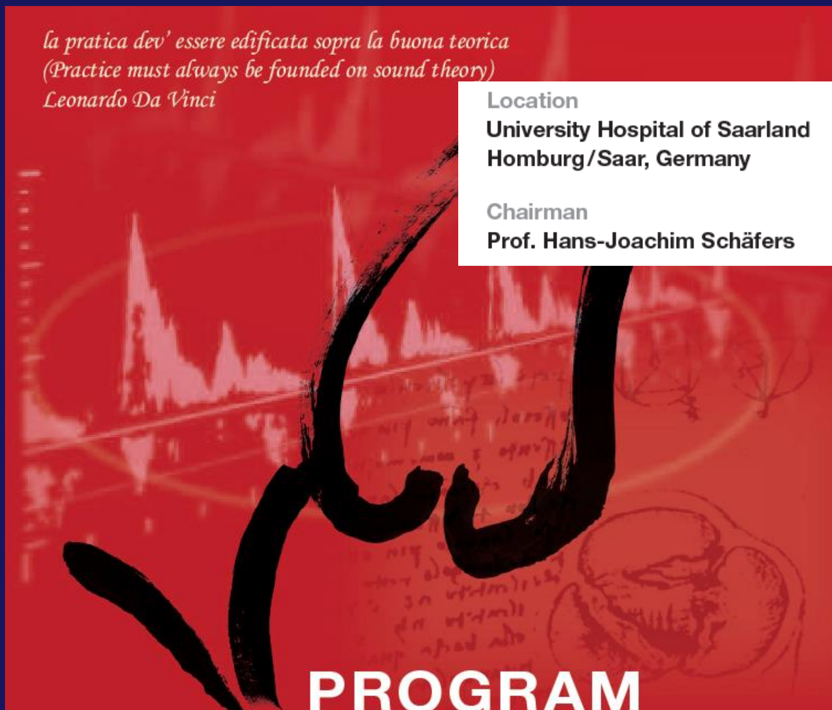
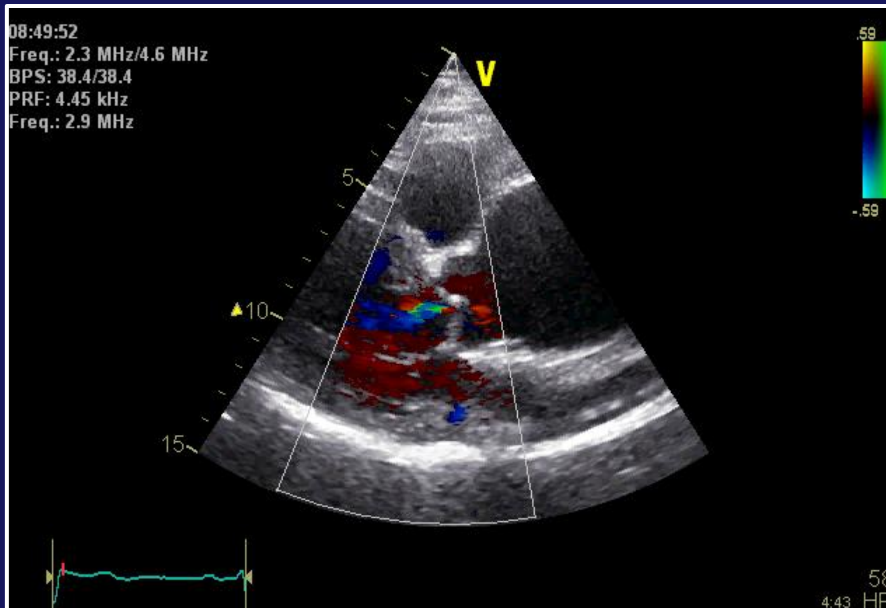
UNIVERSITÄT LEIPZIG
Medizinische Fakultät

Reconstruction of the Aortic Valve and Root
- A Practical Approach -

Universitätsklinikum Leipzig
Anstalt öffentlichen Rechts

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -





Wednesday 14th September - 9.45

Practice must always be founded on sound theory.
Leonardo Da Vinci

EBAC

Declaration of Interests Policy and Rules

EBAC

I declare for the last 3 years and the subsequent 12 month the following conflicts of interests:

Section I: Support for Research Activities - grant of the DEGUM
- no other financial research support

Section II: Support for Educational Activities - MIFO, GE Healthcare, Astra Zeneca, Servier, Novartis, Berlin-Chemie, Pfizer, Cardiac Dimension, Abbott, Bayer, Kelcon

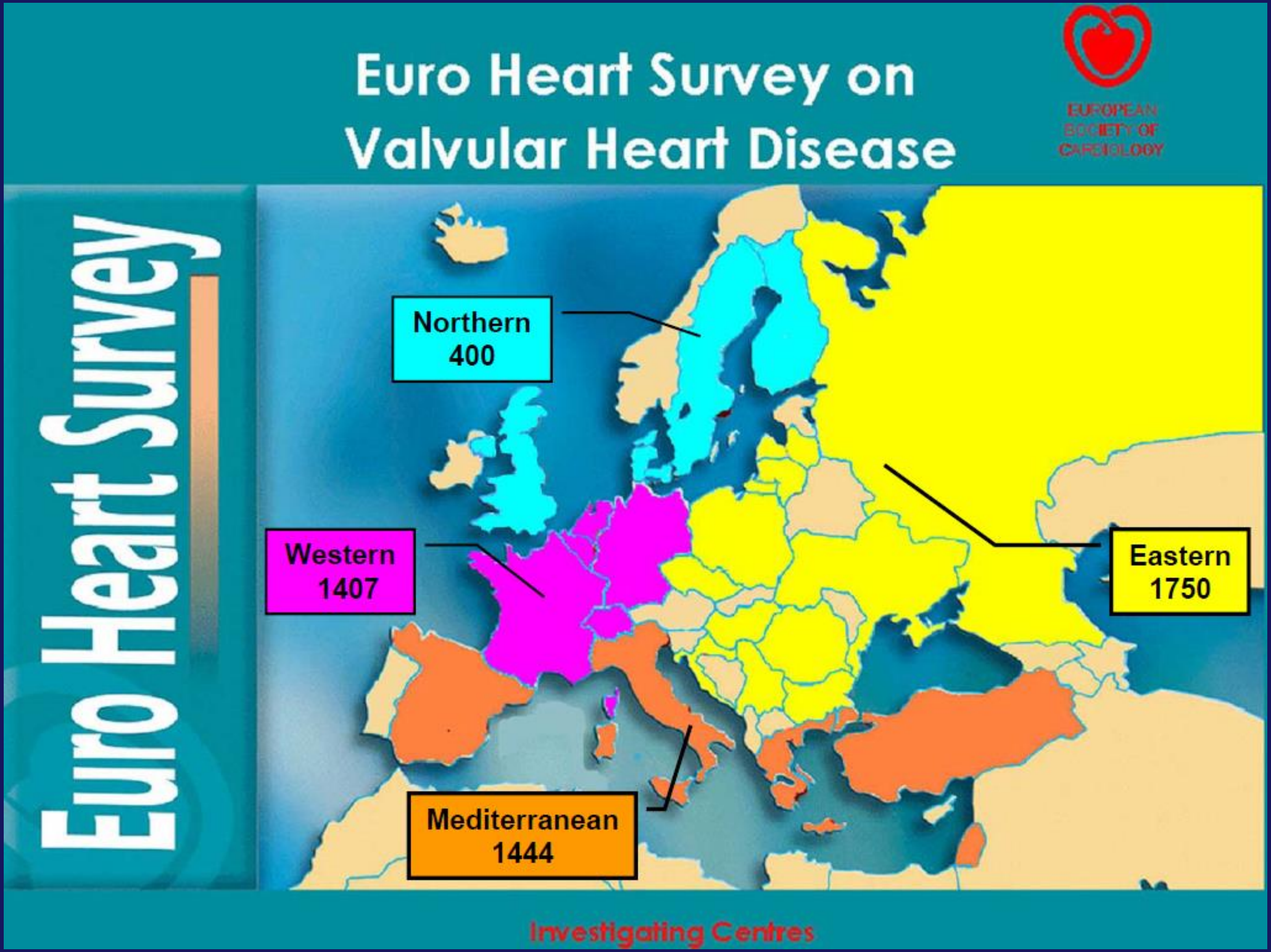
Section III: Honorarium for Promotional Activities - none

Section IV: Personal Financial Interests in Vommercial Activities - none

IB1; 2A11
Member of the German Society of Cardiology,
The German Society of Ultrasound, the German Society of Internal Medicine and the European Society of Cardiology/Cardiovascular Imaging
Councillor of the EACVI Board

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

The Euro Heart Survey on Valvular Heart Disease included prospectively 5001 patients.



according to
Iung et al., EurHeartJ 2003:24, 1231-1243

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Aims To identify the characteristics, treatment, and outcomes of contemporary patients with valvular heart disease (VHD) in Europe, and to examine adherence to guidelines.
Methods and results The Euro Heart Survey on VHD was conducted from April to July 2001 in 92 centres from 25 countries; it included prospectively 5001 adults with moderate to severe native VHD, infective endocarditis, or previous valve intervention. VHD was native in 71.9% of patients and 28.1% had had a previous intervention. Mean age was 64±14 years. Degenerative aetiologies were the most frequent in aortic VHD and mitral regurgitation while most cases of mitral stenosis were of rheumatic origin.

Conclusions This survey provides unique contemporary data on characteristics and management of patients with VHD. Adherence to guidelines is globally satisfying as regards investigations and interventions.

Incidence in epidemiology is a measure of the probability of occurrence of a given medical condition in a population within a specified period of time.
The cumulative incidence is the number of new cases within a specified time period divided by the size of the population initially at risk , e.g cases per 100.000 persons per year.

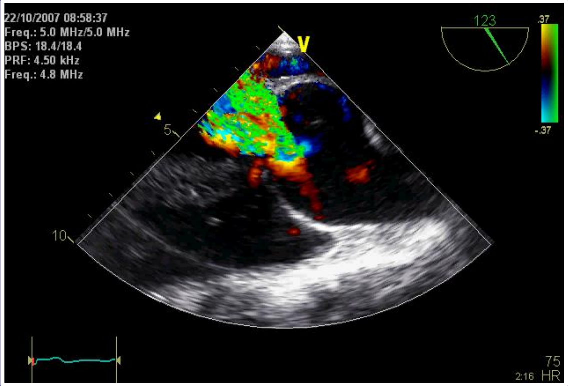
Prevalence is the proportion of cases in the population at a given time usually expressed as a fraction, as a percentage or as the number of cases per 10.000 or 100.000 people.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

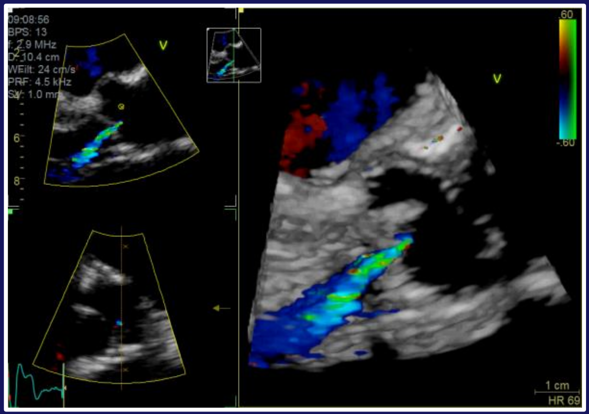
A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease

European Heart Journal (2003) 24, 1231–1243

Bernard Iung[a*], Gabriel Baron[b], Eric G. Butchart[c], François Delahaye[d], Christa Gohlke-Bärwolf[e], Olaf W. Levang[f], Pilar Tornos[g], Jean-Louis Vanoverschelde[h], Frank Vermeer[i], Eric Boersma[j], Philippe Ravaud[b], Alec Vahanian[a]



	Aortic stenosis *n*=1197	Aortic regurgitation *n*=369
Degenerative (%)	81.9	50.3
Rheumatic (%)	11.2	15.2
Endocarditis (%)	0.8	7.5
Inflammatory (%)	0.1	4.1
Congenital (%)	5.4	15.2
Ischaemic (%)	0	0
Other (%)	0.6	7.7



Age ≥18 years and:
– primary and significant VHD as defined by echocardiography:
  – aortic stenosis (AS) with a maximal jet velocity ≥2.5 m/sec,
  – or mitral stenosis (MS) with a valve area ≤2 cm^2,
  – or mitral regurgitation (MR) grade ≥2/4,
  – or aortic regurgitation (AR) with a grade ≥2/4,
– or diagnosis of suspected or definite endocarditis as assessed by Duke criteria,
– or patients who had undergone any operation on a cardiac valve (percutaneous balloon commissurotomy, valve repair, valve replacement).

