.2 (3.3–195.0)	0.001	16.7 (2.2–128.7)	0.007
ELI ≤0.50 cm^2/m^2	4.5 (1.8–11.5)	0.002	—	—
SVi/PP ≤0.50 $ml/m^2/mm\ Hg$	2.9 (1.1–7.6)	0.025	—	—
Z_{va} ≥5.0 $mm\ Hg/ml/m^2$	N/A	N/A	4.2 (1.7–10.3)	0.001

JACC Vol. 46, No. 2, 2005

Proposition of Algorithm for DD in pts with AS and preserved LVEF

Heart September 2010 Vol 96 No 18



Curr Cardiol Rep(2010) 12:108-115

Pitfalls and DD

Measurements errors

Small body size

Inconsistency in guidelines criteria

1. Potential cause of discordance of AVA versus gradient in pts with normal EF (indexed AVA, SV and AVA by independent methods, typical features of paradoxical low-flow AS)

2. Rule out the presence of pseudo-severe stenosis (exercise stress test, low dose DSE should be used with caution)

3. Plasma natriuretic peptides

4. Multislice CT (flow independent method) – Valve calcium score >1500-1600Agatston units would support the presence of true severe stenosis and the indication of AVR

Quantifying Severity in the presence of low LV output

TRUE-SEVERE or PSEUDO-SEVERE AS?

- TOPAS study
- BNP>550pg/mL – poor outcome

(with or without contractile reserve)

- It cannot be excluded that valvular obstruction relief, even if moderate by current guidelines criteria, may have beneficial effects on the outcome of some low-flow, low-gradient AS pts with pseudo-severe stenosis

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

The combination of a rest gradient >35 mmHg and an exercise-induced increase in gradient >20 mmHg was associated with markedly increased risk of event (HR = 9.6; $P < 0.0001$) compared to the absence of these two factors (HR = 1.0, referent group) (*Figure 1C*). Patients with a rest gradient >35 mmHg and an increase in gradient ≤20 mmHg during exercise had a 2.5-fold increase in the risk of event compared with the referent group, whereas those with a rest gradient ≤35 mmHg and an increase in gradient >20 mmHg did not display a significant increase in event risk (HR = 0.8; P = NS). There were however very few patients ($n = 9$) in this latter group.

These results show that ESE provides important incremental prognostic information that is unrevealed by standard exercise testing or resting echocardiography. These findings support the utilization of ESE for risk stratification in asymptomatic AS patients.

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

Risk Stratification of pts with AS

Risk stratification in asymptomatic moderate to severe aortic stenosis: the importance of the valvular, arterial and ventricular interplay

Patrizio Lancellotti,[1] Erwan Donal,[2] Julien Magne,[1] Marie Moonen,[1] Kim O'Connor,[1] Jean-Claude Daubert,[2] Luc A Pierard[1]

Conclusions In asymptomatic patients with moderate to severe AS, measurements that integrate the ventricular, vascular and valvular components of the disease improve risk stratification.

Heart 2010;**96**:1364–1371.

