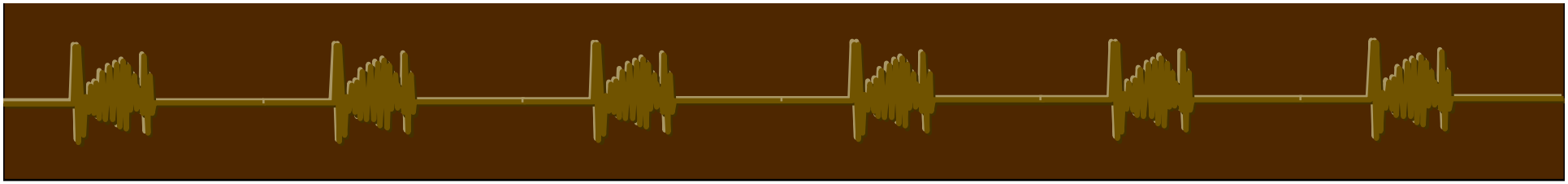


Sténose aortique: Investigations noninvasives

Cours de formation postgradué

Service de cardiologie HUG

06 juin 2007

Cardiac auscultation

Direct auscultation 460 – 370 BC

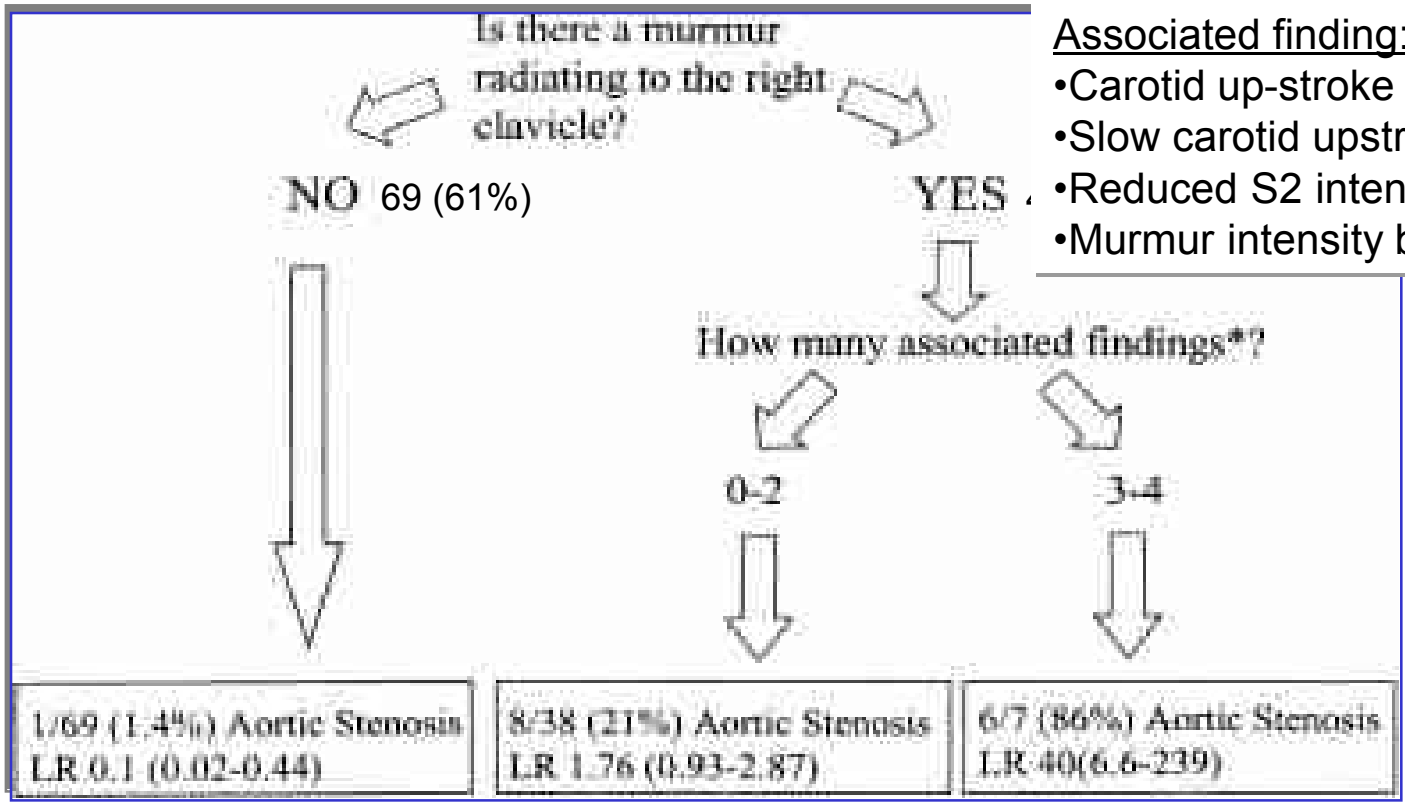
Stethoscope: R.T.H. Laennec 1816

« … I rolled a quire of paper into a sort of cylinder …….. I could perceive the action of the heart in a manner much more clear and distinct than I had ever been able to do by the immediate application of the ear. »

« A History of Cardiac Auscultation and Some of its Contributors »
Hanna and Silverman. Am J Cardiol 2002; 90: 259-267

Bedside clinical prediction of aortic stenosis

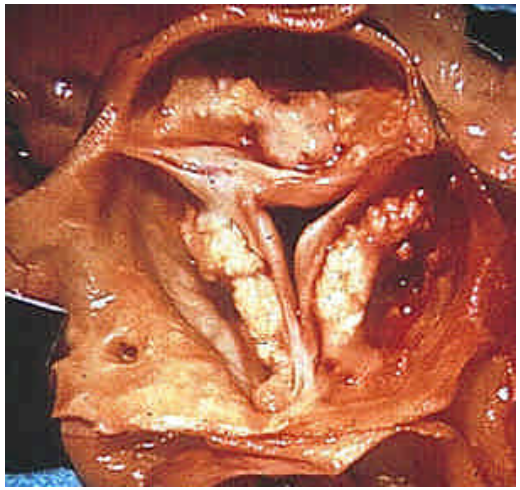
114 patients, ≥ 50 years, referred for echocardiography
Physical examination by 2 experienced physicians before echocardiogram



Associated finding:
- Carotid up-stroke volume
- Slow carotid upstroke
- Reduced S2 intensity
- Murmur intensity base>apex

Etchells et al, J Gen Int Med 1998; 13: 1525-1497

Aortic stenosis



Key elements for follow-up:

- Severity of stenosis
- Symptoms

Aortic stenosis: Grading of severity

	Valve area	
Mild	> 1.5 cm^2	
Moderate	> 1.0 to 1.5 cm^2	
Severe	≤ 1.0 cm^2	(≤ 0.6 cm^2/m^2)

ACC/AHA Guidelines for the Management of Patients with Valvular Heart Disease Circulation 2006

Guidelines on the management of valvular heart disease. Eur Heart J 2007; 28: 230-268

Aortic stenosis:
Echocardiography

Nevertheless, it has to be emphasized that valve area measurements also have their potential inaccuracies and are less robust than gradient estimates in clinical practice. Thus, valve area alone with absolute cut-off points cannot be relied upon for clinical decision-making and it should be considered in combination with flow rate, pressure gradient, ventricular function as well as functional status.

Guidelines on the management of valvular heart disease. Eur Heart J 2007; 28: 230-268

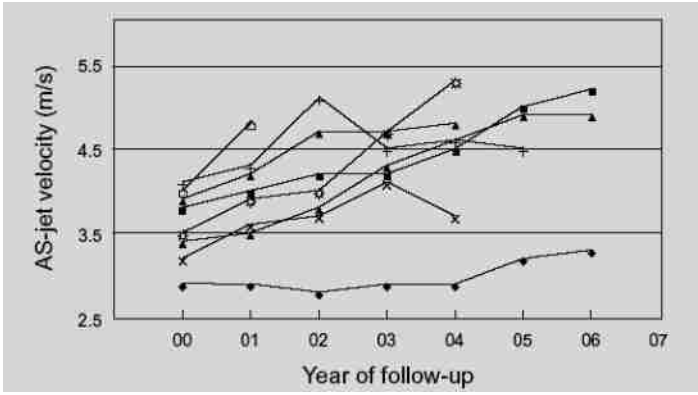
Aortic stenosis: Echocardiography

Average disease progression

Increase of maximal velocity	0.3 m/sec per year
Increase of mean pressure gradient	7 mmHg per year
Decrease of valve area	0.1 cm^2 per year

(Stout and Otto, J intensive Care Med 2007; 22: 14-25)

….. but large variability



Follow-up of asymptomatic patients with aortic valve calcification

TABLE 4

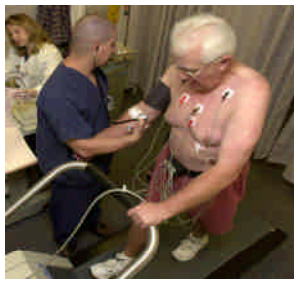
Suggested follow-up intervals for echocardiographic evaluation of asymptomatic aortic stenosis in the absence of a change in clinical status

Aortic valve disease severity	Aortic jet velocity (m/s)	AVA (cm^2)	Follow-up interval
Aortic sclerosis	<2.5		4–5 years
Mild stenosis	2.5–3.0	>1.5	2–3 years
Moderate stenosis	3.0–4.0	1.0–1.5	Annually
Severe stenosis	>4.0	<1.0	Annually

(Otto et al, Proc R Coll Physicians Edinb 2001; 31: 208-215)

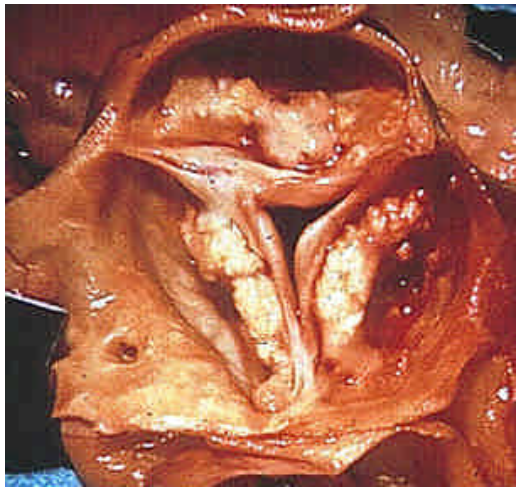
Aortic stenosis:
Recommendation on participation in sports

Severity of aortic stenosis	Physical activity
Mild	→ No restriction
Moderate	→ Stress test ↓ Individual counseling
Severe	→ Low activity



ACC/AHA Guidelines for the Management of Patients with Valvular Heart Disease
Circulation 2006