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Table 6 Characteristics of the patients who underwent valve intervention

	Aortic stenosis *n*=512	Aortic regurgitation *n*=119	Mitral stenosis *n*=112	Mitral regurgitation *n*=155	Multiple valve disease *n*=185	Previous intervention *n*=164
Age ≥ 70 years (%)	54.3	19.3	17.9	31.6	25.4	33.5
Symptoms						
NYHA Class (%)						
Class I	15.8	20.7	5.4	15.0	7.2	14.1
Class II	37.1	31.9	31.3	27.5	18.2	18.4
Class III	38.8	36.2	58.9	42.5	48.6	44.8
Class IV	8.3	11.2	4.4	15.0	26.0	22.7
Left ventricular						
Ejection fraction (%)						
<30%	2.9	2.7	0	3.5	0.6	2.7
30-50%	16.4	21.8	8.7	16.2	21.6	15.4
50-60%	24.2	36.4	32.7	17.6	40.1	25.5
≥60%	56.5	39.1	58.6	62.7	37.7	56.4

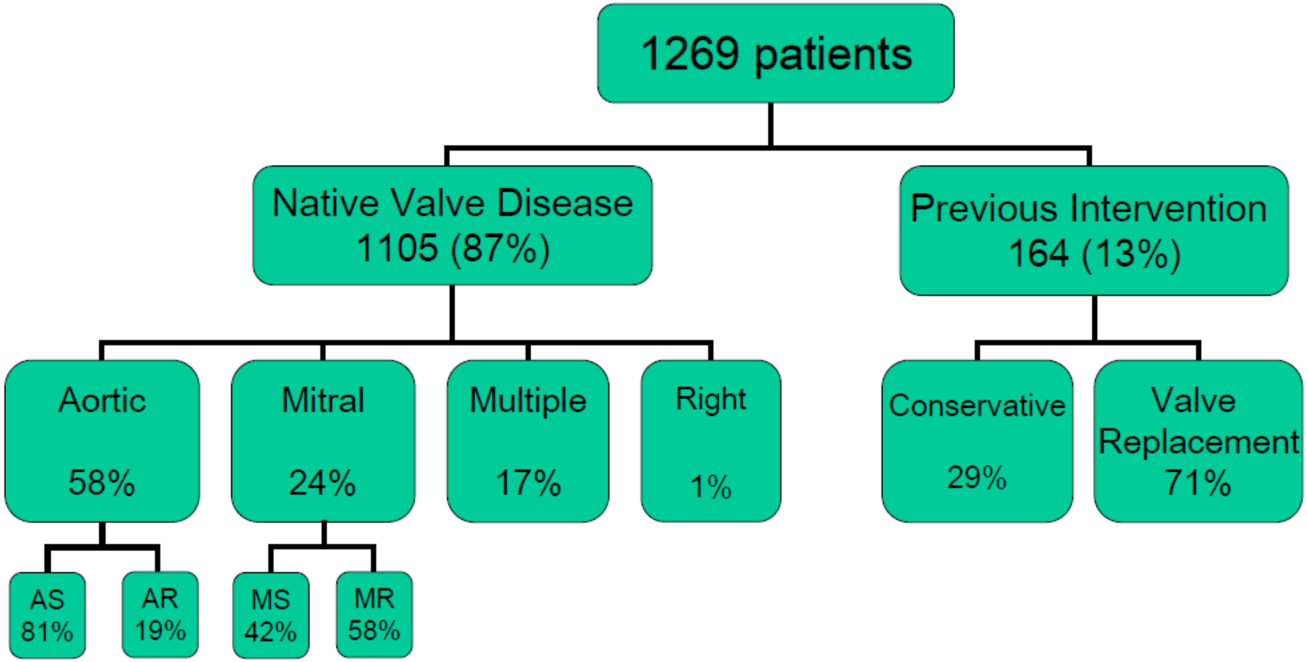
Table 7 Type of intervention in single native left-sided valve disease

	Aortic stenosis *n*=512	Aortic regurgitation *n*=119
Mechanical prosthesis (%)	49.0	76.5
Bioprosthesis (%)	50.0	17.6
Homograft (%)	0.6	2.5
Autograft (%)	0.4	1.7
Valve repair (%)	0	1.7
Percutaneous intervention (%)	0	0
Associated procedures		
— CABG (%)	33.0	15.1
— Total aorta replacement (%)	0.6	19.3
— Anti-arrhythmic surgery (%)	0.2	0.8

Euro Heart Survey on Valvular Heart Disease

Alec Vahanian, Bernard Iung
on behalf of the Scientific Expert Committee

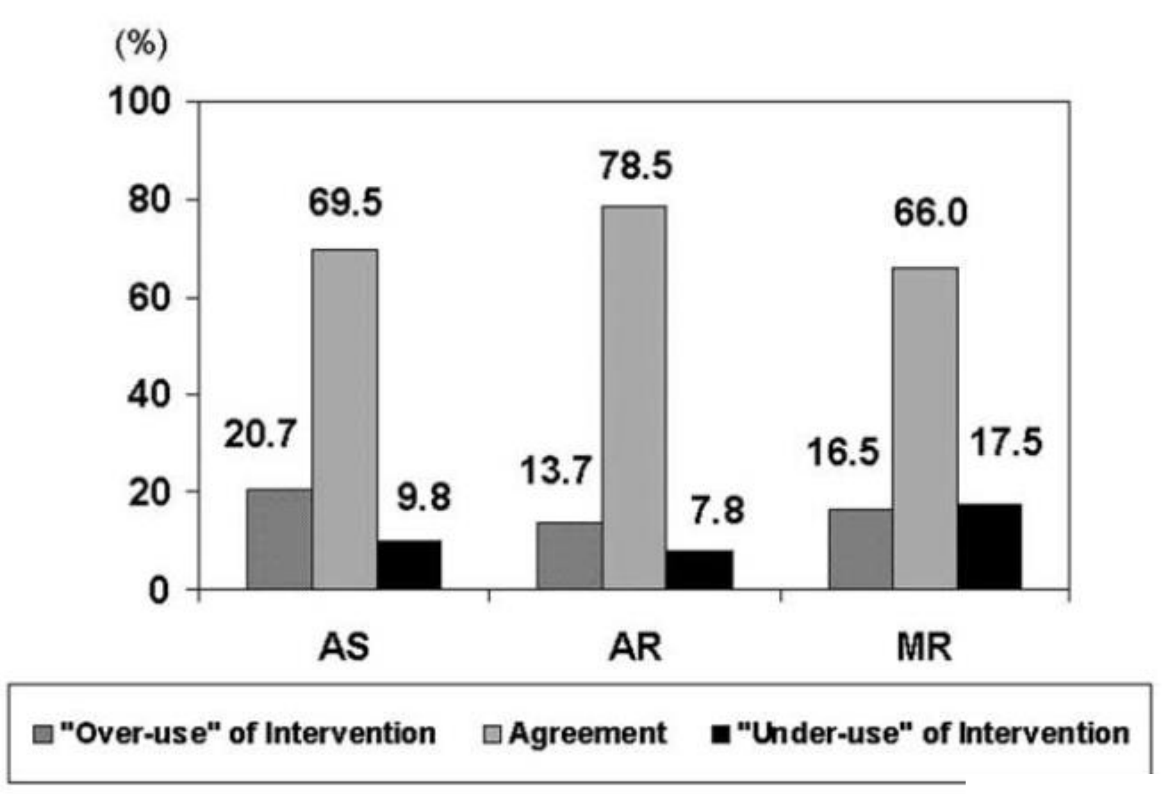
Interventions Performed

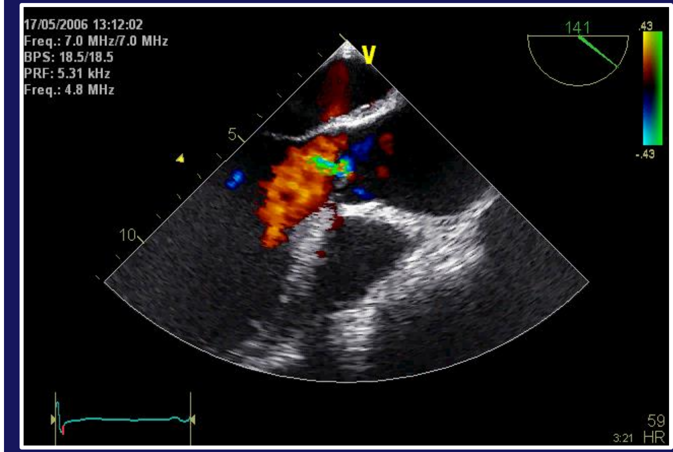


Euro Heart Survey on Valvular Heart Disease 11

EUROPEAN SOCIETY OF CARDIOLOGY

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -





And – the grading of the severity of VHD seems to be a real problem.

Thus, the Euro Heart Survey contains interesting data on characteristics and management of patients with valvular heart disease, but no epidemiological data concerning incidence and prevalence of VHD.

Fig. 1 Comparison between the indications retained for intervention in asymptomatic patients with severe single-valve disease and the recommendations from Working Group on Valvular Heart Disease of the European Society of Cardiology.[11] 'Over-use of intervention' refers to patients who underwent interventions without having an indication according to the guidelines. 'Under-use of intervention' refers to patients who had no intervention but for whom there was an indication according to the guidelines. AS: aortic stenosis; AR: Aortic regurgitation; MR: mitral regurgitation

Prevalence and Clinical Determinants of Mitral, Tricuspid, and Aortic Regurgitation (The Framingham Heart Study)

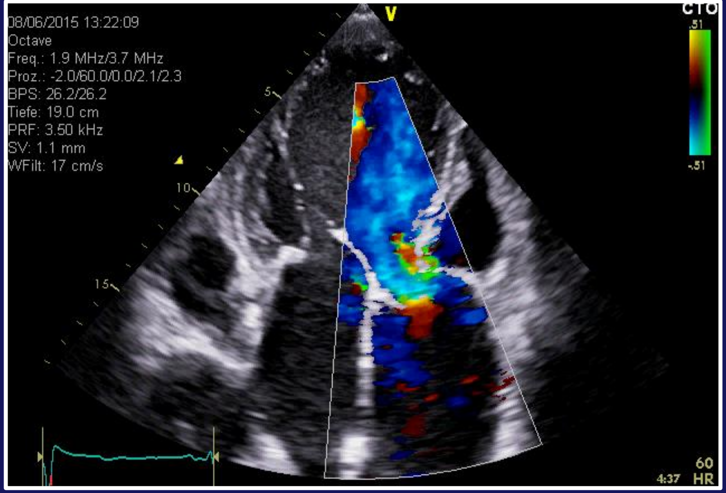
(Am J Cardiol 1999;83:897–902)

Jagmeet P. Singh, MD, DPhil, Jane C. Evans, MPH, Daniel Levy, MD, Martin G. Larson, ScD, Lisa A. Freed, MD, Deborah L. Fuller, RDCS, Birgitta Lehman, RDCS, and Emelia J. Benjamin, MD, ScM

TABLE I Definitions of Grades of Regurgitation

Grades	MR	TR	AR
Absent	—	—	—
Trace	w/in 1 cm of valve	w/in 1 cm of valve	JH/LVOH < 10%
Mild	RJA/LAA<19%	RJA/RAA<19%	10%–24%
Moderate	20%–40%	20%–40%	25%–49%
Severe	>41%	>41%	>50%

Valvular regurgitation was assessed qualitatively using these semiquantitative categories as guidelines. JH = jet height; LAA = left atrial area; LVOH = left ventricular outflow height; RAA = right atrial area; RJA = regurgitant jet area; w/in = within.