Recently (2012)
Lancelloti et al have shown that

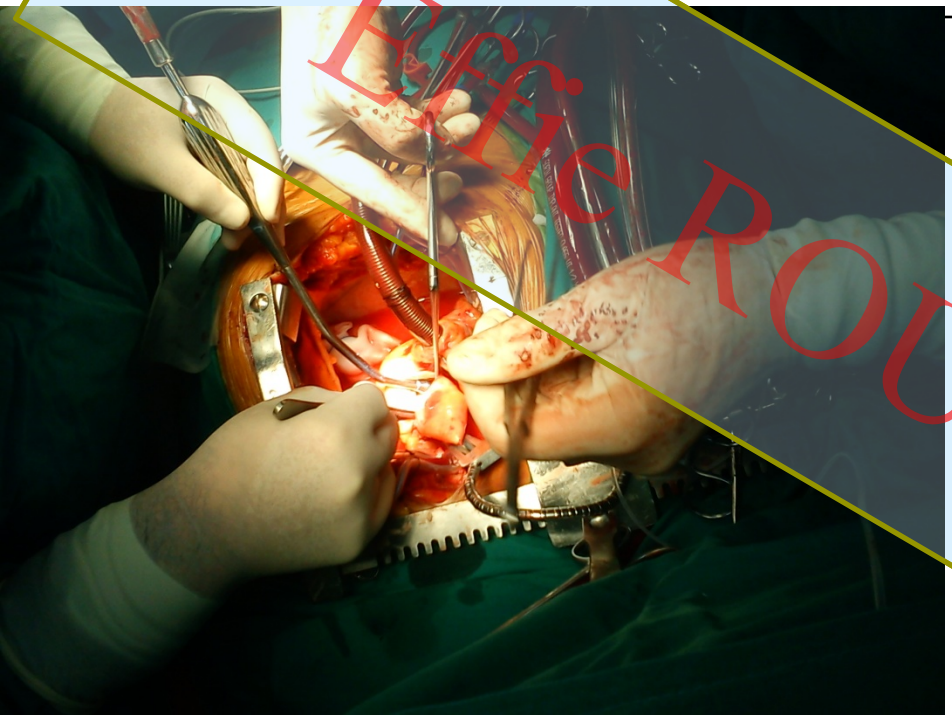
prognosis is better

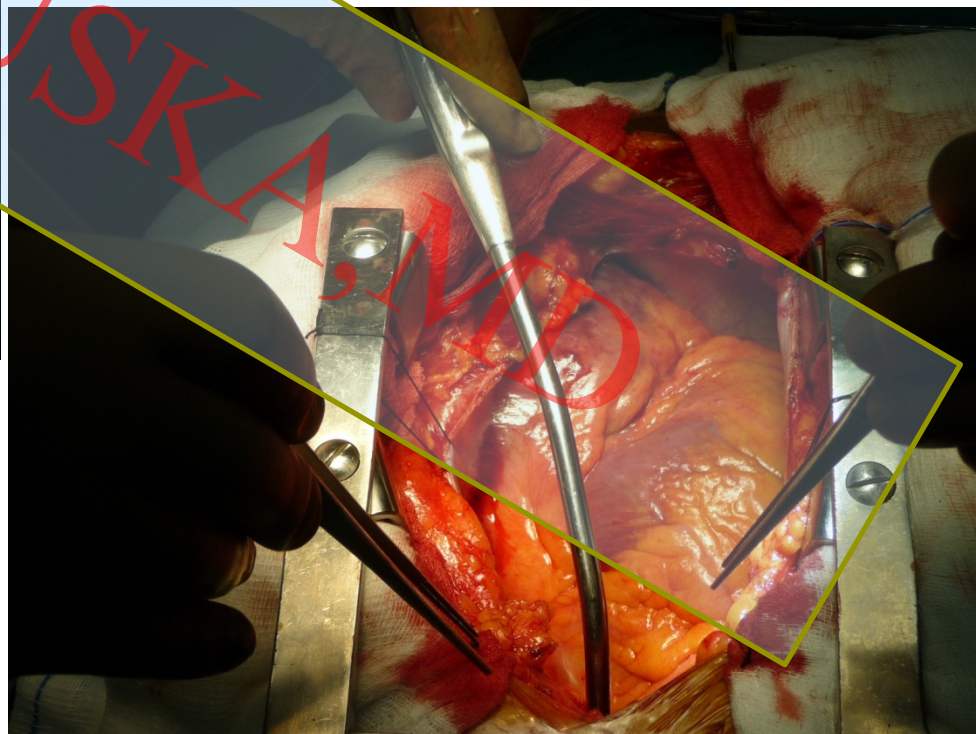
with normal flow, low gradient AS with preserved EF

than with low flow, low gradient AS with preserved EF
or high-gradient AS.

Such pts are common and most likely represent moderate rather than severe AS

Time for surgery?