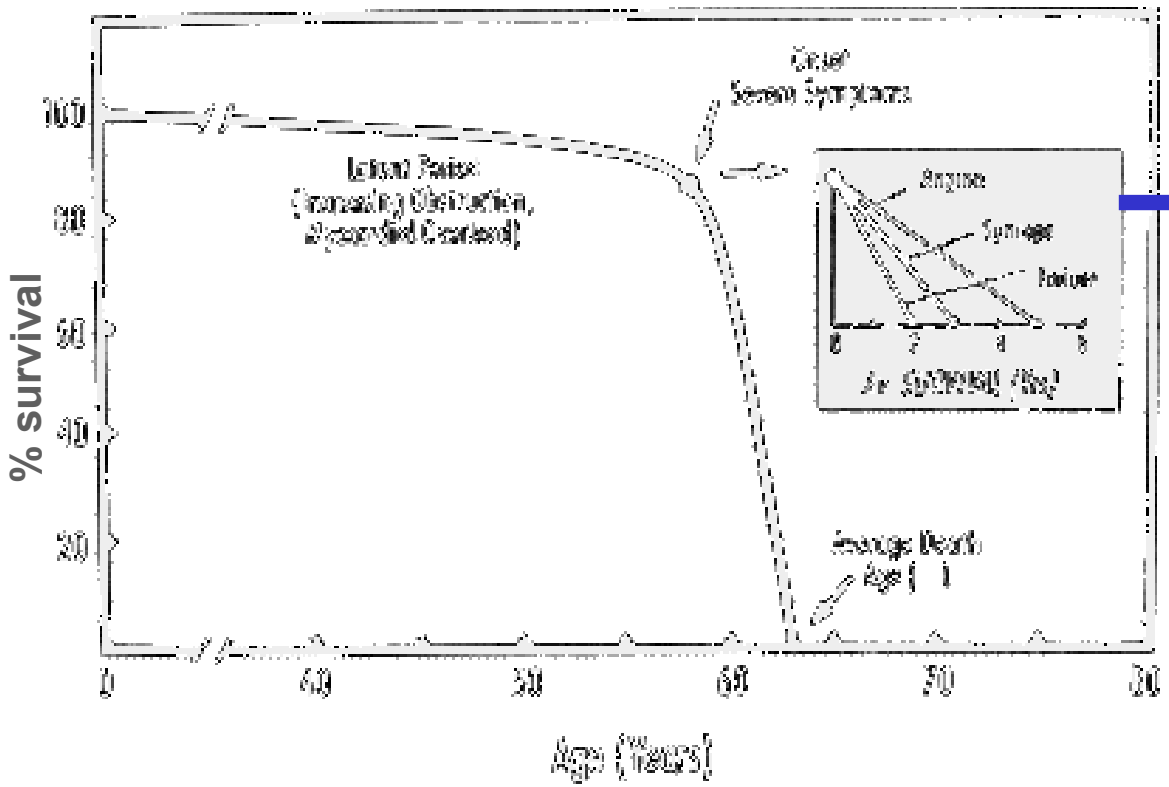
Aortic stenosis



Key elements for follow-up:

- Severity of stenosis
- Symptoms

Aortic stenosis:
Natural history of severe aortic stenosis



J. Ross, Jr. and E. Braunwald. Circulation 1968; 38: V-61–V-67.

3-years mortality of symptomatic pts.

75 %

(Carabello, JACC 2004; 376-383)

Aortic stenosis:
Risk of sudden death in asymptomatic patients

Table 11. Studies of the Natural History of Asymptomatic Patients With Aortic Stenosis

Study, y	Number of patients	Mean follow-up, year	Severity of aortic stenosis	Sudden death without symptoms (number of patients)	Comments
Chizner et al 1980 (91)	8	5.7	AVA < 1.1 cm^2	0	retrospective study
Turina et al 1987 (77)	17	2.0	AVA < 0.9 cm^2	0	retrospective study
Henriksen and Lougen 1988 (88)	25	"years"	AVA = 0.4–0.8 cm^2	3	retrospective study
Kelly et al 1988 (90)	51	1.5	PV = 3.5–5.0 m/s	0	prospective study
Pellikka et al 1990 (92)	113	1.7	PV > 4.0 m/s	0	prospective study
Faggiano et al 1992 (81)	27	2.0	AVA = 0.85 ± 0.15 cm^2	0	prospective study
Otto et al 1997 (84)	114	2.5	PV = 3.6 ± 0.6 m/s	0	prospective study
Total	375	2.1		3	average risk of sudden death = 0.4%/y

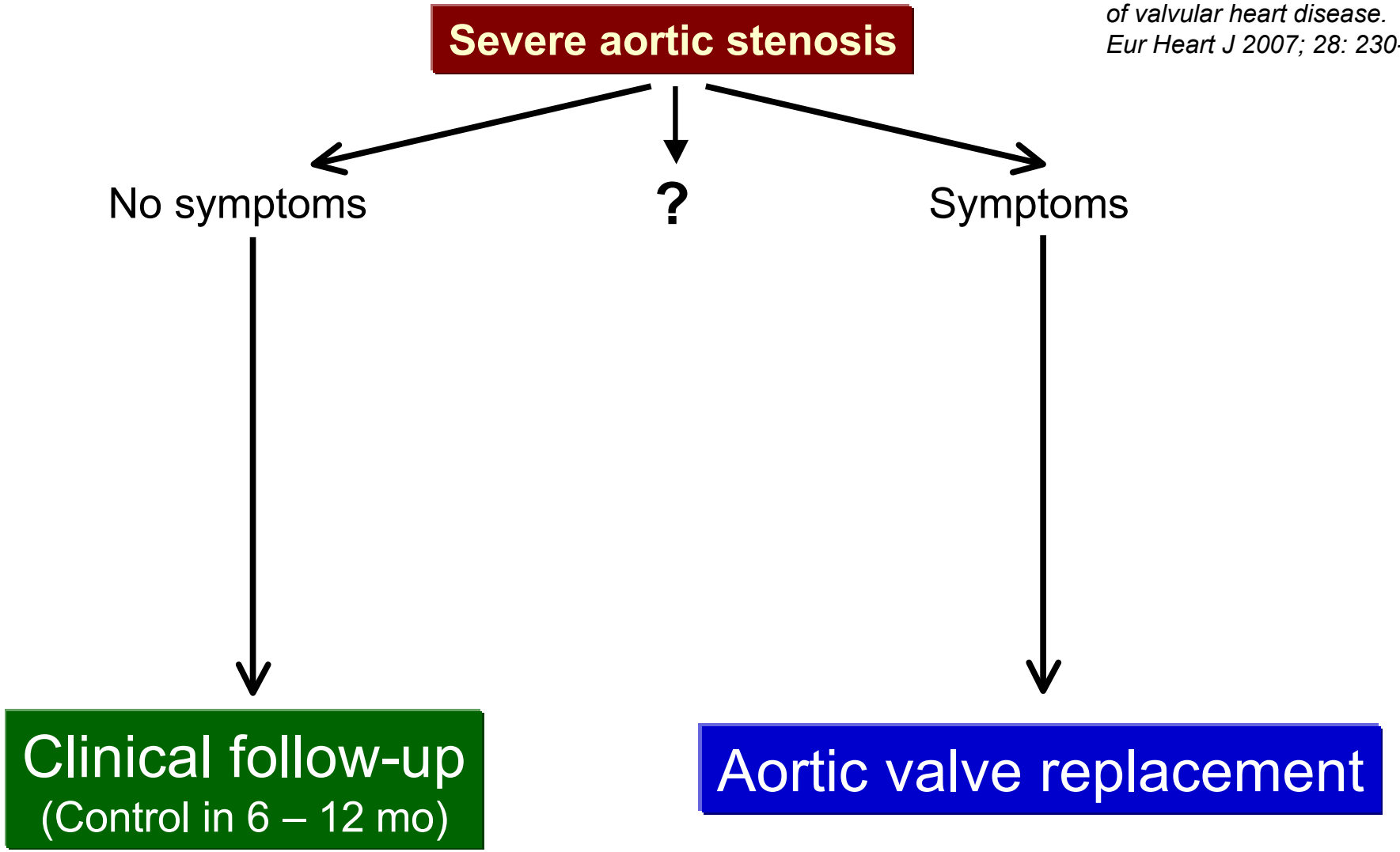
Abbreviations: AVA = aortic valve area; PV = peak instantaneous velocity

Average annual risk of sudden death < 1%

ACC/AHA Guidelines for the Management of Patients with Valvular Heart Disease
Circulation 2006

Recommendations for the management of severe aortic stenosis

Guidelines on the management of valvular heart disease. Eur Heart J 2007; 28: 230-268



Aortic stenosis:
Is this patient really asymptomatic?

Exercise testing may be helpful in apparently asymptomatic patients with severe aortic stenosis!

(! careful observation of symptoms, blood pressure, ECG !)

Pathological test result:

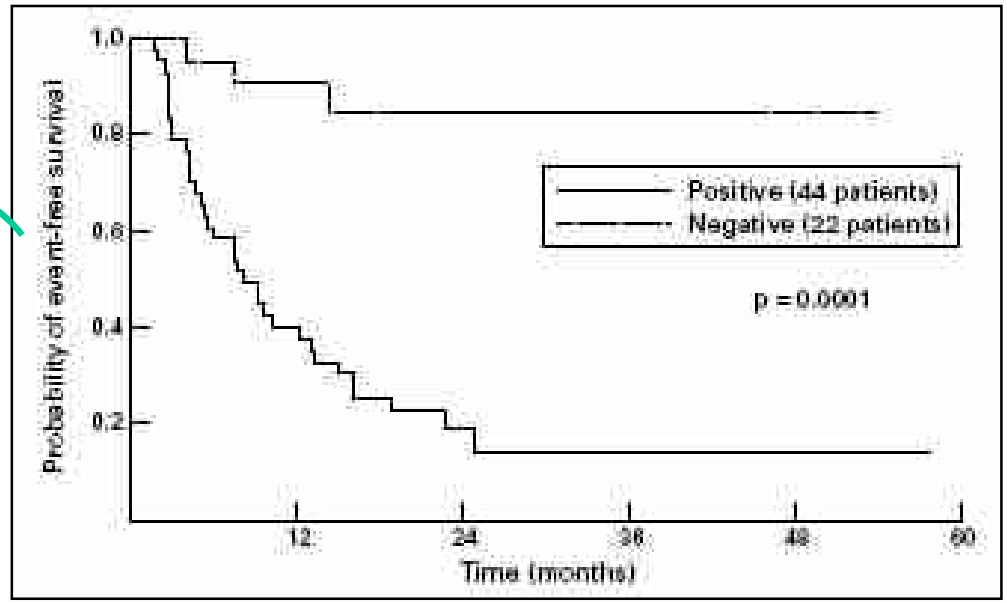
- Symptoms (dyspnea, angina, syncope, dizziness)
- Raise in syst BP < 20 mmHg
- Exercis tolerance < 80% of normal
- ST-segment depression (≥2mm)
- Complex arrhythmia

Aortic stenosis:
Is this patient really asymptomatic?

Exercise testing may be helpful in apparently asymptomatic patients with severe aortic stenosis!

➡ 66 asymptomatic patients with severe aortic stenosis

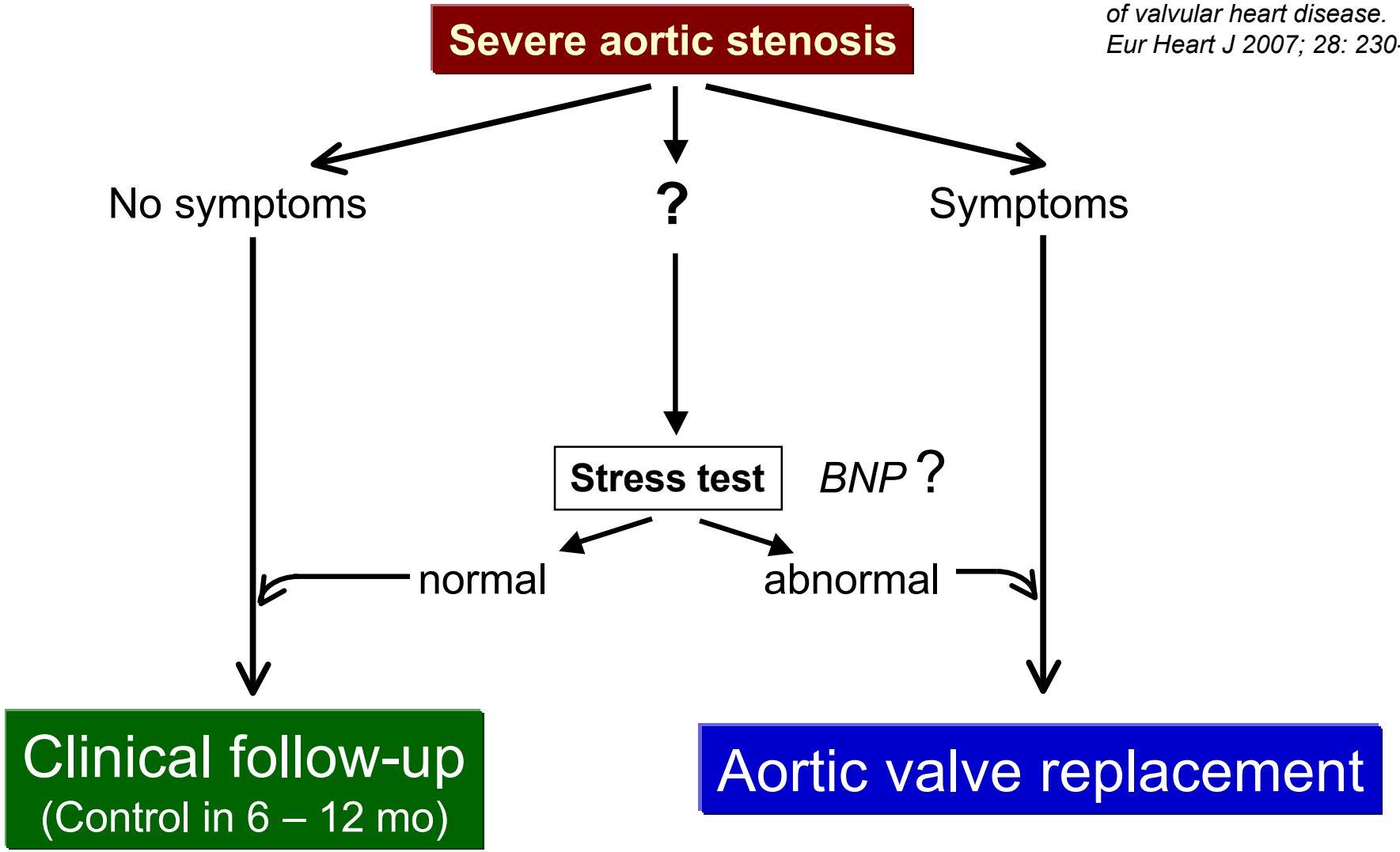
« Event-free »
no symptoms



(Amato et al, Heart 2001; 86: 381-386)