Echocardiographic characterisation of patients with the ultrasound technique of the nineties.

Technology of 2015

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

TABLE IIa Prevalence of Valvular Regurgitation Stratified by Age and Severity in Men

	Age (yr)				
Aortic regurgitation	26–39 (n = 91)	40–49 (n = 352)	50–59 (n = 433)	60–69 (n = 359)	70–83 (n = 91)
None (%)	96.7	95.4	91.1	74.3	75.6
Trace (%)	3.3	2.9	4.7	13.0	10.0
Mild (%)	0.0	1.4	3.7	12.1	12.2
≥Moderate (%)	0.0	0.3	0.5	0.6	2.2

TABLE IIb Prevalence of Valvular Regurgitation Stratified by Age and Severity in Women

	Age (yr)				
Aortic regurgitation	26–39 (n = 93)	40–49 (n = 451)	50–59 (n = 515)	60–69 (n = 390)	70–83 (n = 90)
None (%)	98.9	96.6	92.4	86.9	73.0
Trace (%)	1.1	2.7	5.5	6.3	10.1
Mild (%)	0.0	0.7	1.9	6.0	14.6
≥Moderate (%)	0.0	0.0	0.2	0.8	2.3

Data are presented as percentage of subjects.

according to Singh et al., Am J Cardiol 1999;83:897-902

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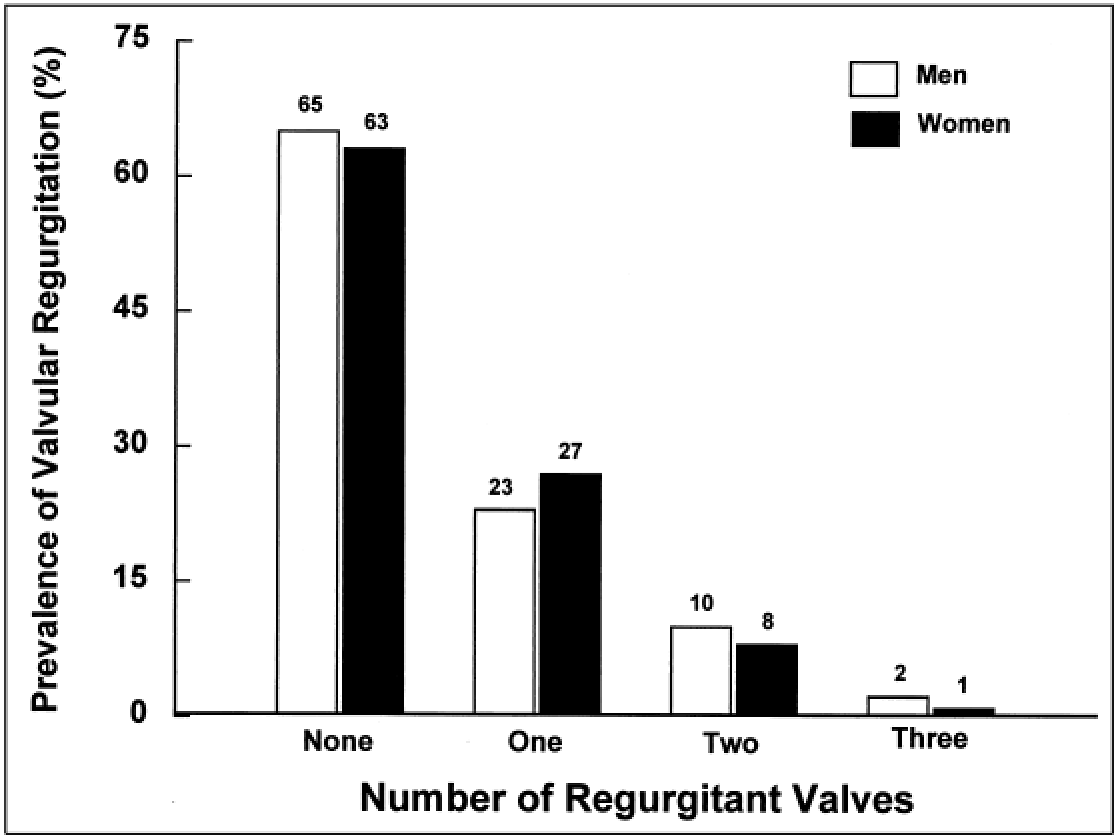
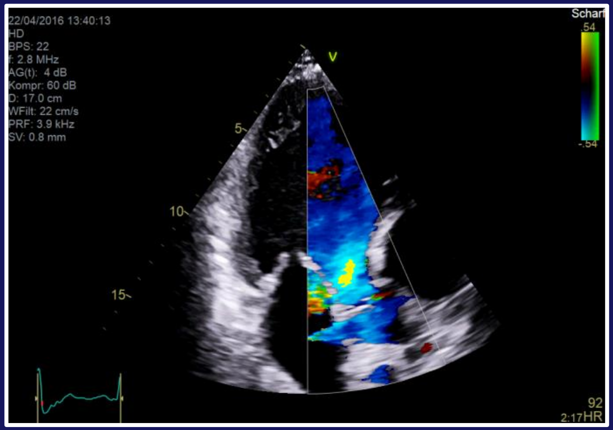
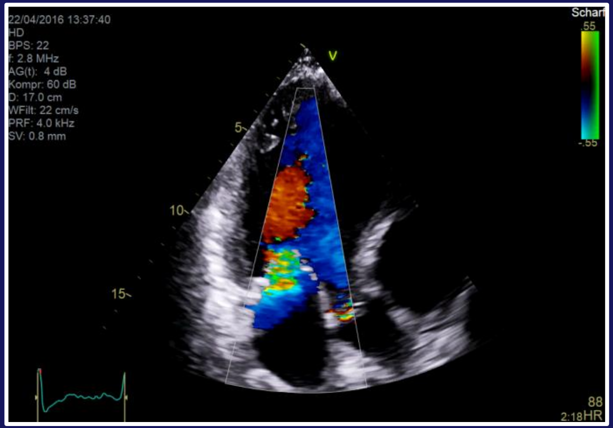


FIGURE 1. Histogram showing prevalence of valvular regurgitation by number of regurgitant valves. One indicates any single regurgitant valve; Two, any 2 regurgitant valves; Three, combined aortic, mitral, and tricuspid regurgitation. Regurgitation was defined as ≥mild severity for mitral and tricuspid regurgitation and ≥trace severity for aortic regurgitation.

according to Singh et al., Am J Cardiol 1999;83:897-902





This study sought to assess the prevalence and clinical determinants of mitral (MR), tricuspid (TR), and aortic (AR) regurgitation in a population-based cohort. Color Doppler echocardiography was performed in 1696 men and 1893 women (aged 54 6 10 years) attending a routine examination at the Framingham Study.

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

TABLE IIIc Clinical Characteristics and Severity of Aortic Regurgitation

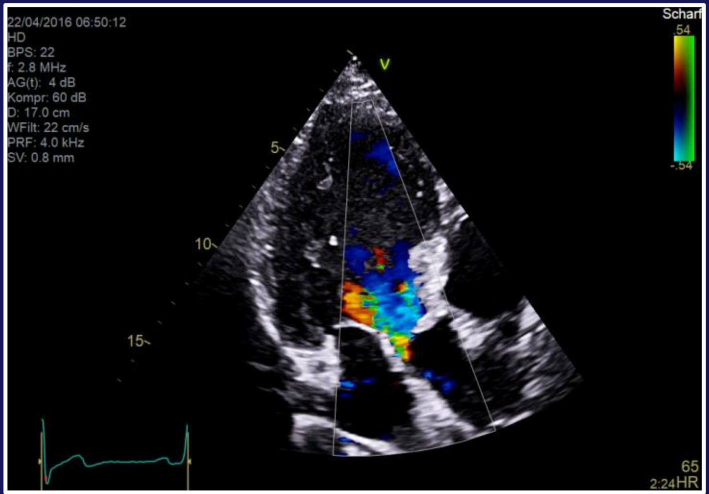
Clinical Characteristics	Degree of Regurgitation: None	Trace	Mild	≥Moderate	r	p Value
Men/women (%)	45/55	54/46	60/40	54/46	−0.07	0.0001
Age (yrs) (mean ± SD)	53 ± 10	60 ± 10	63 ± 8	63 ± 10	0.24	0.0001
BMI (kg/m^2)	26.7 ± 0.8	26.5 ± 0.3	26.5 ± 0.4	25.6 ± 1.2	−0.009	0.62
Systemic HTN (%)	30	34	32	12	0.029	0.12
Total cholesterol (mg/dl)	205 ± 1	201 ± 3	207 ± 3	195 ± 10	−0.01	0.54
Diabetes mellitus (%)	5	6	10	0	0.03	0.18
Smoking (pack-years)	16 ± 1	15 ± 2	16 ± 2	11 ± 6	−0.24	0.19
CHF or MI (%)	3	4	6	0	0.006	0.76

Data expressed as mean ± SEM.
r = Spearman rank correlations.

TABLE IV Results of Multivariable Regression Analyses

Clinical Determinants	Unit	MR OR (95% CI)	TR OR (95% CI)	AR OR (95% CI)
Age (yr)	9.9	1.3 (1.2, 1.5)	1.5 (1.3, 1.7)	2.3 (2.0, 2.7)
Sex	M/F	1.1 (0.9, 1.3)	1.2 (1.0, 1.6)	0.6 (0.5, 0.8)
BMI (kg/m^2)	4.3	0.8 (0.7, 0.9)	0.7 (0.6, 0.8)	1.0 (0.8, 1.1)
HTN	Y/N	1.6 (1.2, 2.0)	1.1 (0.8, 1.4)	1.2 (0.9, 1.5)

Data expressed as odds ratio (95% confidence intervals). Odds ratios for continuous variables expressed for 1 SD of age and BMI.



according to Singh et al., Am J Cardiol 1999;83:897-902

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Valve disease

AORTIC REGURGITATION

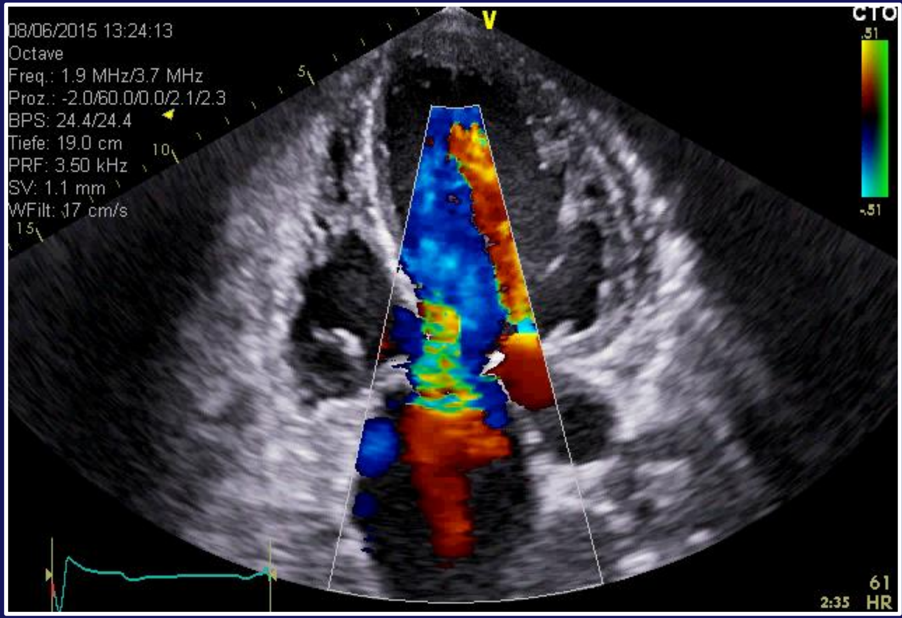
Heart 2006;**92**:994–1000.