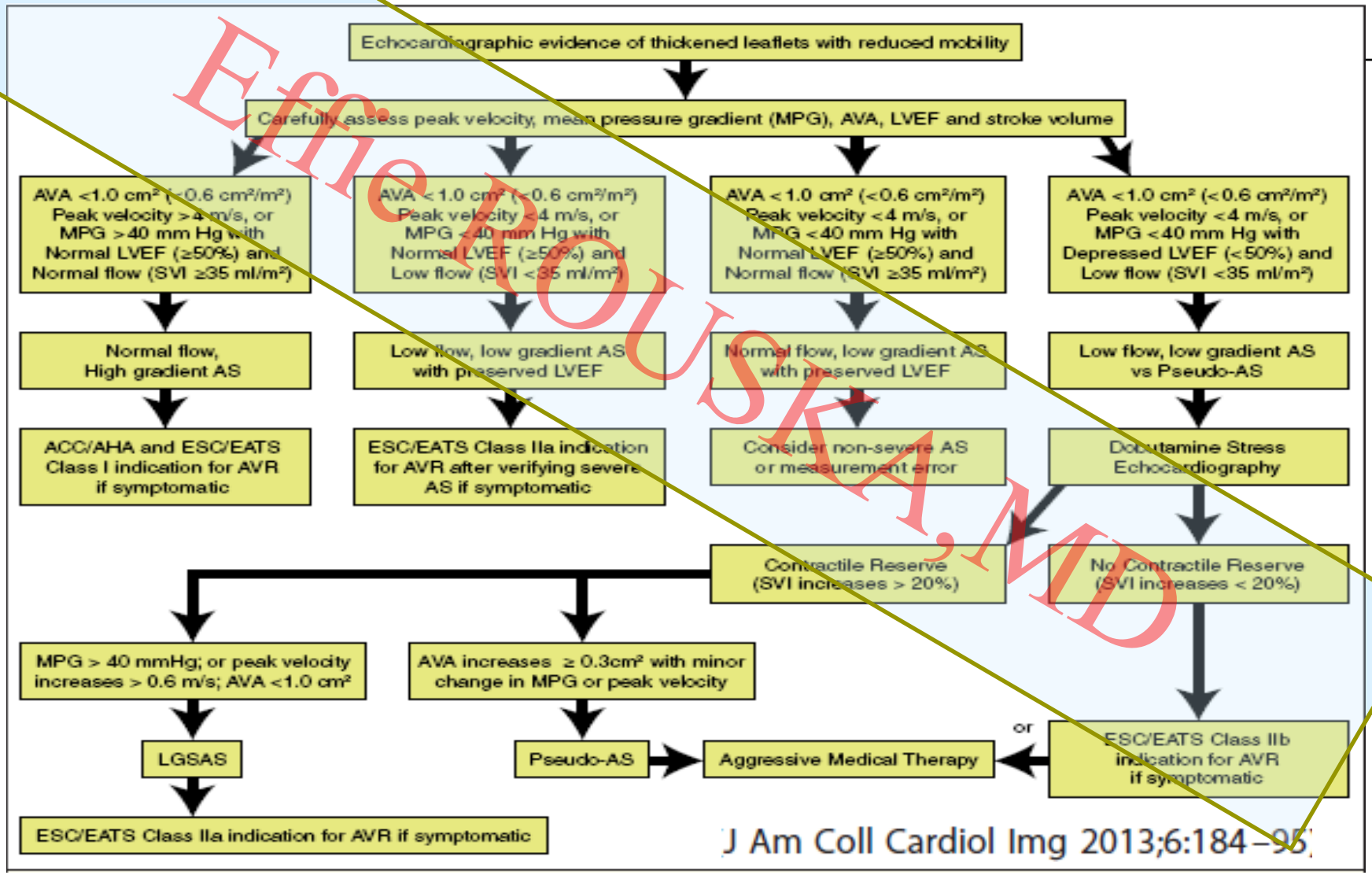


Indications for aortic valve replacement in aortic stenosis

	Class[a]	Level[b]
AVR is indicated in patients with severe AS and any symptoms related to AS.	I	B
AVR is indicated in patients with severe AS undergoing CABG, surgery of the ascending aorta or another valve.	I	C
AVR is indicated in asymptomatic patients with severe AS and systolic LV dysfunction (LVEF <50%) not due to another cause.	I	C
AVR is indicated in asymptomatic patients with severe AS and abnormal exercise test showing symptoms on exercise clearly related to AS.	I	C
AVR should be considered in high risk patients with severe symptomatic AS who are suitable for TAVI, but in whom surgery is favoured by a 'heart team' based on the individual risk profile and anatomic suitability.	IIa	B
AVR should be considered in asymptomatic patients with severe AS and abnormal exercise test showing fall in blood pressure below baseline.	IIa	C
AVR should be considered in patients with moderate AS[d] undergoing CABG, surgery of the ascending aorta or another valve.	IIa	C
AVR should be considered in symptomatic patients with low flow, low gradient (<40 mmHg) AS with normal EF only after careful confirmation of severe AS.[e]	IIa	C
AVR should be considered in symptomatic patients with severe AS, low flow, low gradient with reduced EF, and evidence of flow reserve.[f]	IIa	C
AVR should be considered in asymptomatic patients, with normal EF and none of the above mentioned exercise test abnormalities, if the surgical risk is low, and one or more of the following findings is present: • Very severe AS defined by a peak transvalvular velocity >5.5 m/s or, • Severe valve calcification and a rate of peak transvalvular velocity progression ≥0.3 m/s per year	IIa	C
AVR may be considered in symptomatic patients with severe AS low flow, low gradient, and LV dysfunction without flow reserve.[f]	IIb	C
AVR may be considered in asymptomatic patients with severe AS, normal EF and none of the above mentioned exercise test abnormalities, if surgical risk is low, and one or more of the following findings is present: • Markedly elevated natriuretic peptide levels confirmed by repeated measurements and without other explanations • Increase of mean pressure gradient with exercise by >20 mmHg • Excessive LV hypertrophy in the absence of hypertension.	IIb	C

European Heart Journal (2012) **33**, 2451–2496

Algorithm for classification of pts with suspected LGSAS



J Am Coll Cardiol Img 2013;6:184–95

Early surgery vs conventional treatment in asymptomatic very severe AS

Duk-Hyun Kang, Sung-Ji Park, Ji Hye Rim, Sung-Cheol Yun, Dae-Hee Kim, Jong-Min Song, Suk Jung Choo, Seung Woo Park, Jae-Kwan Song, Jae-Won Lee and Pyo-Won Park