Recommendations for the management of severe aortic stenosis

Guidelines on the management of valvular heart disease. Eur Heart J 2007; 28: 230-268



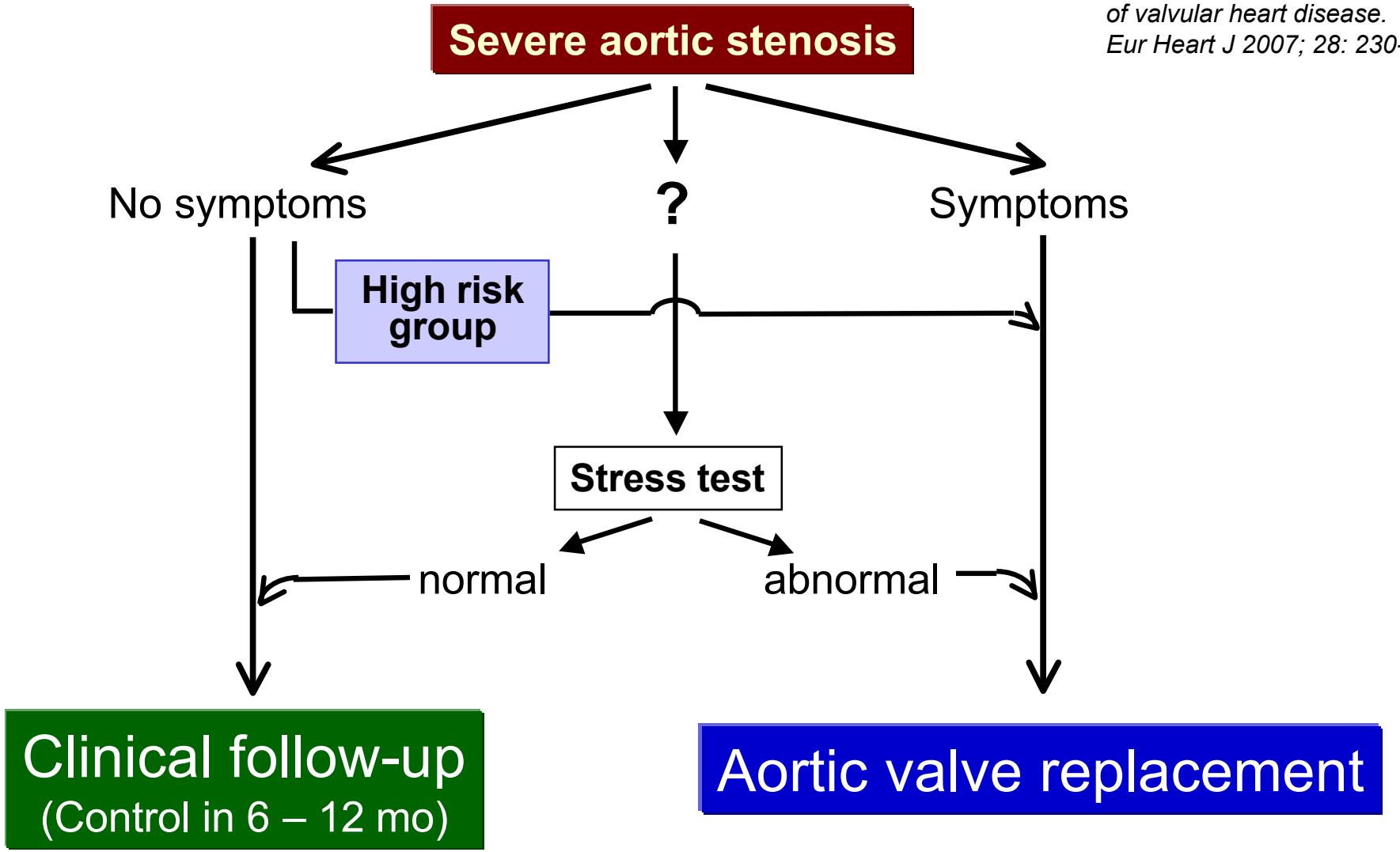
Recommendations for the management of severe aortic stenosis

High risk subgroups of asymptomatic patients:

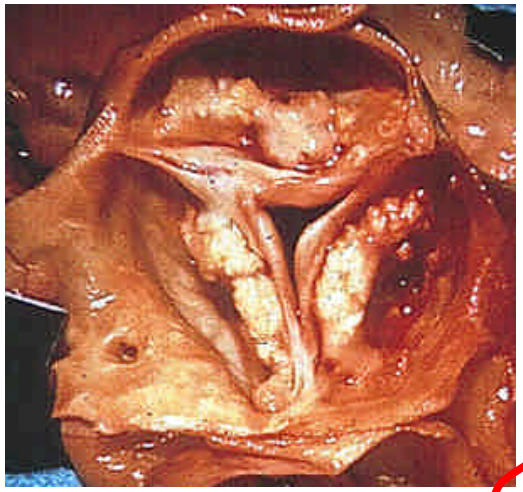
- Progression ≥ 3 m/sec/year
- Calcification +++
- EF ≤ 50%

Recommendations for the management of severe aortic stenosis

Guidelines on the management of valvular heart disease. Eur Heart J 2007; 28: 230-268



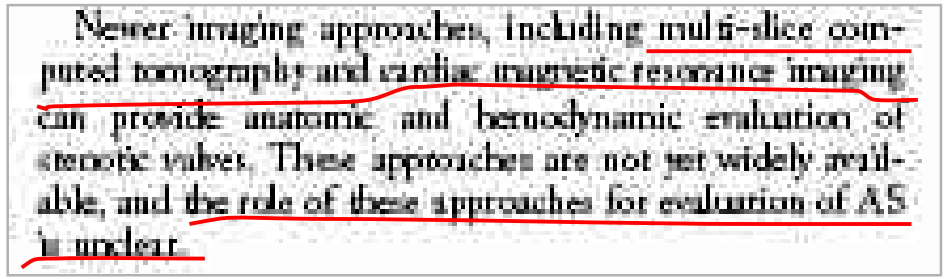
Aortic stenosis



Key elements for follow-up:

- Severity of stenosis
- Symptoms

Aortic stenosis:
Noninvasive diagnostic evaluation of severity



Newer imaging approaches, including multi-slice computed tomography and cardiac magnetic resonance imaging can provide anatomic and hemodynamic evaluation of stenotic valves. These approaches are not yet widely available, and the role of these approaches for evaluation of AS is unclear.

Otto, J Am Coll Cardiol 2006; 47: 2141-51

Echocardiography

(Cardiac magnetic resonance tomography)

(Cardiac computer tomography)

Aortic stenosis:
Echocardiography

Information obtained by echocardiography

- Diagnosis
- Etiology
- Severity
- Left ventricular function
- Left ventricular hypertrophy
- Associated lesions (Aortic dilatation!)

Aortic stenosis:
Echocardiography

Diagnosis

Generally reported: Sensitivity 100%

But :

- Sensitivity dependent on definition of «aortic stenosis»
- Correct for «no pressure gradient at rest»
- Surface often diminished earlier

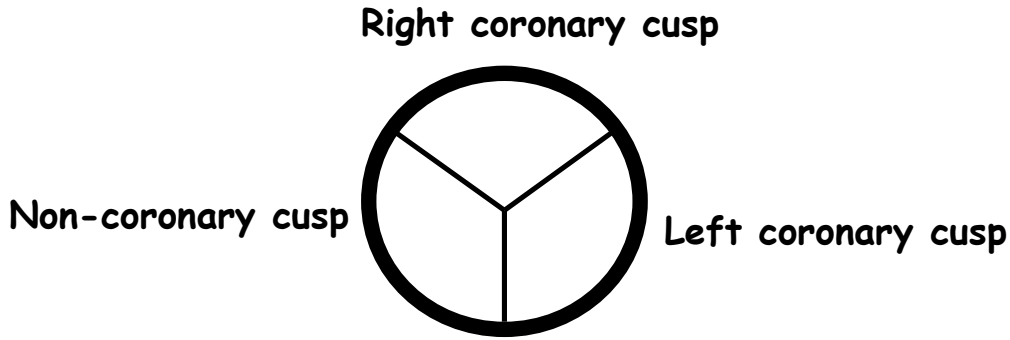
Aortic stenosis:
Echocardiography

Information obtained by echocardiography

- Diagnosis
- Etiology
- Severity
- Left ventricular function
- Left ventricular hypertrophy
- Associated lesions (Aortic dilatation!)