Gerald Maurer

The incidence of clinically significant aortic regurgitation (AR) increases with age, typically peaking in the fourth to sixth decade of life. It is more common in men than women. The prevalence of AR in the Framingham study was reported to be 4.9%, with regurgitation of moderate or greater severity occurring in 0.5%.

Table 1 Aetiology of aortic regurgitation (AR)

Primary valve disease		
Rheumatic		
Congenital:	Bicuspid aortic valve	
	Outlet supracristal VSD	
	Discrete subaortic stenosis	
Endocarditis*		
Other inflammatory disorders		
Degenerative		
Traumatic leaflet rupture*		
Secondary AR		
Aortic root dilatation		
Aortic dissection*		Damage to aortic annulus
		Prolapsing intimal flap with intact leaflets and annulus



Prevalence and Correlates of Aortic Regurgitation in American Indians: The Strong Heart Study

Nathaniel E. Lebowitz, MD, Jonathan N. Bella, MD, Mary J. Roman, MD, FACC, Jennifer E. Liu, MD, Dawn P. Fishman, BA, Mary Paranicas, BA, Elisa T. Lee, PHD,* Richard R. Fabsitz, MA, MPH,† Thomas K. Welty, MD,‡ Barbara V. Howard, PHD,§ Richard B. Devereux, MD, FACC

CONCLUSIONS Aortic regurgitation occurred in 10% of a sample group of middle-aged to older adults and was related to older age, larger aortic root diameter, aortic and mitral stenosis and albuminuria. There was no association of AR with being overweight and a negative association of AR with diabetes. (J Am Coll Cardiol 2000;36:461–7) © 2000 by the American College of Cardiology

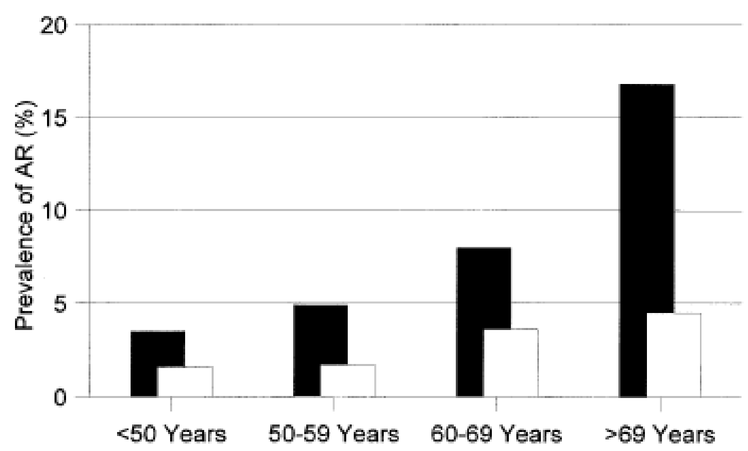


Figure 1. The prevalences of both mild (1+) AR **(solid bars)** and more severe (≥2+) AR **(open bars)** in Strong Heart Study participants show strong positive correlations to increasing age ($p < 0.001$).

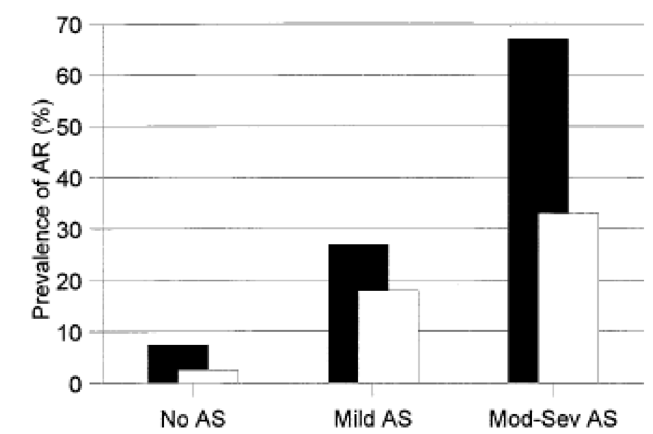


Figure 2. The prevalences of both mild (1+) AR **(solid bars)** and more severe (≥2+) AR **(open bars)** show progressive increases from individuals with no AS to those with mild AS to those with moderate or severe AS ($p < 0.001$).

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

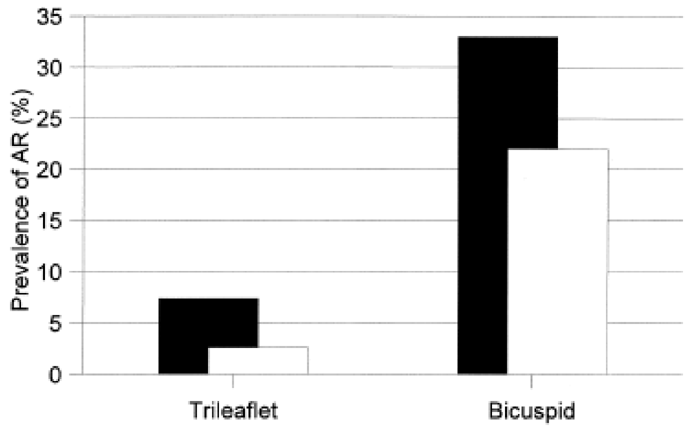


Figure 3. The prevalences of both mild (1+) AR **(solid bars)** and more severe (≥2+) AR **(open bars)** were substantially higher ($p < 0.001$) in individuals with bicuspid as opposed to trileaflet aortic valves.

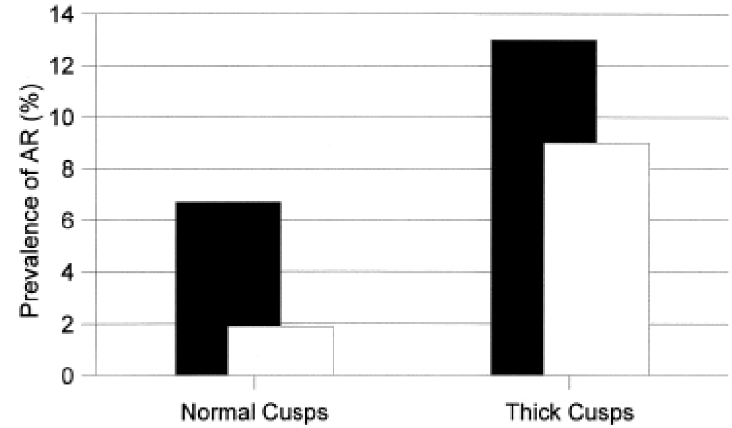
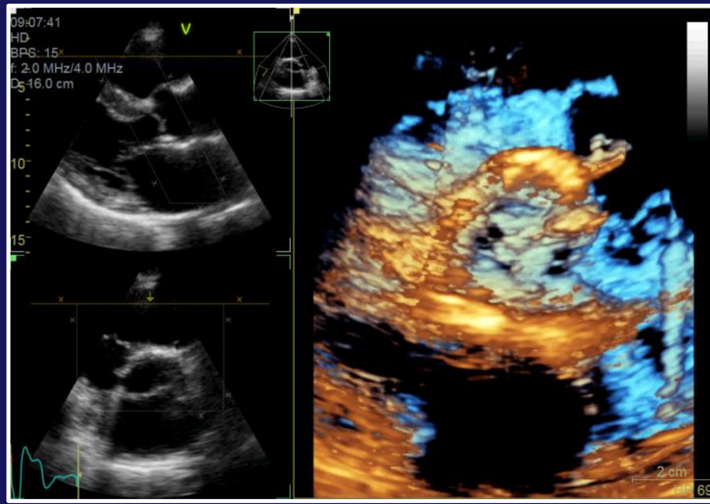
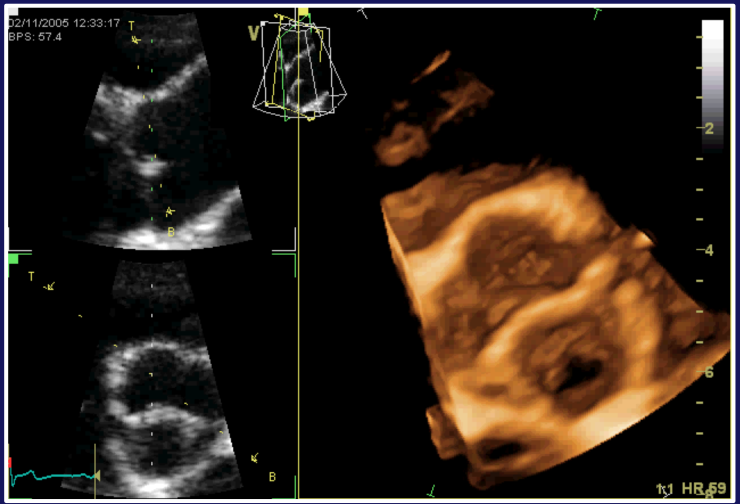


Figure 4. The prevalences of both mild (1+) AR **(solid bars)** and more severe (≥2+) AR **(open bars)** were higher ($p < 0.01$) in individuals with thickened aortic valve cusps versus cusps of normal thickness.

according to Lebowitz et al.,
J Am Coll Cardiol
2000; 36: 461-467





3D-TTE of the aortic valve

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Burden of valvular heart diseases: a population-based study

Lancet 2006; 368: 1005–11

Vuyisile T Nkomo, Julius M Gardin, Thomas N Skelton, John S Gottdiener, Christopher G Scott, Maurice Enriquez-Sarano

Interpretation Moderate or severe valvular diseases are notably common in this population and increase with age. In the community, women are less often diagnosed than are men, which could indicate an important imbalance in view of the associated lower survival. Valve diseases thus represent an important public-health problem.

	Age (years)				
	18–44	45–54	55–64	65–74	≥75
Participants (n)	4351	696	1240	3879	1745
Male, n (%)	1959 (45%)	258 (37%)	415 (33%)	1586 (41%)	826 (47%)
Mitral regurgitation (n=449)	23, 0·5% (0·3–0·8)	1, 0·1% (0–0·8)	12, 1·0% (0·5–1·8)	250, 6·4% (5·7–7·3)	163, 9·3% (8·1–10·9)
Mitral stenosis (n=15)	0, 0% (0–0·1)	1, 0·1% (0–0·8)	3, 0·2% (0·1–0·7)	7, 0·2% (0·1–0·4)	4, 0·2% (0·1–0·6)
Aortic regurgitation (n=90)	10, 0·2% (0·1–0·4)	1, 0·1% (0–0·8)	8, 0·7% (0·3–1·3)	37, 1·0% (0·7–1·3)	34, 2·0% (1·4–2·7)
Aortic stenosis (n=102)	1, 0·02% (0–0·1)	1, 0·1% (0–0·8)	2, 0·2% (0·6–1·9)	50, 1·3% (1·0–1·7)	48, 2·8% (2·1–3·7)

	p value for trend	Frequency adjusted to 2000 US adult population
Participants (n)	..	209 128 094
Male, n (%)	..	100 994 367 (48%)
Mitral regurgitation (n=449)	<0·0001	1·7% (1·5–1·9)
Mitral stenosis (n=15)	0·006	0·1% (0·02–0·2)
Aortic regurgitation (n=90)	<0·0001	0·5% (0·3–0·6)
Aortic stenosis (n=102)	<0·0001	0·4% (0·3–0·5)

Frequency or prevalence of aortic regurgitation is about 0.5% of the adult population.

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Methods We pooled population-based studies to obtain data for 11911 randomly selected adults from the general population who had been assessed prospectively with echocardiography. We also analysed data from a community study of 16501 adults who had been assessed by clinically indicated echocardiography.