Conclusions—Compared with the conventional treatment strategy, early surgery in patients with very severe aortic stenosis is associated with an improved long-term survival by decreasing cardiac mortality. Early surgery is therefore a therapeutic option to further improve clinical outcomes in asymptomatic patients with very severe aortic stenosis and low operative risk. (*Circulation*. **2010;121:1502-1509.**)

Circulation. 2010;121:1502-1509

Recommendations for the use of TAVI

Recommendations for the use of transcatheter aortic valve implantation

Recommendations	Class [a]	Level [b]	Ref [c]
TAVI should only be undertaken with a multidisciplinary 'heart team' including cardiologists and cardiac surgeons and other specialists if necessary.	I	C	
TAVI should only be performed in hospitals with cardiac surgery on-site.	I	C	
TAVI is indicated in patients with severe symptomatic AS who are not suitable for AVR as assessed by a 'heart team' and who are likely to gain improvement in their quality of life and to have a life expectancy of more than 1 year after consideration of their comorbidities.	I	B	99
TAVI should be considered in high-risk patients with severe symptomatic AS who may still be suitable for surgery, but in whom TAVI is favoured by a 'heart team' based on the individual risk profile and anatomic suitability.	IIa	B	97

European Heart Journal (2012) **33**, 2451–2496

Contra-indications for TAVI

Contraindications for transcatheter aortic valve implantation

Absolute contraindications
Absence of a 'heart team' and no cardiac surgery on the site
Appropriateness of TAVI, as an alternative to AVR, not confirmed by a 'heart team'
Clinical
Estimated life expectancy <1 year Improvement of quality of life by TAVI unlikely because of comorbidities Severe primary associated disease of other valves with major contribution to the patient's symptoms, that can be treated only by surgery
Anatomical
Inadequate annulus size (<18 mm, >29 mm[a])
Thrombus in the left ventricle
Active endocarditis
Elevated risk of coronary ostium obstruction (asymmetric valve calcification, short distance between annulus and coronary ostium, small aortic sinuses)
Plaques with mobile thrombi in the ascending aorta, or arch
For transfemoral/subclavian approach: inadequate vascular access (vessel size, calcification, tortuosity)
Relative contraindications
Bicuspid or non-calcified valves
Untreated coronary artery disease requiring revascularization
Haemodynamic instability
LVEF <20%
For transapical approach: severe pulmonary disease, LV apex not accessible

European Heart Journal (2012) **33**, 2451–2496

To conclude….