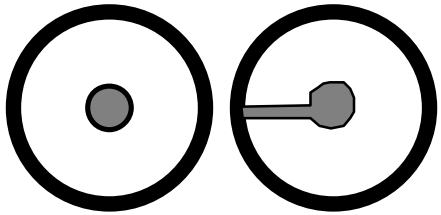
Aortic stenosis: Echocardiography

Ethiology



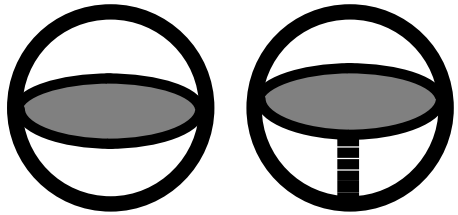
Congenital

Monocusp



without commissure — with commissure

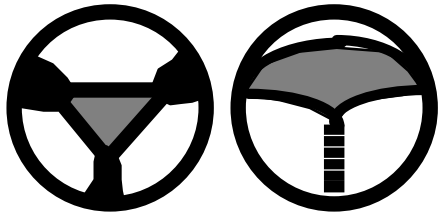
Bicuspid



without pseudocommissure — with pseudocommissure

Acquired

Rheumatic

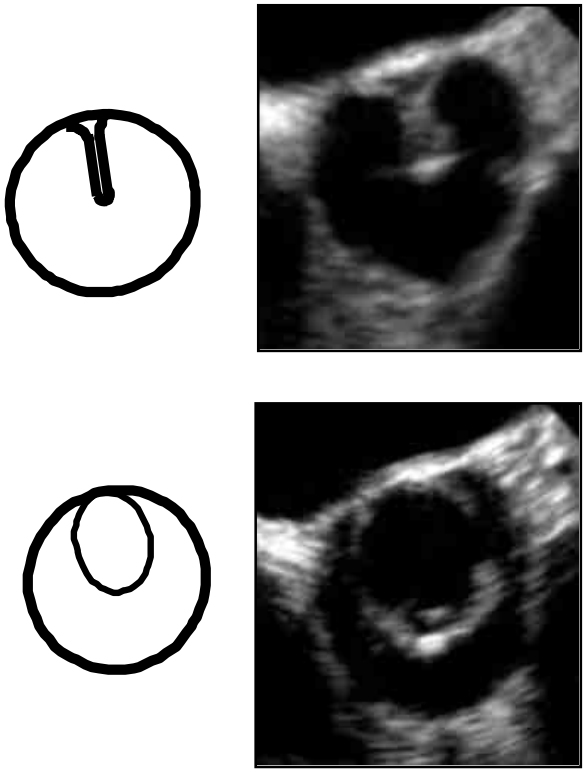


commissural fusion

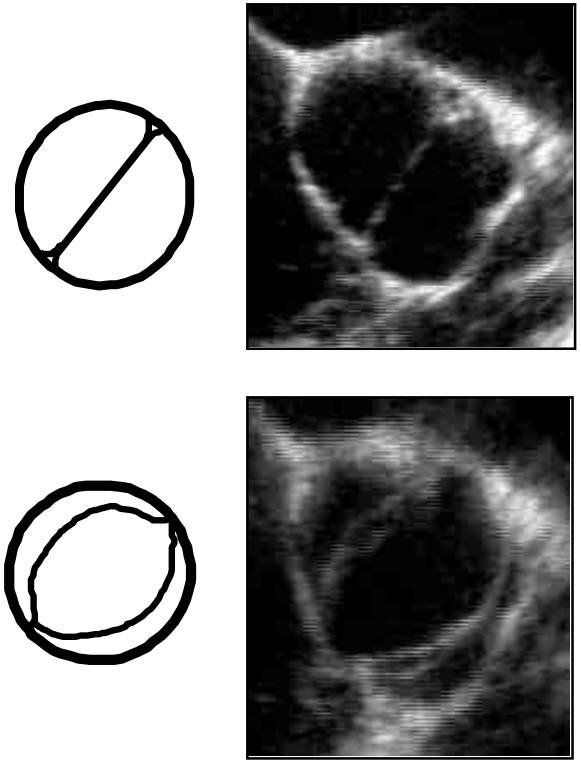
Sclerosis

Aortic stenosis:
Echocardiography

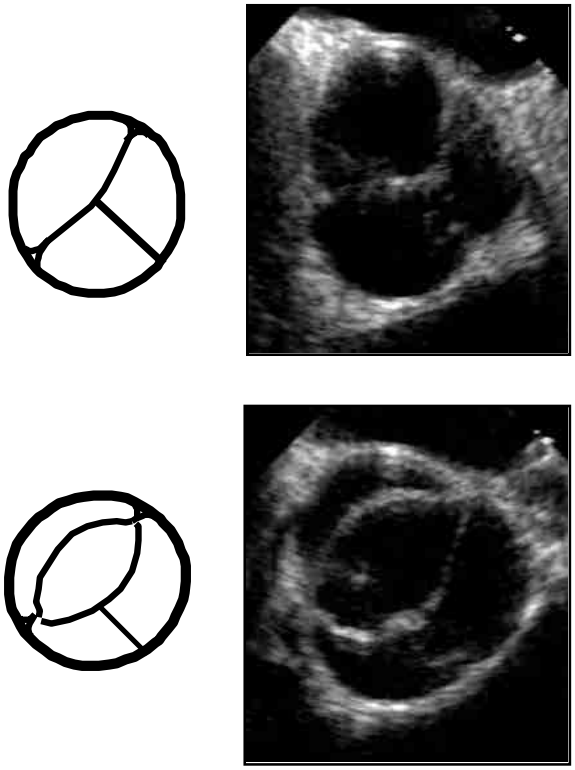
Monocusp



Bicuspid



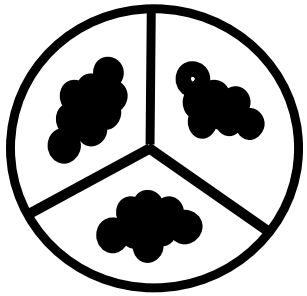
Bicuspid
with pseudocommissure



Aortic stenosis:
Echocardiography

Degenerative

Mobility	↓↓
Thickness	↑↑
Doming	-



Rheumatic

Mobility	(↓)
Thickness	↑
Doming	+

Aortic stenosis: Echocardiography

Information obtained by echocardiography

- Diagnosis
- Etiology
- Severity
- Left ventricular function
- Left ventricular hypertrophy
- Associated lesions (Aortic dilatation!)

Aortic stenosis:
Echocardiography

Severity

- Peak aortic velocity
- Pressure gradient
- Aortic valve area

Aortic stenosis:
Echocardiography

Predictive value of peak aortic velocity

(Otto Arch Int Med 1988; 148: 2553)

> 4.0 m/sec : in most cases «surgical-degree» stenosis

3.0 - 4.0 m/sec : calculate AVA !!

< 3.0 m/sec : in most cases mild to moderate stenosis

Aortic stenosis:
Echocardiography

Pressure gradient in aortic stenosis :
Different Doppler gradients

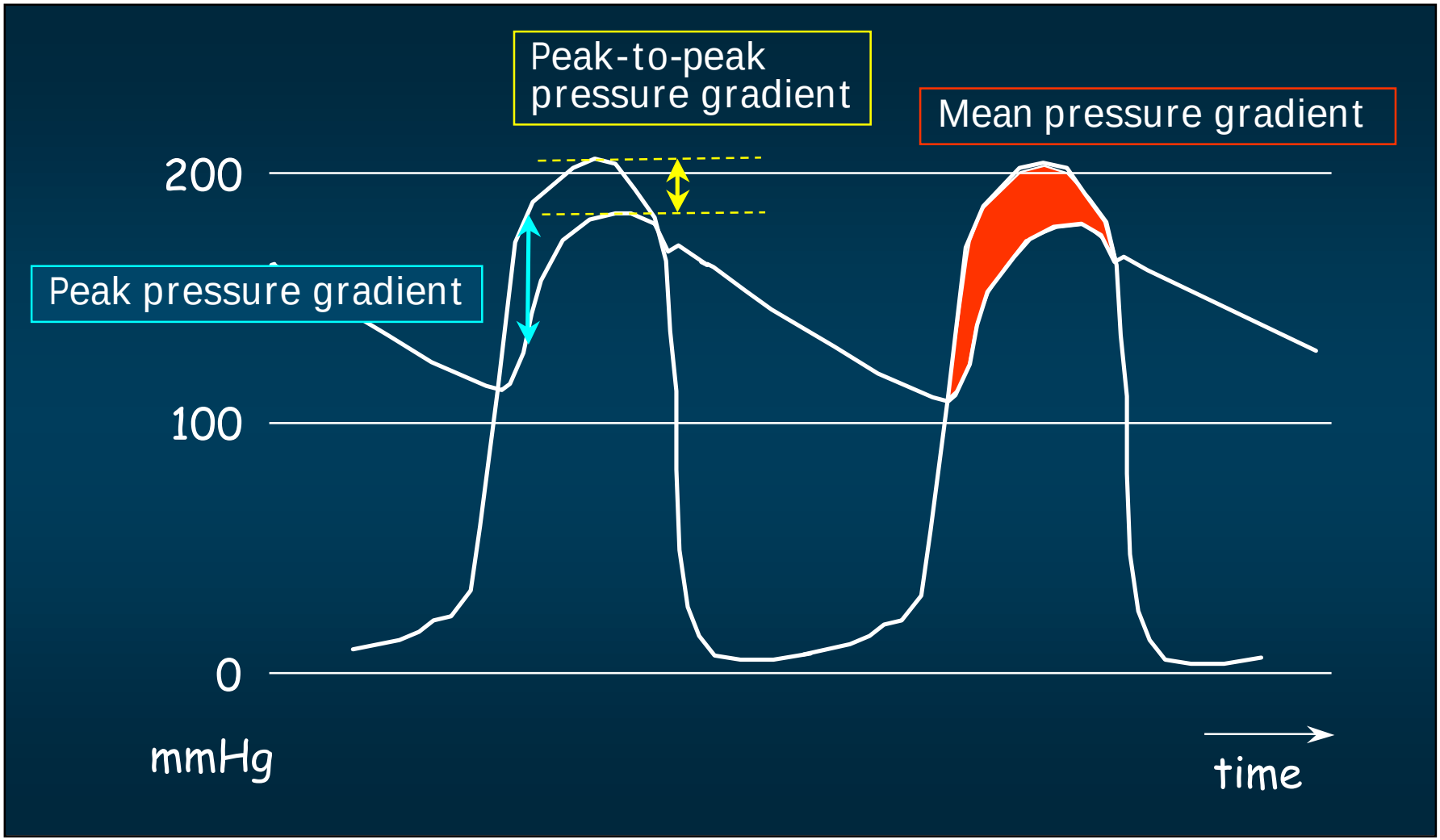
Maximal gradient uncorrected for v_1

Mean gradient uncorrected for v_1

Maximal gradient corrected for v_1

Mean Gradient corrected for v_1

Echocardiography in aortic stenosis:
Pressure gradients



Echocardiography in aortic stenosis: *Pressure gradients*

Bernoulli equation for calculation of Doppler gradients

$$p_1 - p_2 = 1/2\rho\,(v_2^2 - v_1^2) + \rho\int \frac{dv}{dt}\,ds + R(\mu, v)$$

Convective acceleration | Flow acceleration | Viscous friction

Simplification

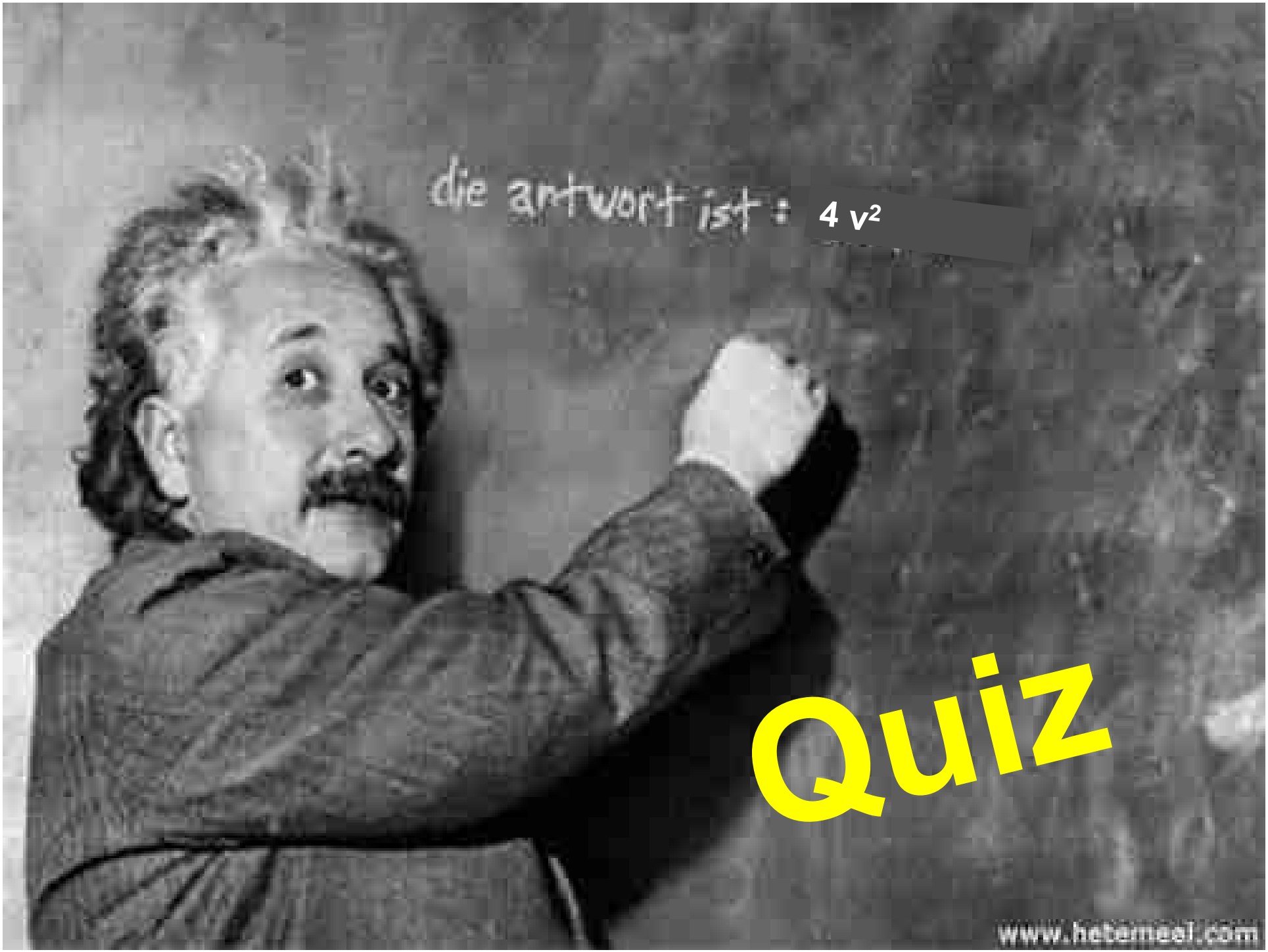
$$\Delta p = 1/2\rho\,(v_2^2 - v_1^2);$$

$$\Delta p = 4\,(v_2^2 - v_1^2);$$ (Δp in mmHg)