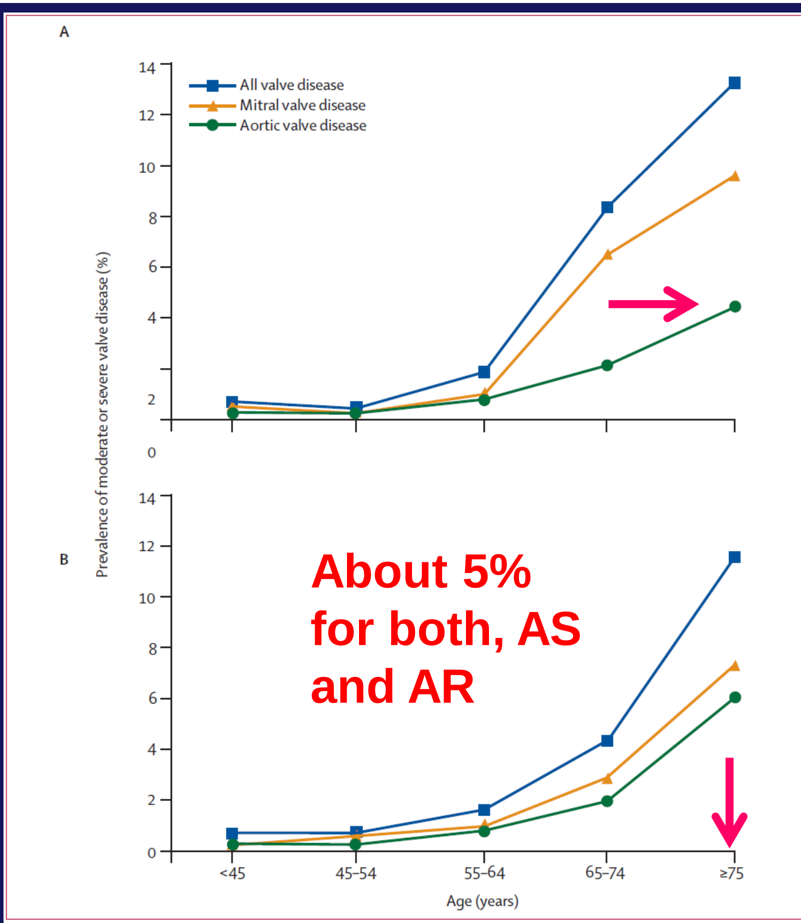
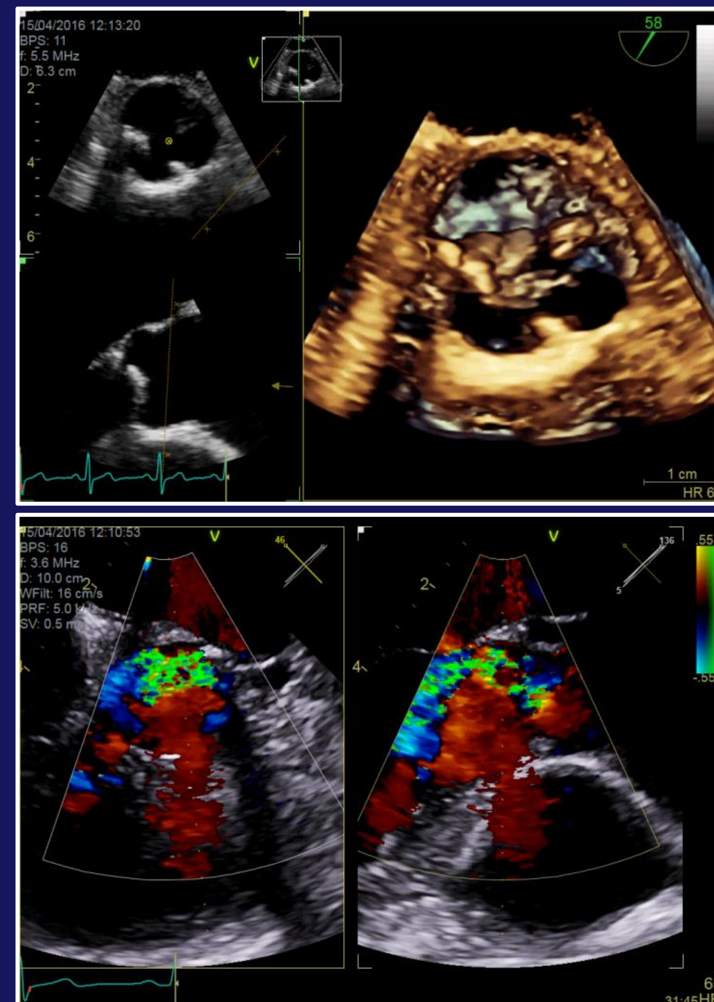


Figure 1: Prevalence of valvular heart disease by age
(A) Frequency in population-based studies and (B) in the Olmsted County community.



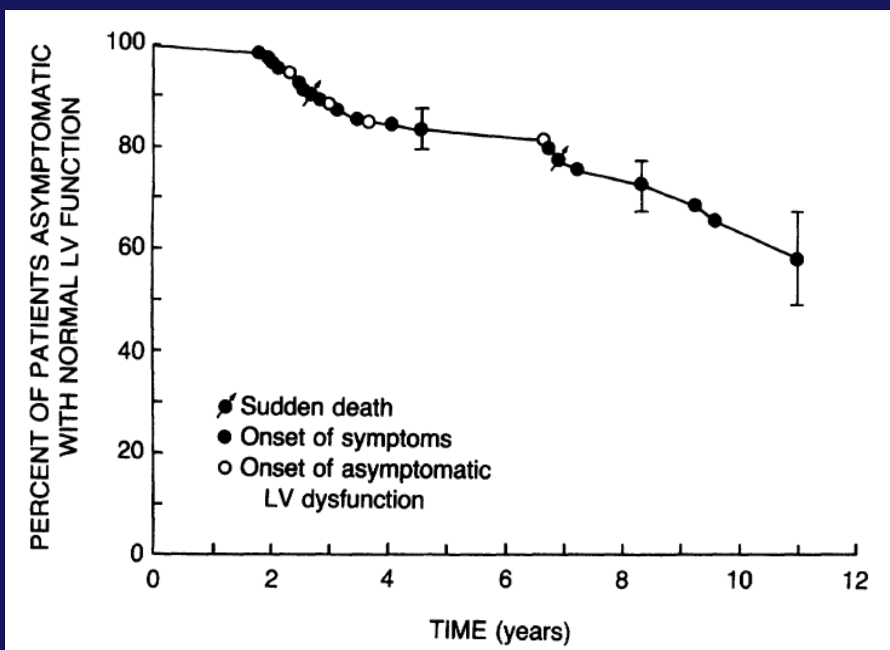
according to Nkomo et al., Lancet 2006;368: 1005-1012

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Serial Long-term Assessment of the Natural History of Asymptomatic Patients With Chronic Aortic Regurgitation and Normal Left Ventricular Systolic Function

Robert O. Bonow, MD; Edward Lakatos, PhD; Barry J. Maron, MD; and Stephen E. Epstein, MD

Conclusions. Thus, in addition to indexes of left ventricular function determined on initial evaluation, serial long-term changes in systolic function identify patients likely to develop symptoms and require operation. Patients have a higher risk of symptomatic deterioration if there is progressive change in end-systolic dimension or resting ejection fraction during the course of serial studies. (*Circulation* 1991;84:1625–1635)



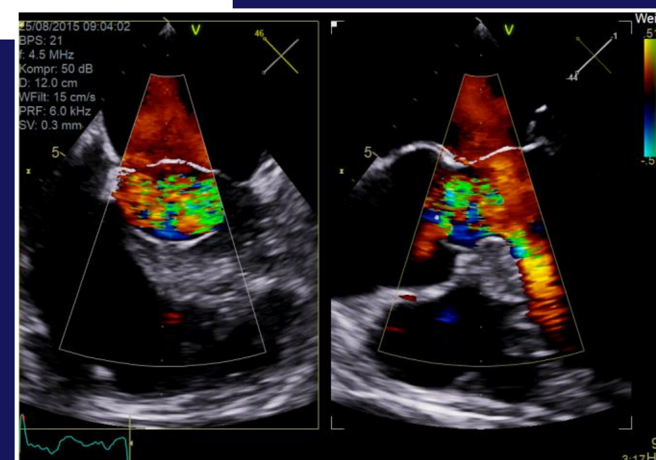


FIGURE 1. *Life table depicting the clinical course of the 104 patients. Brackets indicate SEE. At 11 years, 58±9% of the patients were alive and asymptomatic with normal left ventricular (LV) function.*

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

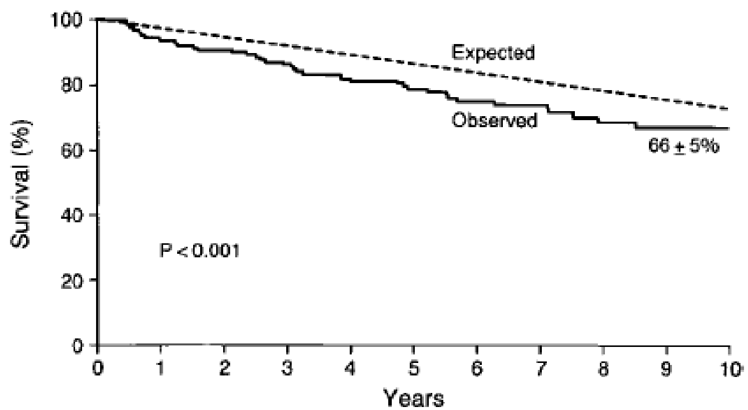
Mortality and Morbidity of Aortic Regurgitation in Clinical Practice

A Long-Term Follow-Up Study

Karl S. Dujardin, MD; Maurice Enriquez-Sarano, MD; Hartzell V. Schaff, MD; Kent R. Bailey, PhD; James B. Seward, MD; A. Jamil Tajik, MD

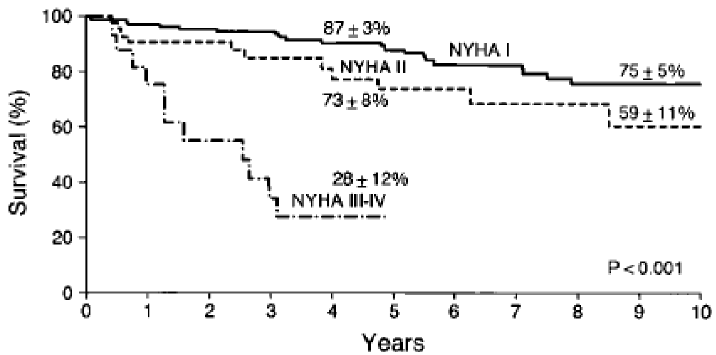
Conclusions—Patients diagnosed with severe aortic regurgitation in clinical practice incur excess mortality and high morbidity, underscoring the serious prognosis of the disease. Surgery, which reduces cardiac mortality rates, should be considered promptly in high-risk patients. (*Circulation*. 1999;99:1851-1857.)

Survival in pts with severe AR depends on symptons and NYHA classification



n = 246	148	130	119	106	92	73	58	47	37	20

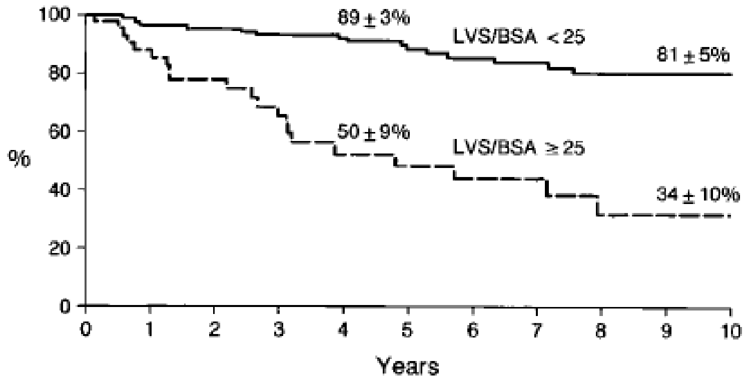
Figure 1. Survival with conservative treatment of the entire study population compared with expected survival of age- and sex-matched 1990 US white population. Excess mortality rate (expected 10-year survival is 75%) is observed in patients with aortic regurgitation.