"in pts with suspected LGSAS……."

"perform a more comprehensive evaluation of AS severity

going beyond the classical measurements to include indices that are less flow-dependent"

Take home messages

In pts with suspected LGSAS

- Focus not only on the VALVE (AoV)

(Appearance of the valve, Number of cusps,Pattern of thickening, Mobility)

- Focus also on the LEFT VENTRICLE (LV)
- Focus also on the AORTA (Ao)
- Measure BP at the time of examination

LGSAS is relatively frequent (up to 35% of cases)

and such pts have a poorer prognosis if treated medically rather than surgically

Assessment of LGSAS and further management needs echocardiologists well trained and experienced!


Effie ROUSKA,MD

Global LV Afterload

As a measure of global LV afterload, we calculated the valvulo-arterial impedance:[1]

$$Z_{va} = \frac{SAP + MG}{SVI}, \quad (8)$$

where SAP is the systolic arterial pressure and MG is the mean transvalvular pressure gradient. Hence Z_{va} represents the valvular and arterial factors that oppose ventricular ejection by absorption of the mechanical energy developed by the left ventricle.[1] The measurement of systemic arterial pressure was not performed at the time of the Doppler echocardiographic study in 86 patients. Systemic vascular resistance, SAC, and Z_{va} could thus not be determined in these patients. However, there was no significant difference in the missing rates of these variables as well as those of the LVEF and stroke volume measured by the Simpson method between the NF and PLF groups.

Gorlin Equation (cath lab)

the Gorlin equation ($AVA = \frac{CO/SEP*HR}{44.3\sqrt{\Delta Pm}}$, CO indicating cardiac output, SEP systolic ejection period, HR heart rate