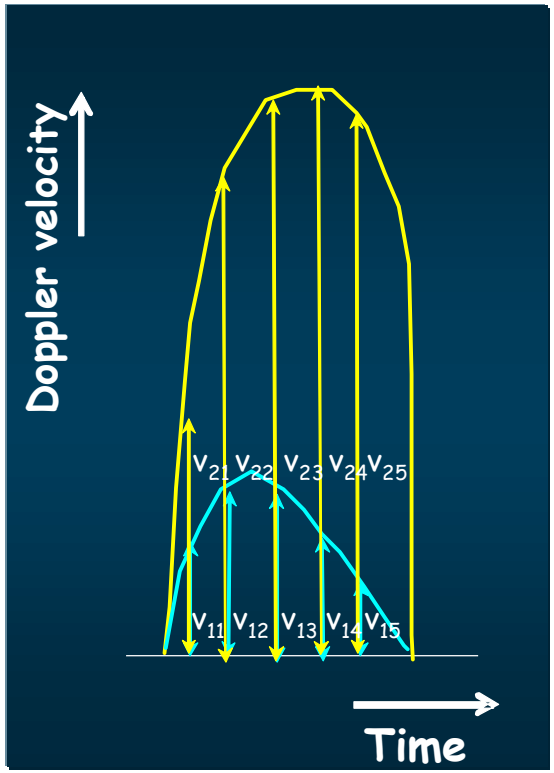
$$\Delta p = 4\,v_2^2$$ if $v_2 \ggg v_1$

Echocardiography has become very easy !

$$p_1 - p_2 = 1/2\rho\,(v_2^2 - v_1^2) + \rho \int \frac{dv}{dt}\,ds + R\,(\mu, v)$$


die antwort ist : 4 v²
Quiz
www.hetemeel.com

Echocardiography in aortic stenosis:
Pressure gradients

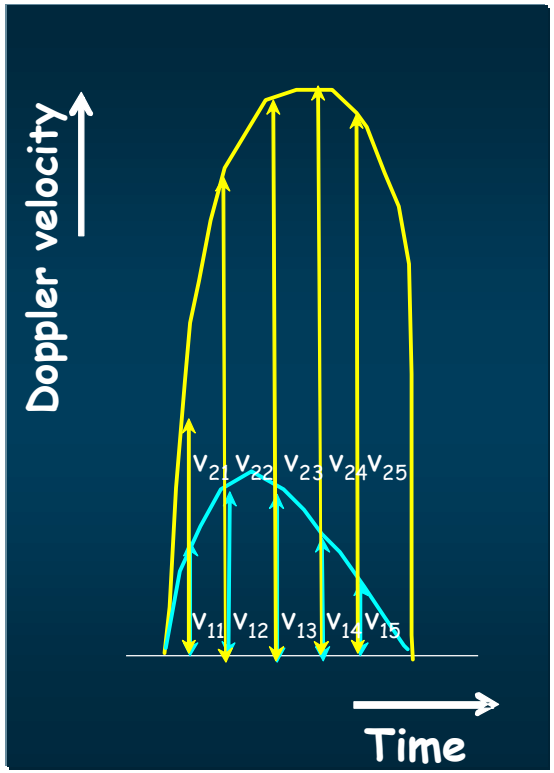


How much is the maximum pressure gradient?

	1	2	3	4	5	«VTI»
V_1	1	2	2	1	0.5	6.5
V_2	2	3	4	4	4	17

Velocity in m/sec

Echocardiography in aortic stenosis: *Pressure gradients*



How much is the **mean** pressure gradient?

	1	2	3	4	5	∑
V_1	1	2	2	1	0.5	6.5
V_2	2	3	4	4	4	17
$v_2^2-v_1^2$	3	5	12	15	15.75	50.75

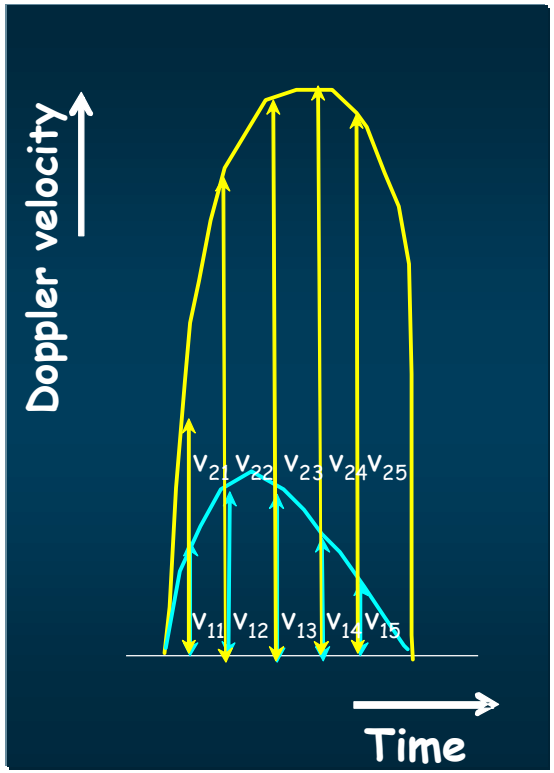
$$\frac{4\sum_{n} v_2^2-v_1^2}{n}$$

~~$(V_2 - V_1)^2$~~

~~$(VTI_1 - VTI_2)^2$~~

~~$VTI_1^2 - VTI_2^2$~~

Echocardiography in aortic stenosis:
Pressure gradients



$$\overline{\Delta p} = \frac{4\int(v_2^2 - v_1^2)}{\text{ejection time}}$$

Echocardiography in aortic stenosis: *Pressure gradients*

Factors responsible for differences in the Doppler- and catheter-derived gradients

A) Apparent overestimation by Doppler

1. Comparison of peak gradient with peak to peak gradient
2. Failure to account for increased subvalvular velocity
3. Pressure recovery
4. Changing physiological conditions

B) Apparent underestimation by Doppler

1. Poor Doppler signal
2. Inappropriate alignement
3. Changing physiological conditions

Echocardiography in aortic stenosis: *Pressure gradients*

Correction for subvalvular velocity necessary

if :

- Pressure gradient small (Valve prostheses!)

- Proximal velocity > 1.5 m/sec

Echocardiography in aortic stenosis: *Pressure gradients*

Factors responsible for differences in the Doppler- and catheter-derived gradients

A) Apparent overestimation by Doppler

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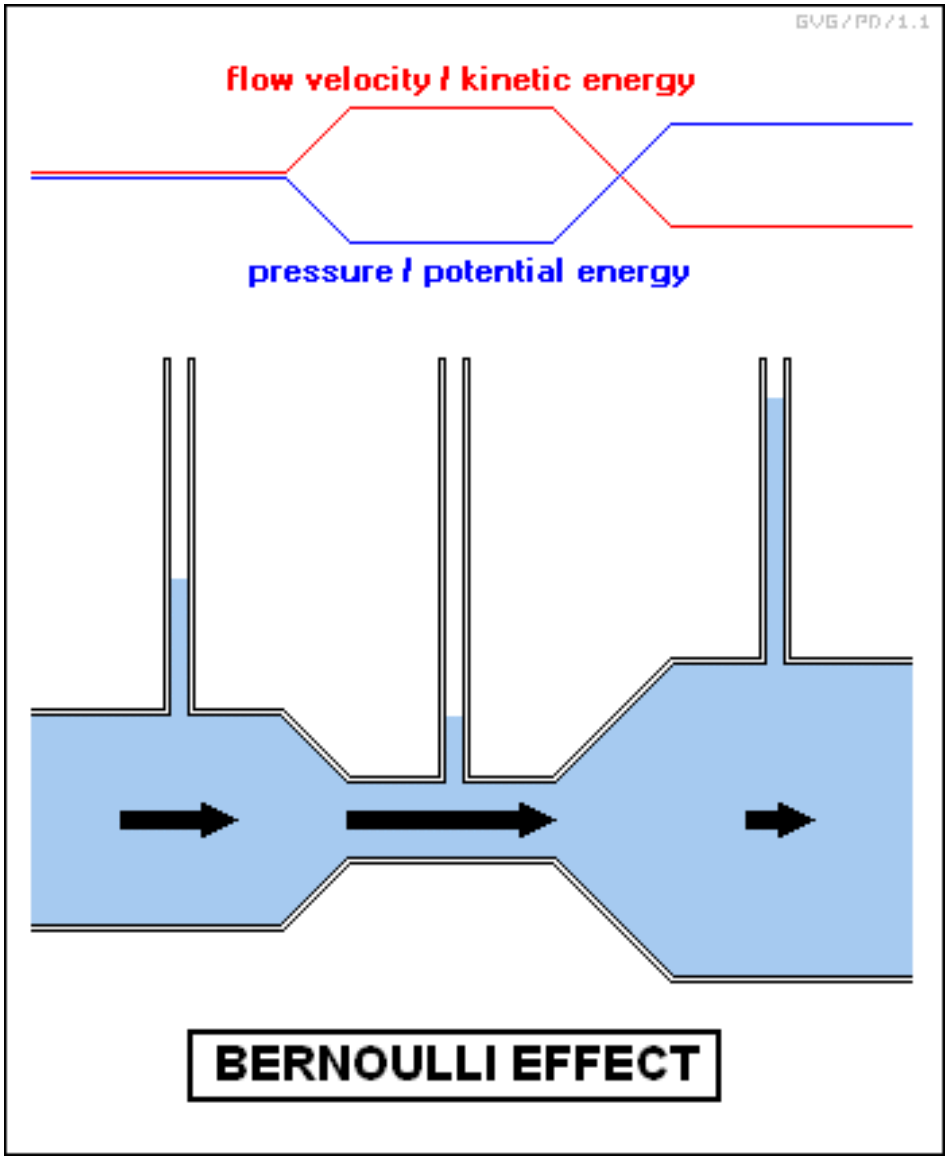
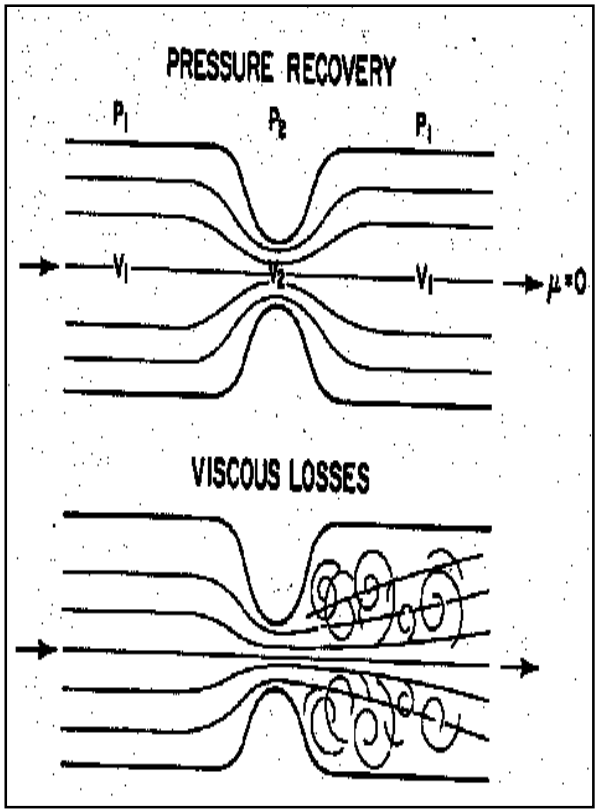
Echocardiography in aortic stenosis:
Pressure gradients