NYHA I	122	100	91	88	81	71	55	48	37	31	16
NYHA II	64	37	31	26	21	19	16	9	9	6	4
NYHA III-IV	60	11	8	5	4	2					

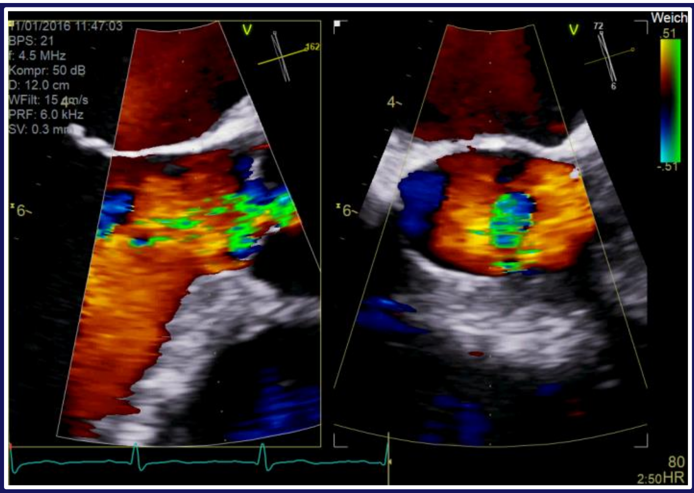
Figure 2. Survival with conservative treatment of the entire study population of patients with severe aortic regurgitation stratified according to NYHA class at baseline. Survival of patients in class III or IV is significantly different from expected survival ($P<0.001$) and from that of class I or II patients ($P<0.001$). Survival of patients in class II is lower than expected ($P=0.02$) and lower than that of patients in class I ($P=0.04$). Survival of patients in class I is not different from expected ($P=0.38$).

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -



LVS/BSA < 25	79	33	27	22	15	12	10	8	6	4	2
LVS/BSA ≥ 25	154	106	96	90	85	76	61	48	39	32	17

Figure 3. Survival with conservative treatment of entire study population of patients with severe aortic regurgitation stratified according to LVS/BSA. Survival of patients with baseline values ≥25 mm/m^2 was lower than expected (P<0.001) and different from that of patients with values <25 mm/m^2 (P<0.001), whose survival was not different from expected (P=0.52).



according to Dujardin et al.,
Ciculation 1999; 99: 1851-1857

Survival is higher,
if LVS-diameter/BSA is < 25mm/m^2

If AR is severe, event rate is high.

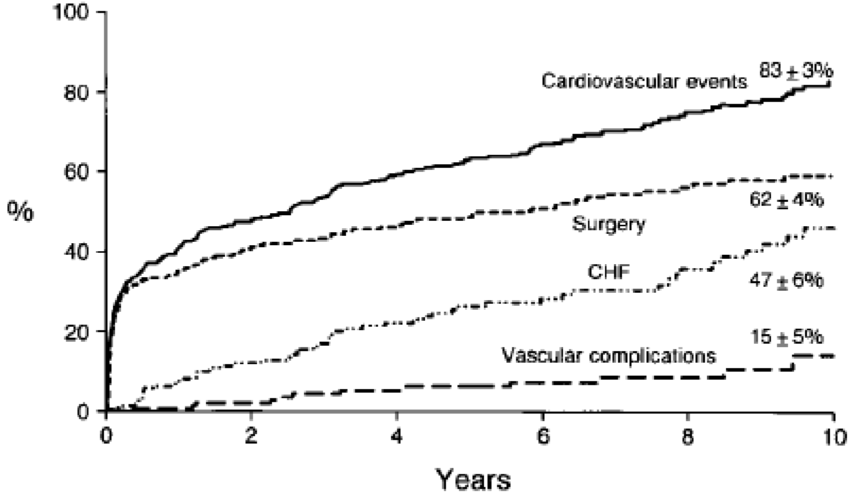


Figure 4. Follow-up events under conservative treatment in patients with severe aortic regurgitation. Vascular complications were either thromboembolism or aortic dissection. Cardiovascular events were cardiac deaths, surgery, congestive heart failure (CHF), vascular complications, new atrial fibrillation, and new endocarditis.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Conclusions and Clinical Implications

Severe AR diagnosed in clinical practice is a serious condition complicated both by excess mortality and high morbidity. Within 10 years after diagnosis, 75% of the patients had either died or required aortic valve replacement and 83% had a cardiac event.

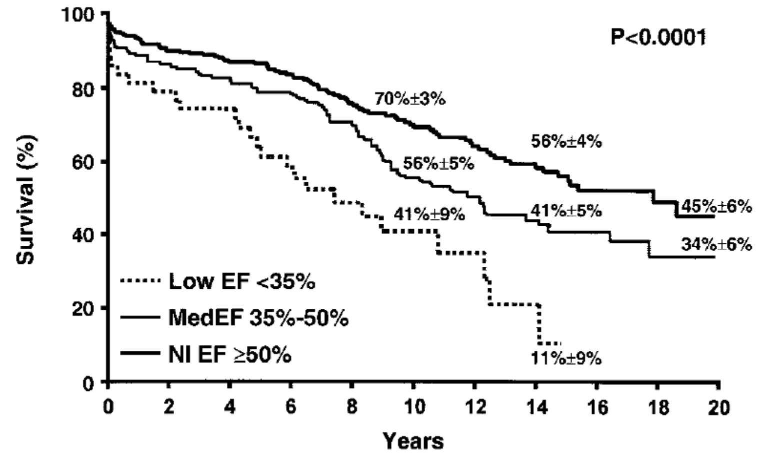
Patients at high risk under conservative management include those with (1) severe symptoms, even transient and improved by treatment; (2) mild, class II symptoms; (3) EF <55% or LVS/BSA $\geq$25 mm/m^2 with or without symptoms; or (4) atrial fibrillation. Because surgery during follow-up is associated significantly with reduced cardiac mortality rates, these patients should promptly be considered for surgical correction of AR.

according to Dujardin et al., Ciculation 1999; 99: 1851-1857

Outcomes After Aortic Valve Replacement in Patients With Severe Aortic Regurgitation and Markedly Reduced Left Ventricular Function

Hari P. Chaliki, MD; Dania Mohty, MD; Jean-Francois Avierinos, MD; Christopher G. Scott, MS; Hartzell V. Schaff, MD; A. Jamil Tajik, MD; Maurice Enriquez-Sarano, MD

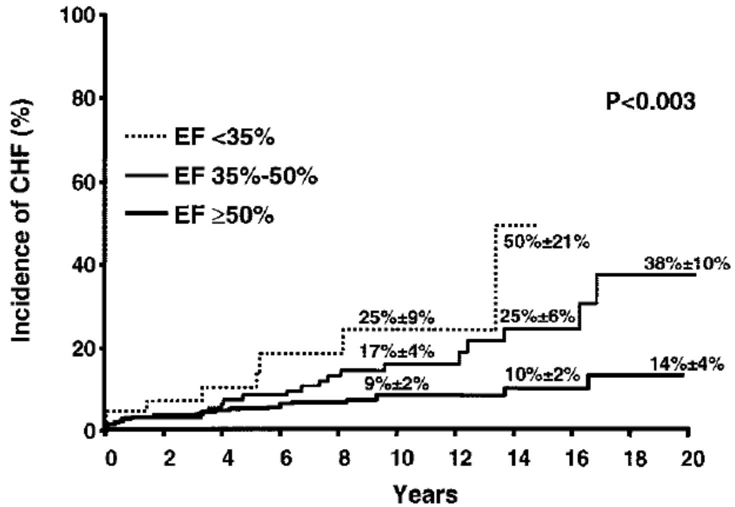
Conclusions—Patients with severe AR and markedly low EF incur excess operative mortality rates, postoperative mortality rates, and congestive heart failure after AVR. However, postoperative EF improves markedly, and most patients enjoy a long postoperative survival without recurrence of heart failure after AVR; thus they should not be denied the benefits of AVR. (***Circulation*. 2002;106:2687-2693.**)



LoEF (EF <35%)	43	35	31	21	15	8	6	3			
MedEF (EF 35%-50%)	134	115	108	95	78	50	34	30	19	9	2
NI EF (EF ≥50%)	273	245	231	184	141	112	83	60	32	17	1

Figure 1. Survival after AVR for the entire study population, with significant AR stratified according to EF. Patients with markedly low EF had significantly lower survival rates than those with normal EF and moderately reduced EF before AVR.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -



LoEF (EF <35%)	43	34	29	20	15	8	6	3			
MedEF (EF 35%-50%)	134	113	103	89	70	45	35	24	15	6	2
NI EF (EF ≥50%)	273	240	226	178	136	106	77	57	30	16	1

Figure 3. Congestive heart failure (CHF) after AVR in the entire study population with significant AR, stratified according to EF. Patients with markedly low EF had a higher rate of CHF than patients who had moderately reduced or normal EF before AVR.

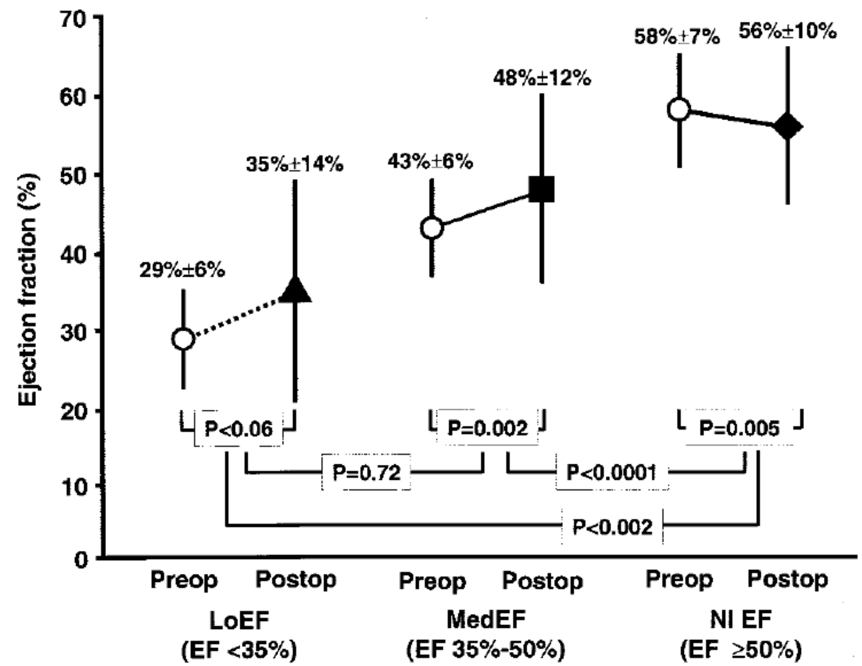


Figure 4. Ejection fraction improved significantly in patients who had lower preoperative EF (groups LoEF and MedEF). There was a slight decrease in EF in patients with normal EF (NI EF).

Conclusions

In patients with severe AR, those with markedly reduced EF represent a high-risk group, even after successful AVR, and should preferably be operated on before such an advanced LV dysfunction occurs. However, after AVR, mid-term symptom-free survival is obtained in most patients. Hence, a marked EF reduction should not be considered a contraindication to AVR for severe AR.