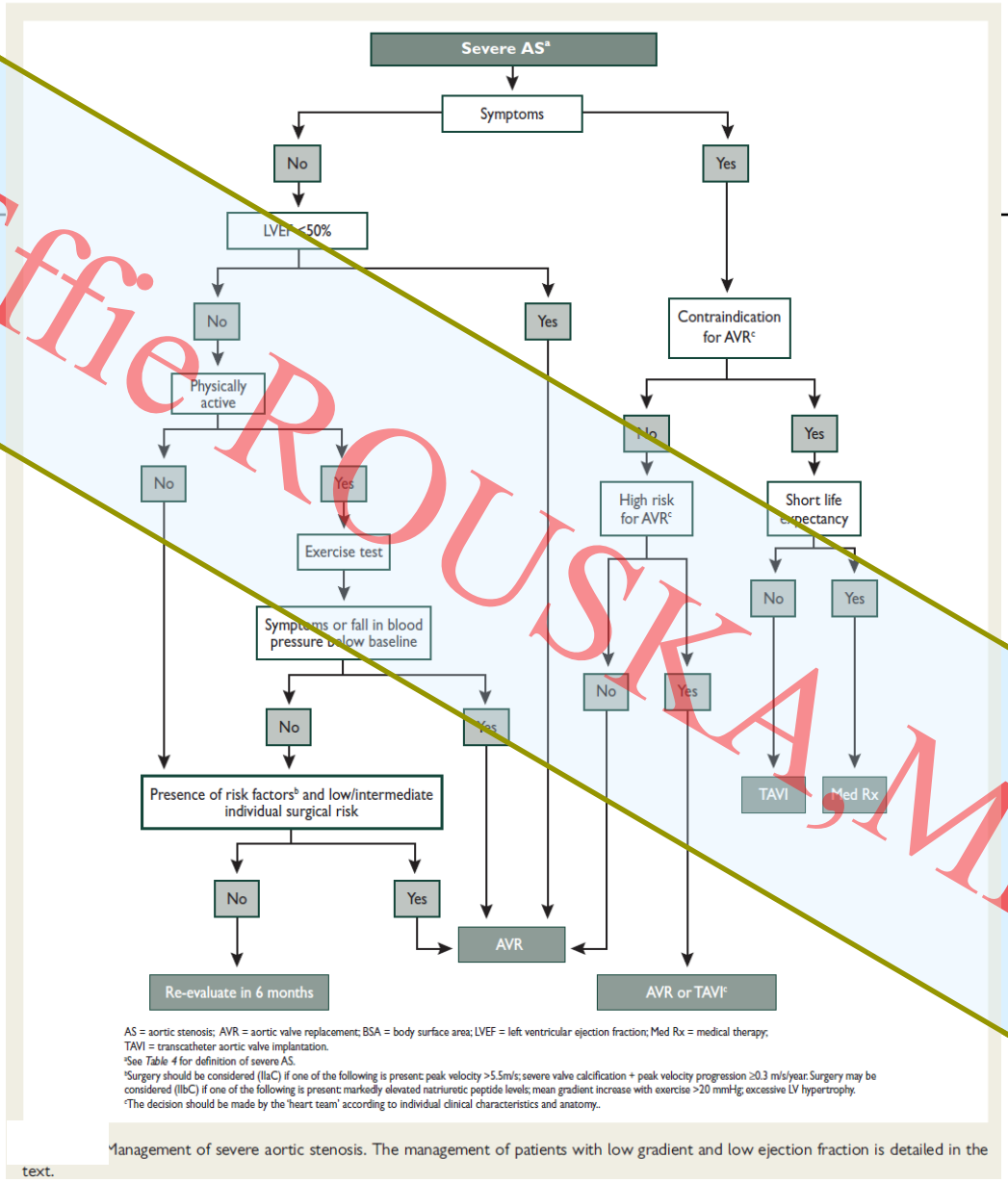
Projected AVA

(Truly or Pseudo Severe Aortic Stenosis) multicenter study recently proposed a new parameter: the projected valve EOA at a normal transvalvular flow rate [22•]. For each patient, EOA is plotted against transvalvular flow (Q) at each dobutamine stage, and the EOA at a standardized value of flow rate of 250 mL/sec is projected from the equation of the regression line fitted to the EOA versus Q plot. The projected EOA can correct for important inter-individual variability in the flow response to dobutamine stress echocardiography and can improve this test's diagnostic accuracy to distinguish true severe from pseudo-severe AS in patients with low-flow, low-gradient AS.

Current Cardiology Reports 2008, **10**:91–97

Exercise Stress Echocardiography

The main finding of this study is that ESE provides incremental prognostic information beyond that obtained by resting echocardiography or exercise testing alone. An increase in mean gradient >20 mmHg during exercise was independently associated with a 3.8-fold increase in the risk of event after adjusting for other risk factors including age, diabetes, LV hypertrophy, rest gradient, and peak exercise LV ejection fraction. Moreover, patients having both