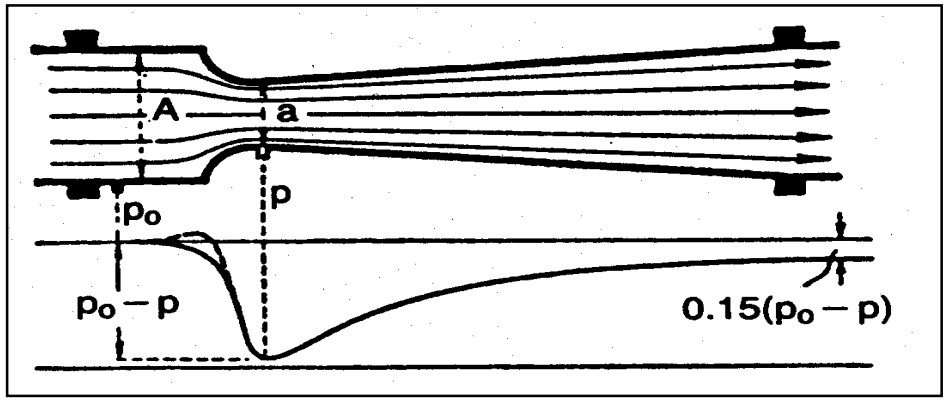


Echocardiography in aortic stenosis: *Pressure gradients*

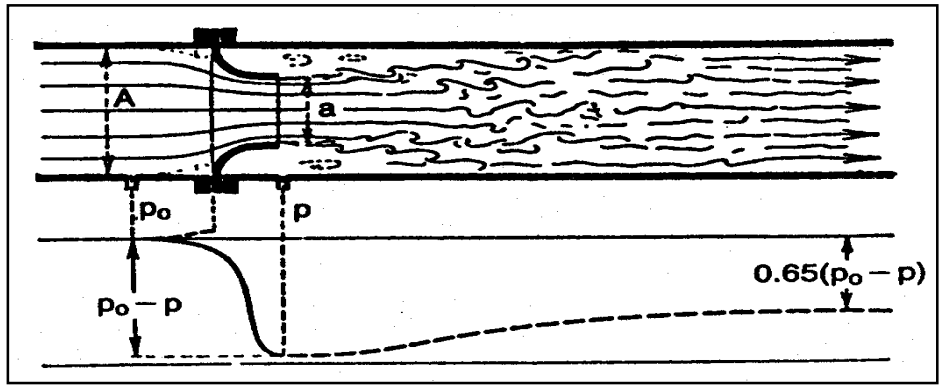
Pressure recovery does occur under conditions of flow acceleration without turbulence



Laminar flow

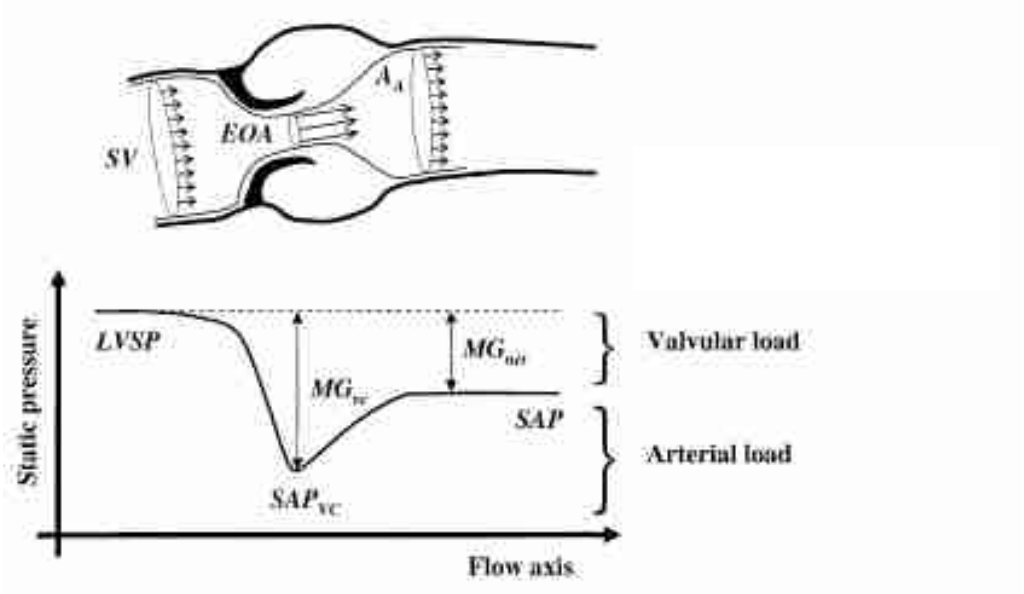


Turbulence



Echocardiography in aortic stenosis: *Pressure gradients*

Effect of pressure-recovery in aortic stenosis on calculation of ventricular load



Z_{VA}: valvulo-arterial impedance

MG_{net} (=ΔP_{net}) = Doppler ΔP_{mean} – {$4v^2$ x [2(AVA/AoA) x (1-AVA/AoA)]}

Briand et al, J Am Coll Cardiol 2005; 46: 291-298

Echocardiography in aortic stenosis: *Pressure gradients*

Factors responsible for differences in the Doppler- and catheter-derived gradients

A) Apparent overestimation by Doppler

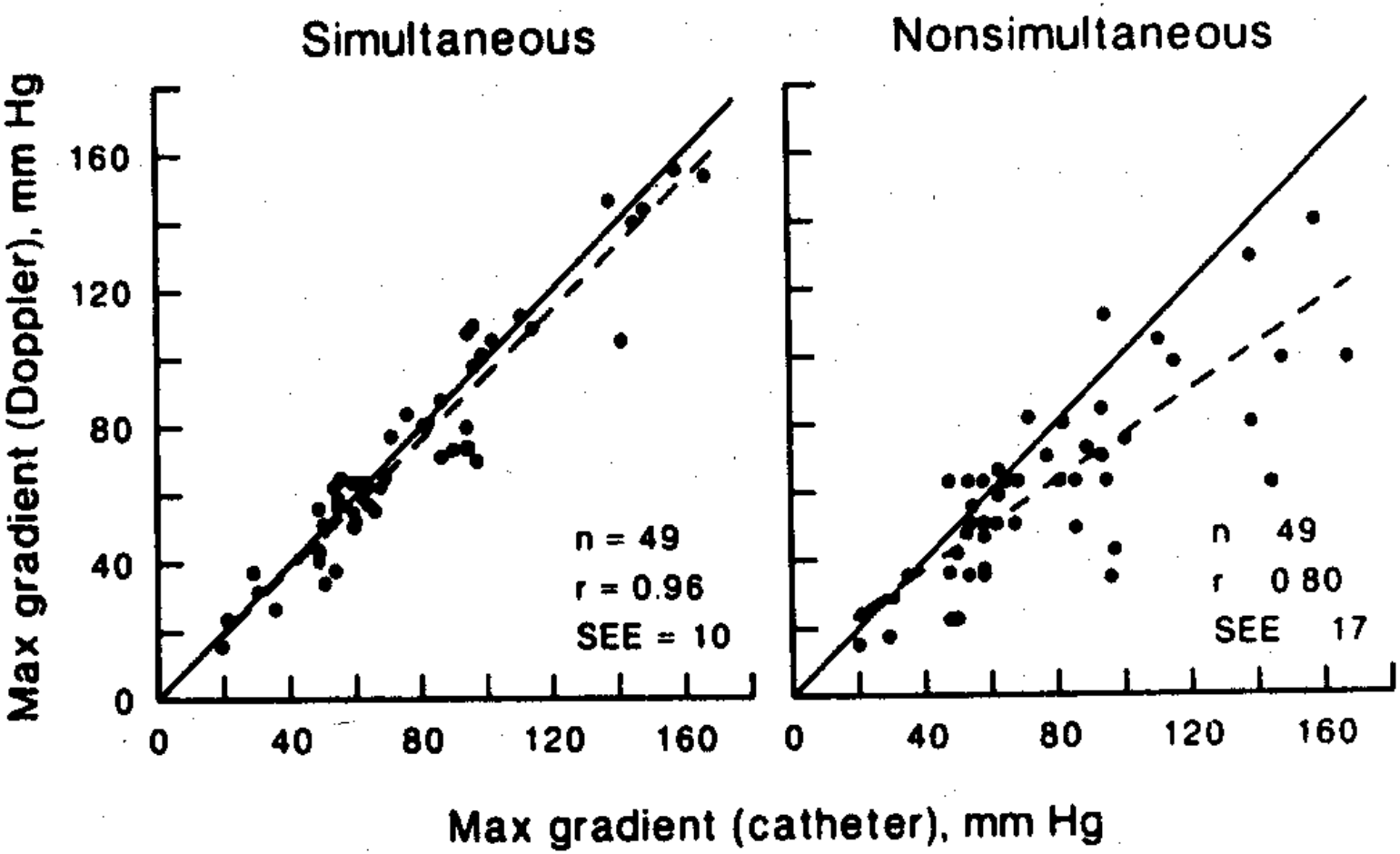
1. Comparison of peak gradient with peak to peak gradient
2. Failure to account for increased subvalvular velocity
3. Pressure recovery
4. Changing physiological conditions

B) Apparent underestimation by Doppler

1. Poor Doppler signal
2. Inappropriate alignement
3. Changing physiological conditions

Echocardiography in aortic stenosis: *Pressure gradients*

Effect of changing physiological conditions



Echocardiography in aortic stenosis: *Pressure gradients*

Factors responsible for differences in the Doppler- and catheter-derived gradients