Reduced LVEF in chronic severe AR is a significant factor of bad prognosis. However, reduced LVEF is not a contraindication to consider AVR.

according to Chaliki et al., Circulation 2002;106:2687-2693

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Prevalence and Clinical Correlates of Isolated Mitral, Isolated Aortic Regurgitation, and Both in Adults Aged 21 to 35 Years (from the CARDIA Study)

Cheryl L. Reid, MD[a], Hoda Anton-Culver, PhD[a], Carla Yunis, PhD[b], and Julius M. Gardin, MD[c,*]

Aortic regurgitation (AR) and mitral regurgitation (MR) can result in serious clinical complications and death. The physiologic and clinical correlates of AR and MR in a free-living young adult population, however, have not been well defined. The prevalence and correlates of AR and MR were investigated in Coronary Artery Risk Development in Young Adults (CARDIA), a multicenter National Heart, Lung, and Blood Institute study of 4,352 men and women aged 21 to 35 years who had 2-dimensionally directed M-mode echocardiographic and spectral and color Doppler examinations. Isolated MR by color Doppler was detected in 10.4% (90.4% with trivial or mild severity). Isolated AR by color Doppler was present in 0.8% (37.7% with mild severity). Combined AR and MR occurred in 0.5%. There was no association between body mass index and the prevalence or severity of MR or AR. Left ventricular mass was greater in subjects with isolated AR (mean ± SD 172 ± 49 g) than in those with MR (155 ± 48 g) and greater in both groups than in subjects without MR and AR (148 ± 44 g). AR was associated with increased aortic root diameter, whereas subjects with isolated MR and those with AR and MR had increased left atrial dimensions and greater left ventricular internal dimensions. In conclusion, MR and AR detected by color Doppler echocardiography are relatively uncommon in a healthy young adult population, but both are associated with evidence of increased left ventricular dimensions and mass.

AR-incidence: 0.8%
Combined AR- and MR-Incidence: 0.5%

AR is associated with aortic root diameter-

according to Reid et al.; Am J Cardiol 2007;99:830-834

Guidelines on the management of valvular heart disease (version 2012)

The Joint Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

Authors/Task Force Members: Alec Vahanian (Chairperson) (France)*, Ottavio Alfieri (Chairperson)* (Italy), Felicita Andreotti (Italy), Manuel J. Antunes (Portugal), Gonzalo Barón-Esquivias (Spain), Helmut Baumgartner (Germany), Michael Andrew Borger (Germany), Thierry P. Carrel (Switzerland), Michele De Bonis (Italy), Arturo Evangelista (Spain), Volkmar Falk (Switzerland), Bernard Iung (France), Patrizio Lancellotti (Belgium), Luc Pierard (Belgium), Susanna Price (UK), Hans-Joachim Schäfers (Germany), Gerhard Schuler (Germany), Janina Stepinska (Poland), Karl Swedberg (Sweden), Johanna Takkenberg (The Netherlands), Ulrich Otto Von Oppell (UK), Stephan Windecker (Switzerland), Jose Luis Zamorano (Spain), Marian Zembala (Poland)

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

ESC/EACTS GUIDELINES

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Aortic regurgitation

Indications for surgery

according to Vahanian et al., Eur Heart J 2012; 33: 2451-2496

- Symptoms
- Endsystolic LV-dimension > 50mm
- LV-ejection fraction < 50%
- Diastolic LV-Dimension > 70mm
- Significant progression of symptoms
- Significant deterioration of indices

In symptomatic acute severe AR, urgent/emergent surgical intervention is indicated.

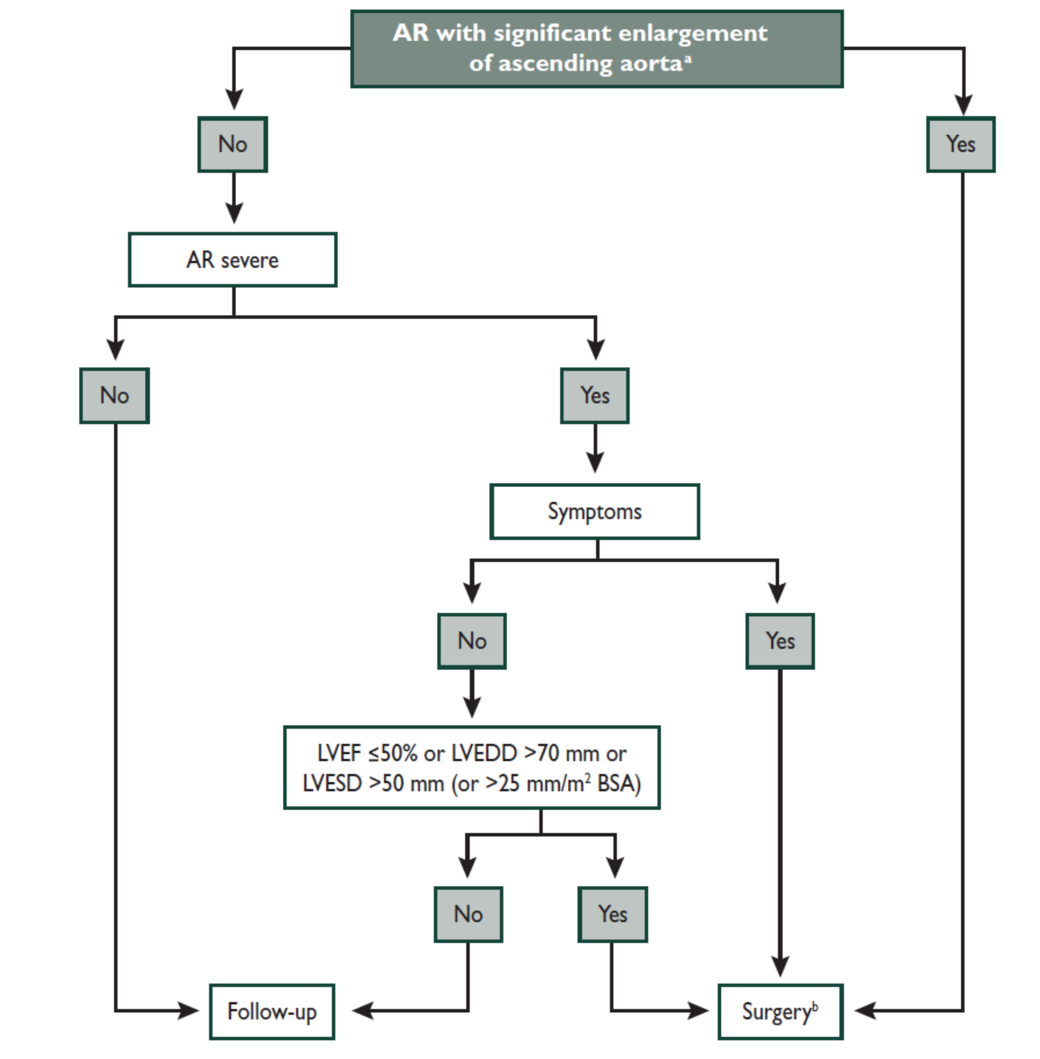
In chronic severe AR, the goals of treatment are to prevent death, to diminish symptoms, to prevent the development of HF, and to avoid aortic complications in patients with aortic aneurysm.[69]

	Class [a]	Level [b]	Ref [c]
A. Indications for surgery in severe aortic regurgitation			
Surgery is indicated in symptomatic patients.	I	B	59
Surgery is indicated in asymptomatic patients with resting LVEF ≤50%.	I	B	71
Surgery is indicated in patients undergoing CABG or surgery of ascending aorta, or on another valve.	I	C	
Surgery should be considered in asymptomatic patients with resting EF >50% with severe LV dilatation: LVEDD >70 mm, or LVESD >50 mm or LVESD >25 mm/m² BSA.[d]	IIa	C	

59. Dujardin KS, Enriquez-Sarano M, Schaff HV, Bailey KR, Seward JB, Tajik AJ. Mortality and morbidity of aortic regurgitation in clinical practice. A long-term follow-up study. *Circulation* 1999;**99**:1851–1857.

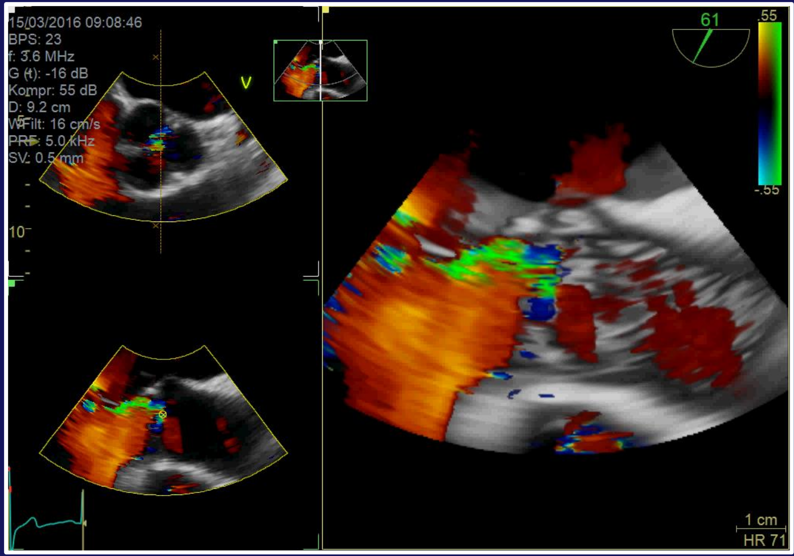
71. Chaliki HP, Mohty D, Avierinos J-F, Scott CG, Schaff HV, Tajik AJ, Enriquez-Sarano M. Outcomes after aortic valve replacement in patients with severe aortic regurgitation and markedly reduced left ventricular function. *Circulation* 2002;**106**:2687–2693.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -



AR = aortic regurgitation; BSA = body surface area; LVEDD = left ventricular end-diastolic diameter; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic diameter.
[a]See *Table 8* for definition.
[b]Surgery must also be considered if significant changes in LV or aortic size occur during follow-up.

according to Vahanian et al., Eur Heart J 2012; 33: 2451-2496



Conclusion: Grading of the AR severity is the crucial point.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Wall Stress and Patterns of Hypertrophy in the Human Left Ventricle