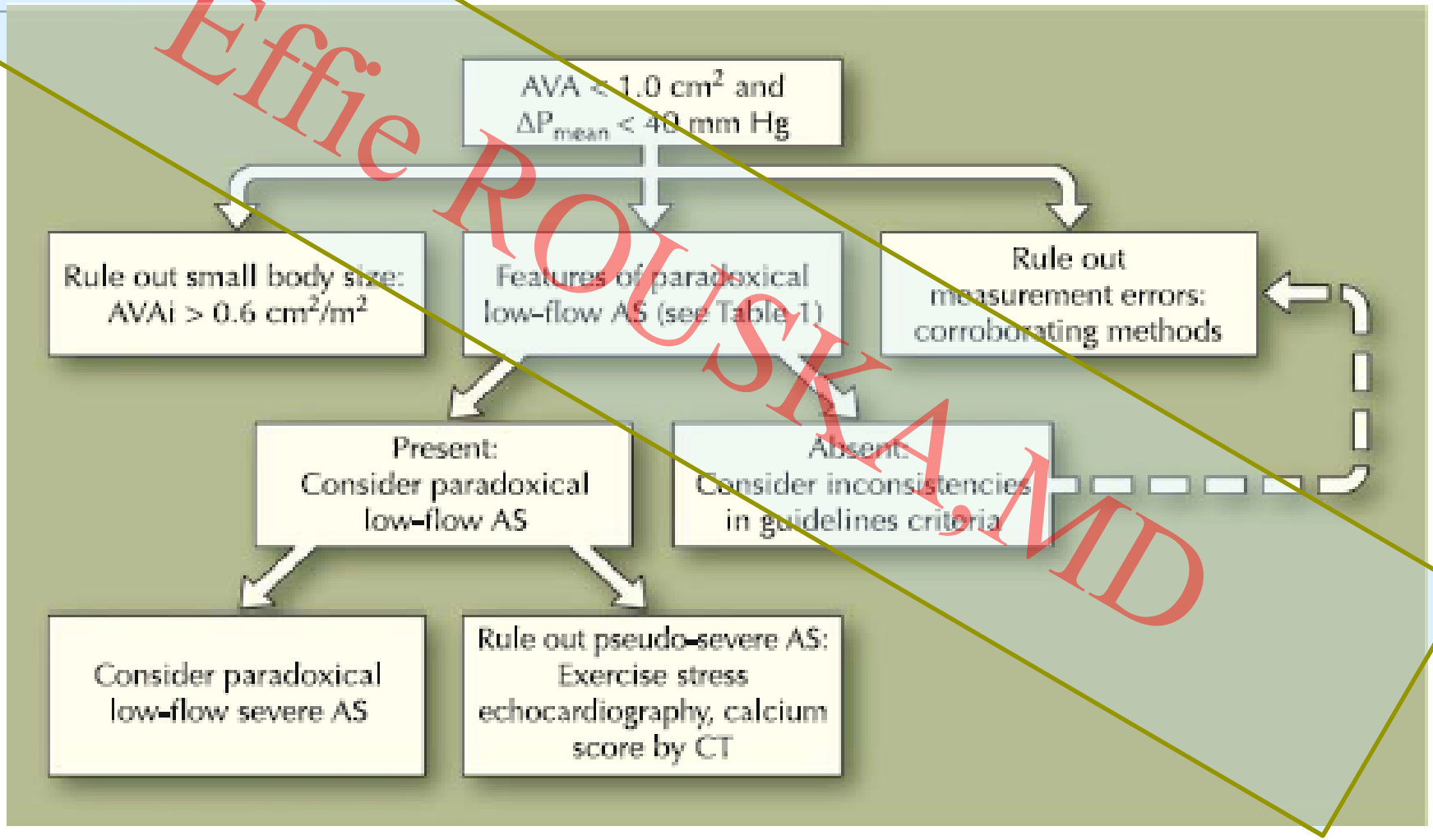


AS = aortic stenosis; AVR = aortic valve replacement; BSA = body surface area; LVEF = left ventricular ejection fraction; Med Rx = medical therapy; TAVI = transcatheter aortic valve implantation.
[a]See *Table 4* for definition of severe AS.
[b]Surgery should be considered (IIaC) if one of the following is present: peak velocity >5.5m/s; severe valve calcification + peak velocity progression ≥0.3 m/s/year. Surgery may be considered (IIbC) if one of the following is present: markedly elevated natriuretic peptide levels; mean gradient increase with exercise >20 mmHg; excessive LV hypertrophy.
[c]The decision should be made by the 'heart team' according to individual clinical characteristics and anatomy..

Management of severe aortic stenosis. The management of patients with low gradient and low ejection fraction is detailed in the text.

European Heart Journal (2012) **33**, 2451–2496

Proposition of Algorithm for DD in pts with AS and preserved LVEF



Curr Cardiol Rep(2010) 12:108-115

LV Stroke Work Loss (SWL)

$$SWL = 100 \times \left(\frac{MG}{MG + SAP} \right)$$

where SAP is the systolic brachial artery pressure in mm Hg

Circulation. 2006;113:711-721