A) Apparent overestimation by Doppler

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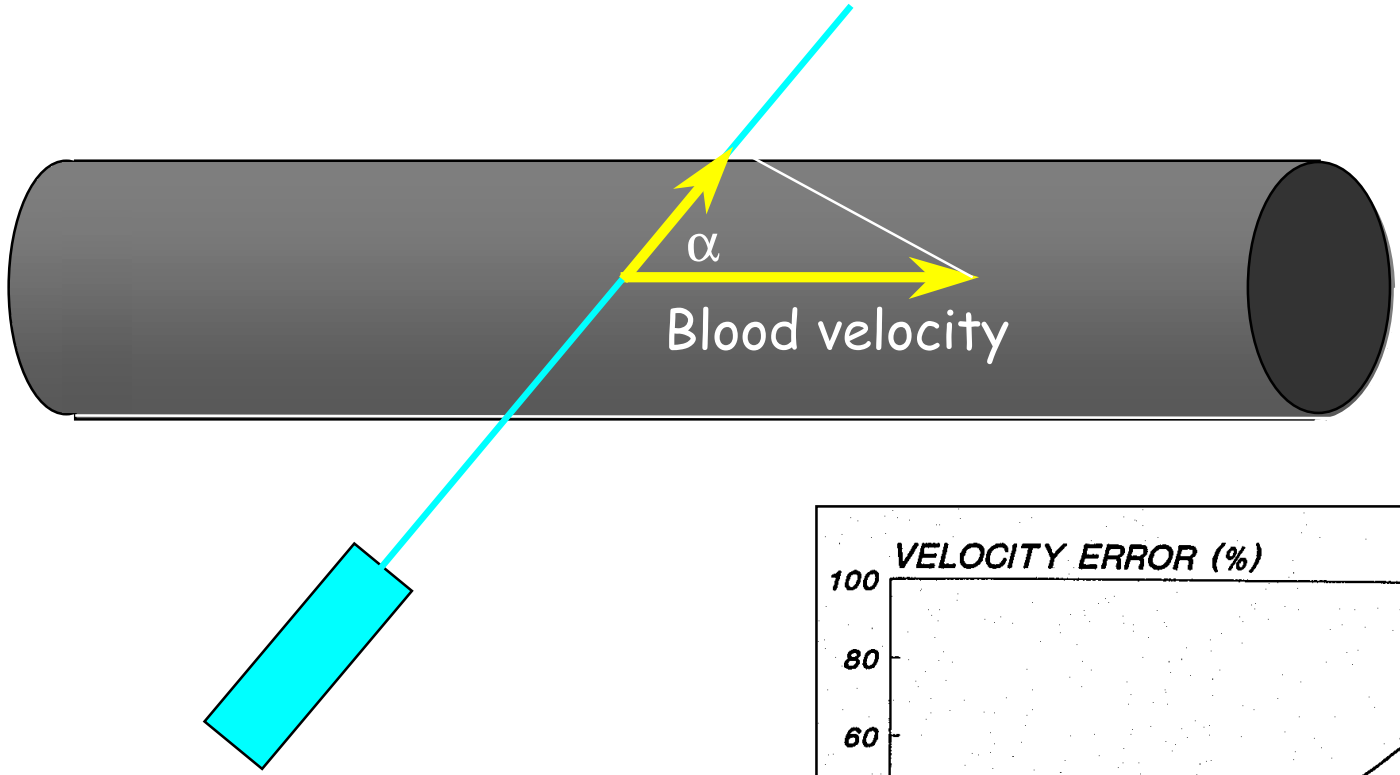
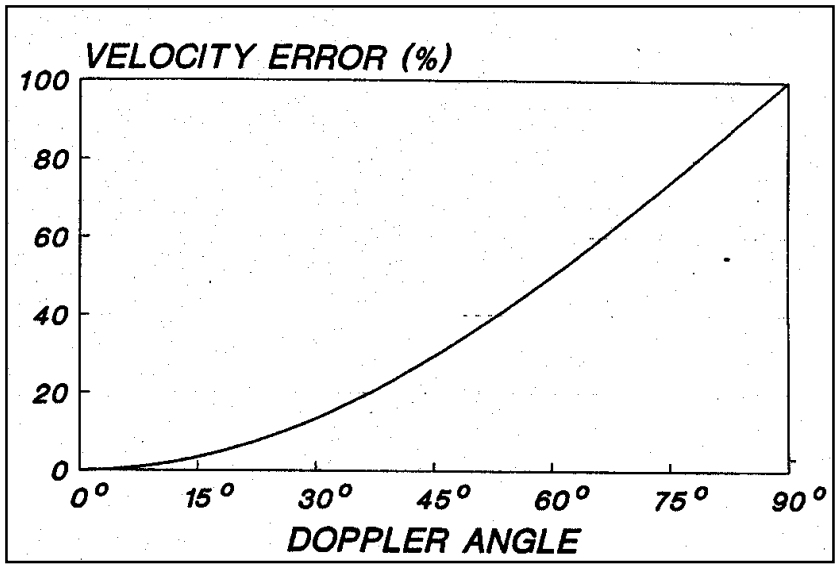
Echocardiography in aortic stenosis: *Pressure gradients*



$$\text{Blood velocity} = \frac{\text{Doppler velocity}}{\text{cosine } \alpha}$$



Echocardiography in aortic stenosis:
Valve opening area

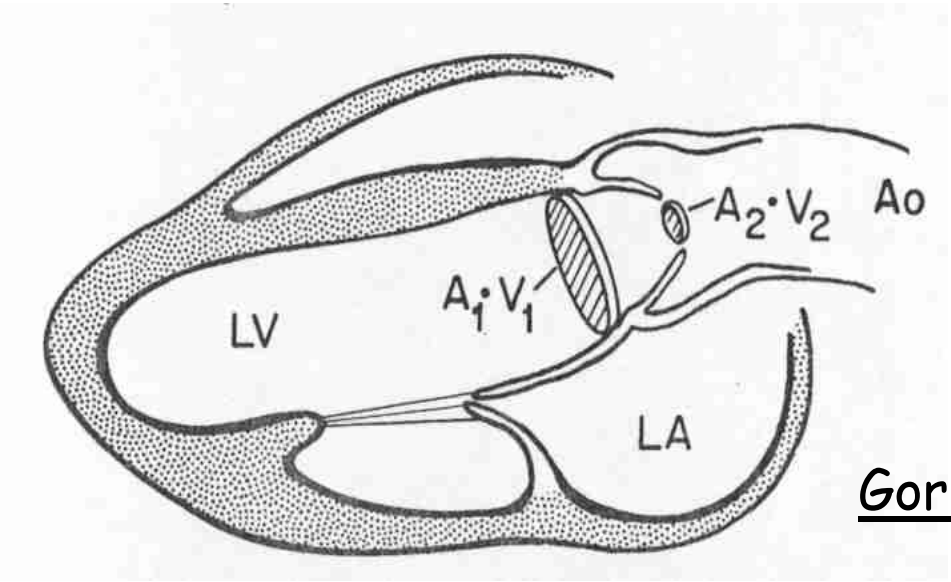
"Flow-independent" index of severity :

Valve opening area

Echocardiography in aortic stenosis: *Valve opening area*

Calculation of aortic valve area by continuity equation

$$Q_1 = Q_2 = A_1 \times v_1 = A_2 \times v_2$$



$$\boxed{A_2 = A_1 (v_1 / v_2)}$$

$$A_1 = (LVOT/2)^2 \times \pi$$

Gorlin formula :

$$A_2 = \frac{\text{Cardiac output}}{\text{HR} \times \text{ejection time} \times 44.3 \times \sqrt{\Delta p}}$$

$$Q = A_2 \times v_2$$

$$v_2^2 = k_a \times \Delta p$$

$$v_2 = k_b \times \sqrt{\Delta p}$$

Aortic stenosis:
Low ejection fraction and low gradient

Major diagnostic challenge:

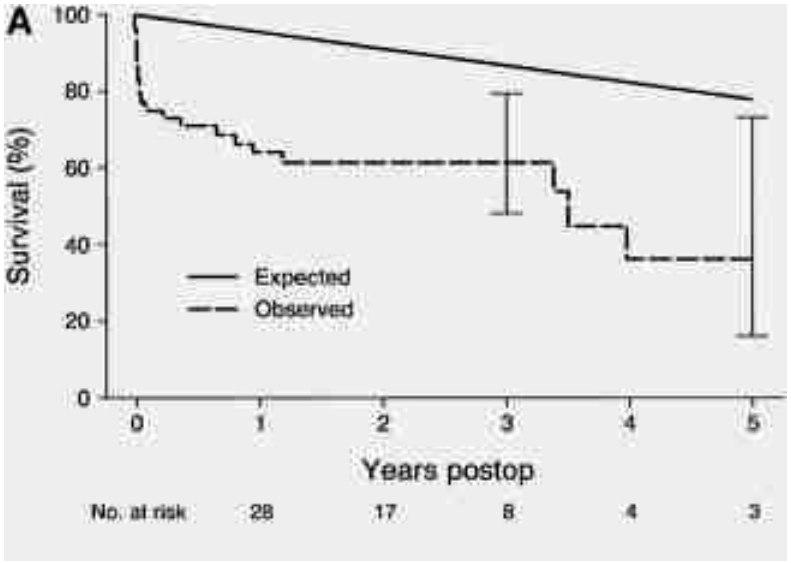
Aortic stenosis with
- small valve opening area
- low gradient
- low ejection fraction

Aortic stenosis:
Low ejection fraction and low gradient

High risk condition!

AVR in 52 pts. with EF <30%
and mean grad. <30 mmHg

Conolly et al,
Circulation 2000; 101: 1940-1946



Aortic stenosis:
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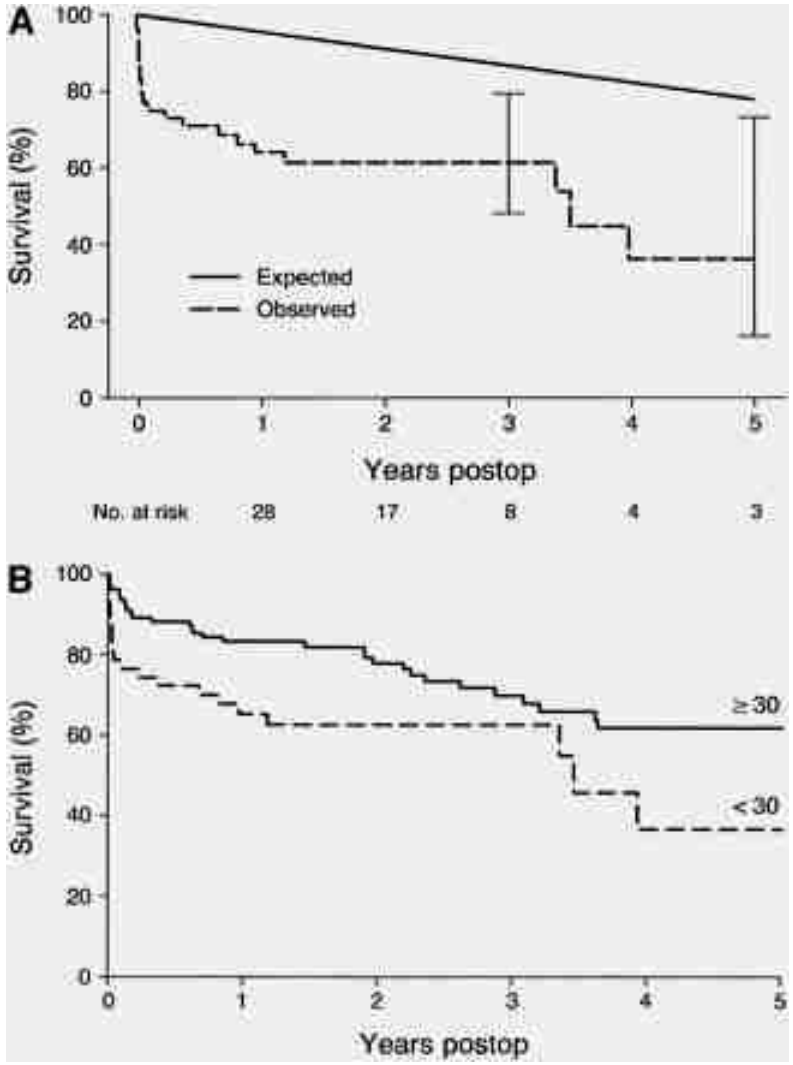
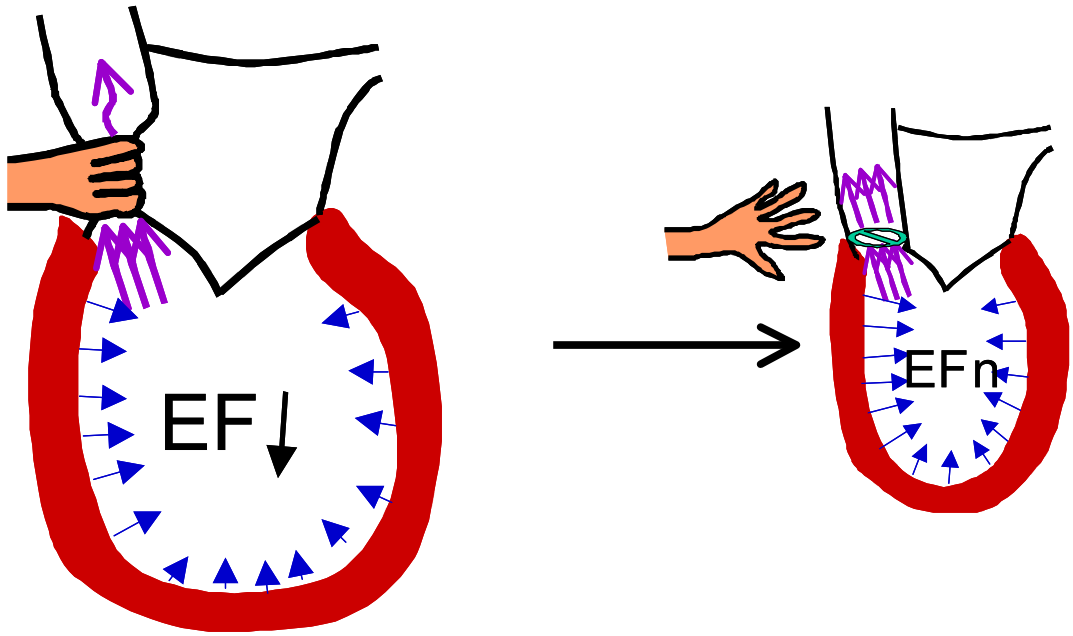


Severe aortic stenosis with low ejection fraction

« Classical » mechanism of reduction of EF in severe aortic stenosis

Afterload mismatch

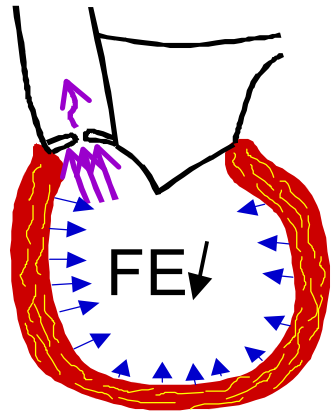
Ejection against increased resistance



Severe aortic stenosis with low ejection fraction

Aortic valve area ≤1 cm^2
Low ejection fraction

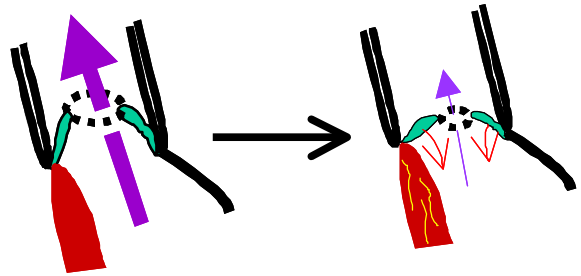
	Afterload mismatch	Myocardial damage
Improvement by AVR	**++**	**(+?)**



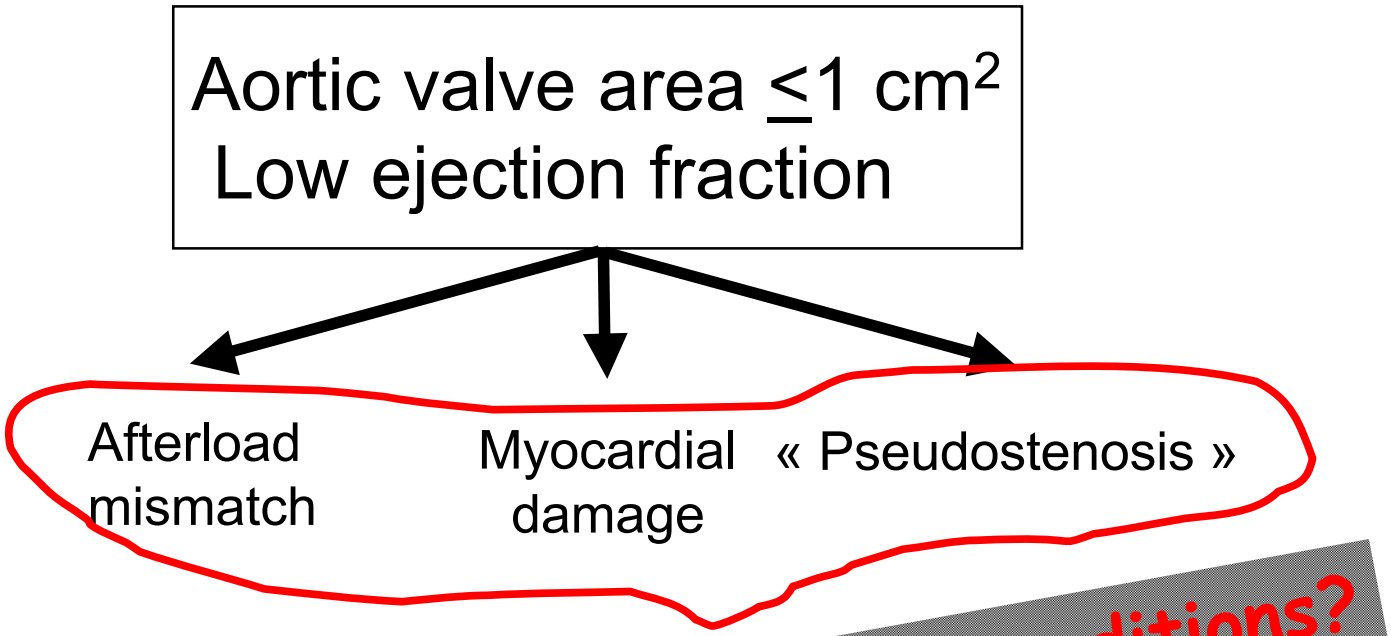
Severe aortic stenosis with low ejection fraction

Aortic valve area ≤1 cm^2
Low ejection fraction

	Afterload mismatch	Myocardial damage	« Pseudostenosis »
Improvement by AVR	**++**	**(+?)**	Primary cardiomyopathic lesion Low cardiac output



Severe aortic stenosis with low ejection fraction



Improvement by AVR

++

How to distinguish these conditions?

Low-gradient aortic stenosis:
Dobutamine stress echocardiography

Dobutamine Stress Echocardiography

Aortic valve area ≤1 cm^2
Low ejection fraction
Low gradient (ΔP_{Max} ≤30 mmHg)

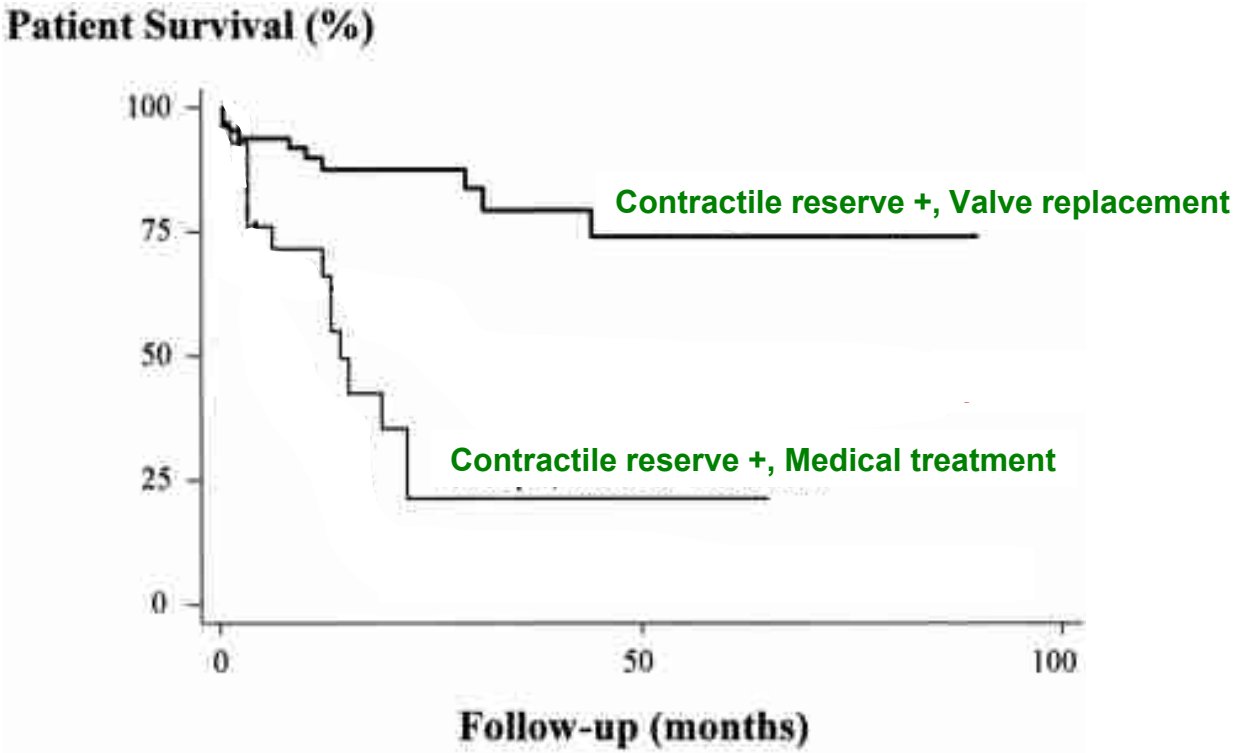
	Afterload mismatch	Myocardial damage	« Pseudostenosis »
Stroke volume	↑	(↑) <30%	↑
ΔP_{Max}	↑	(↑)	=
Aortic valve area	=(change <0.2cm^2)	=	↑

Absence of
« contactile reserve »

Low-gradient aortic stenosis: Dobutamine stress echocardiography

Monin et al, Circulation 2003; 108: 319-324

- 136 pts. with severe AS (≤1cm²), low cardiac index (≤3 l/min/m²) and low mean pressure gradient (≤40 mmHg)
- Dobutamine stress echocardiography (up to 20 µg/kg/min)



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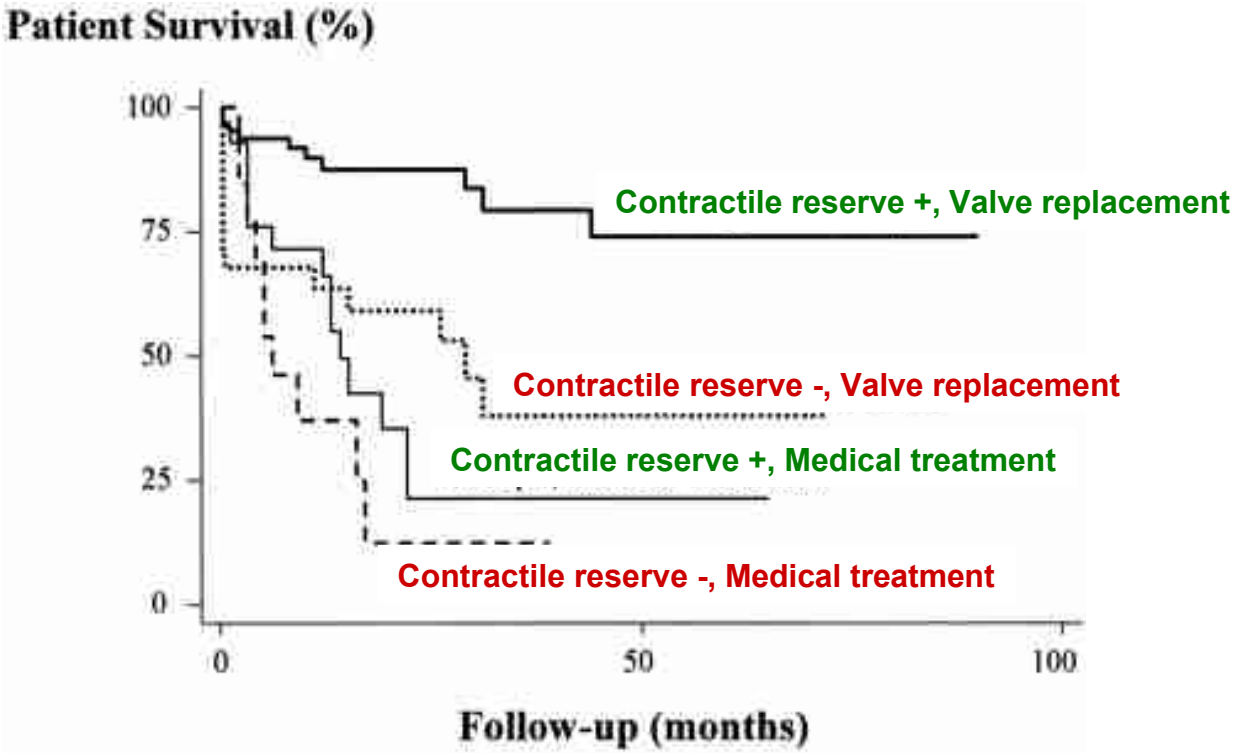

Aortic stenosis:
Treatment

Aortic valve replacement should be considered in every symptomatic patient with severe aortic stenosis, regardless of the ejection fraction!