WILLIAM GROSSMAN, DONALD JONES, and LAMBERT P. MCLAURIN

The Journal of Clinical Investigation Volume 56 July 1975 · 56–64

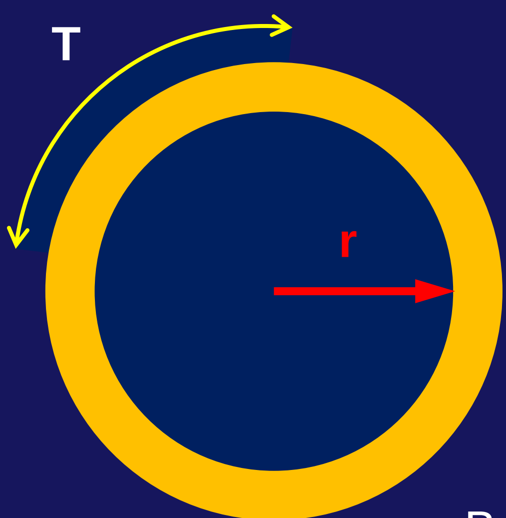
La Place law: T = ½ P r / d

T = wall tension

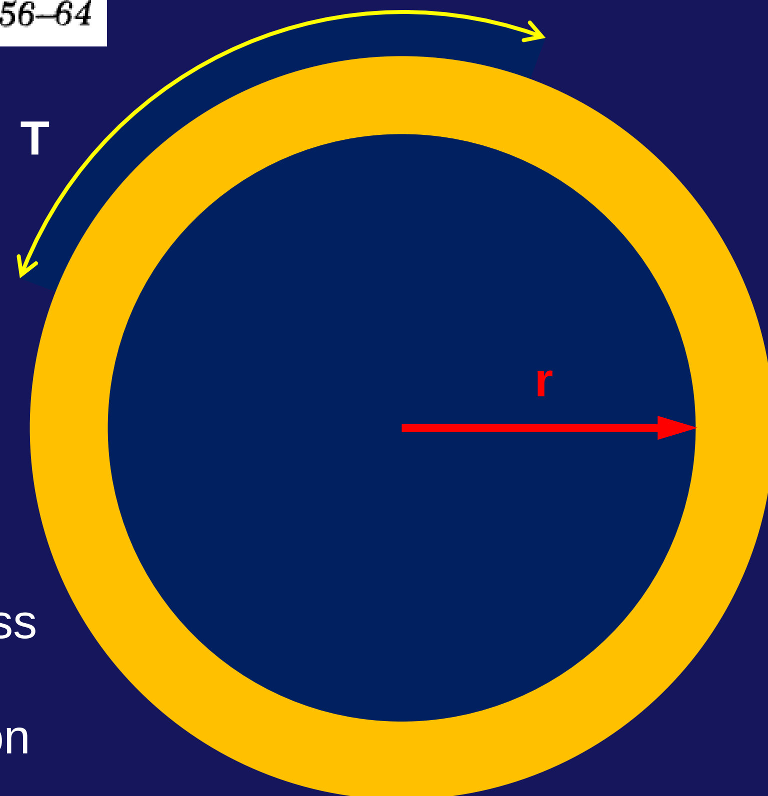
P = transmural pressure

r = radius

d = wall thickness

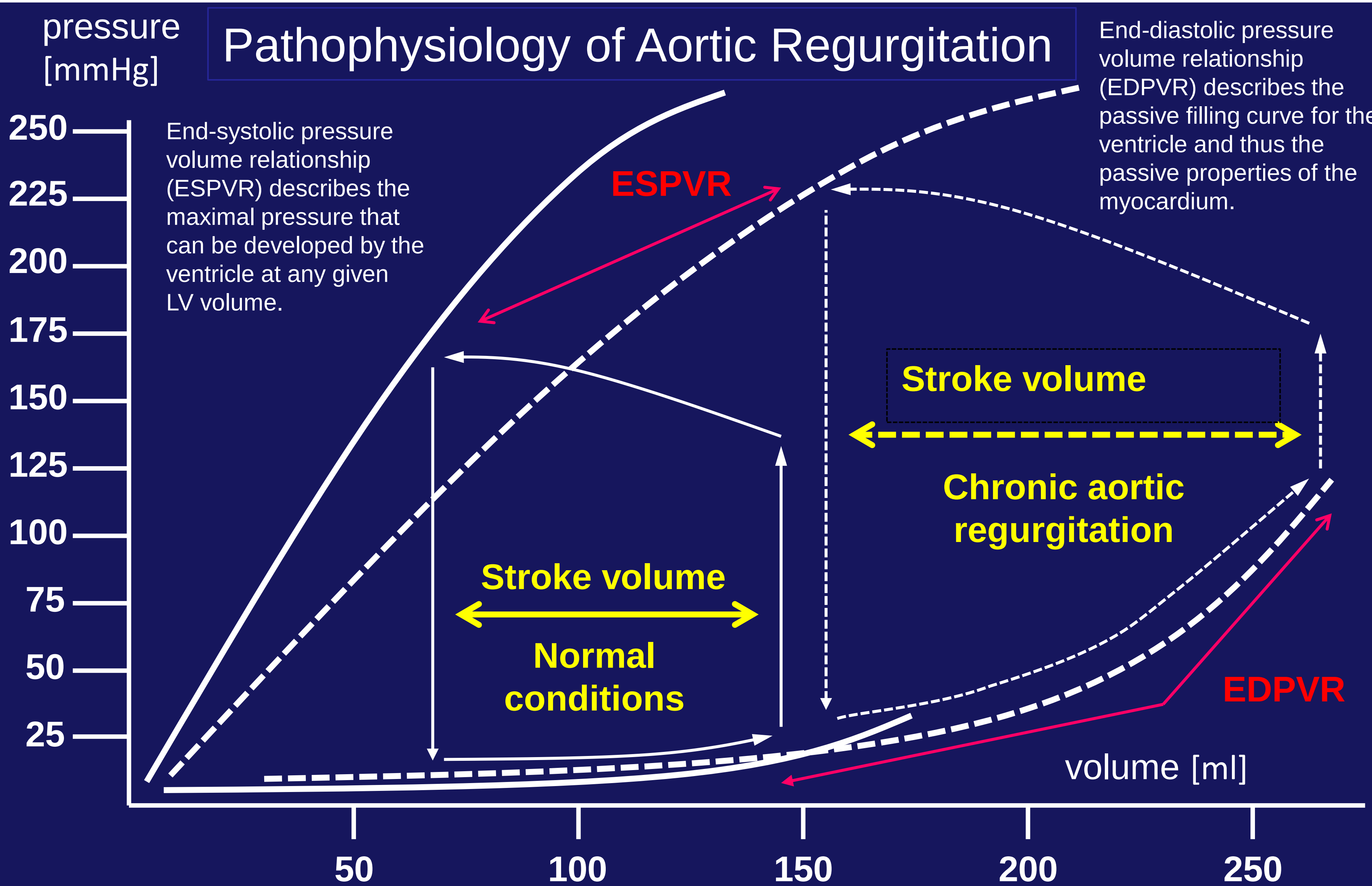


The increase in r compensates volume overload.



Because wall thickness (also = wall stress) increases, wall tension will be normalized.

Pathophysiology of Aortic Regurgitation



Chronic Aortic regurgitation

Progressive myocardial dysfunction is due to:

1. Impaired myocardial function
   - With an increase of functionally abnormal myocytes and fibrosis
2. Decreased coronary flow reserve
   - Secondary to excentric left ventricular hypertrophy and increased wall stress

Patients become symptomatic at different levels of left ventricular dysfunction.
But: how to be sure that symptoms are really related to aortic regurgitation?

Thus, grading of the aortic regurgitation is the crucial point.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Table 2 Grading of aortic regurgitation (AR)

	Mild	Moderate		Severe
Specific signs for AR severity	Vena contracta <0.3 cm* Central jet width <25% of LVOT* No or brief early diastolic flow reversal in descending aorta	Intermediate values Intermediate values		Vena contracta >0.6 cm* Central jet ≥65% of LVOT* Holodiastolic flow reversal in descending aorta Flail or wide coaptation defect
Supportive signs	PHT >500 ms No/minimal flow convergence*			PHT <200 ms Large flow convergence* Moderate or greater LV enlargement
Quantitative parameters†				
Reg volume (ml/beat)	<30	30–44	45–59	≥60
Reg fraction (%)	<30	30–39	40–49	≥50
EROA (cm^2)	<0.10	0.10–0.19	0.20–0.29	≥0.30

according to Maurer, Heart 2006;92: 994-1000

Which method for which approach?

„later“

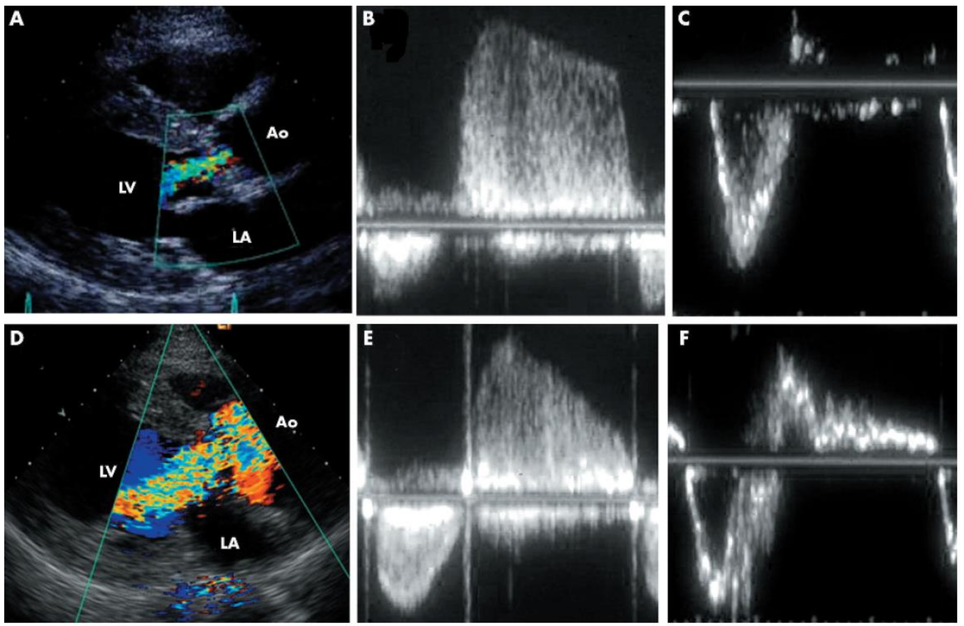


Figure 1 Echo-Doppler evaluation of aortic regurgitation (AR): panels A, B, C—mild AR; panels D, E, F—severe AR. (A) Narrow colour Doppler jet in mild AR (parasternal long axis view). (B) CW-Doppler tracing in mild AR (slow velocity decay). (C) PW-Doppler tracing from the descending aorta (suprasternal approach) in mild AR (minimal diastolic flow reversal). (D) Broad colour Doppler jet and large convergence zone in severe AR (parasternal long axis view). (E) CW-Doppler tracing in severe AR (steep diastolic velocity decay). (F) PW-Doppler tracing from the descending aorta (suprasternal approach) in severe AR (holodiastolic flow reversal). Ao, aorta; LA, left atrium; LV, left ventricle.

Semiquantitative:

- Vena contracta
- Ratio $D_{jet\ width}/D_{LVOT}$
- Reverse diastolic flow
- PHT
- Flow convergence

Quantitative:

- Regurgitant volume by PISA
- Stroke volumes using PW Doppler at the level of LVOT, MV (total) or PV (effective)
- Total stroke volume by biplane planimetry

Functional Anatomy of Aortic Regurgitation

Accuracy, Prediction of Surgical Repairability, and Outcome Implications of Transesophageal Echocardiography

Jean-Benoît le Polain de Waroux, MD*; Anne-Catherine Pouleur, MD*; Céline Goffinet, MD; David Vancraeynest, MD; Michel Van Dyck, MD; Annie Robert, PhD; Bernhard L. Gerber, MD, PhD; Agnès Pasquet, MD, PhD; Gébrine El Khoury, MD; Jean-Louis J. Vanoverschelde, MD, PhD

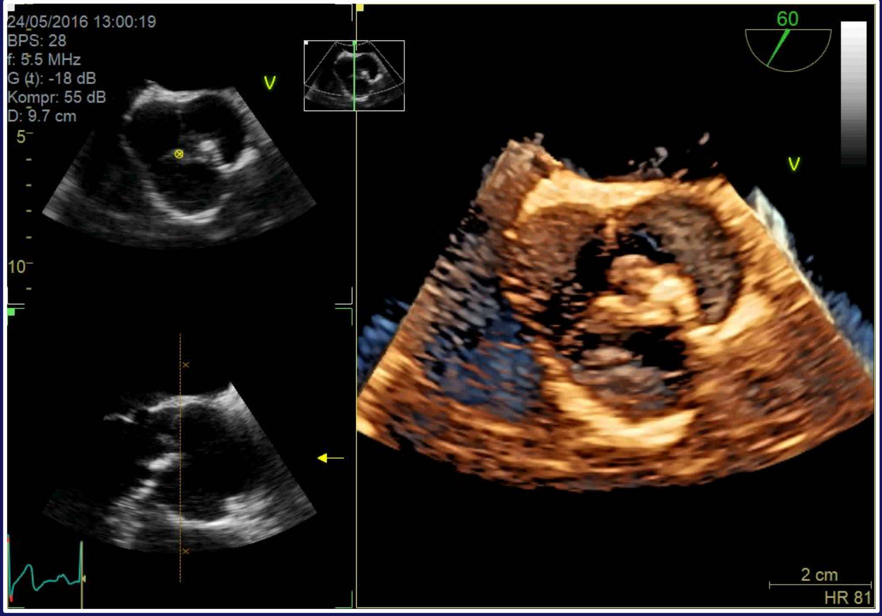
Conclusions—TEE provides a highly accurate anatomic assessment of all types of AR lesions. In addition, the functional anatomy of AR defined by TEE is strongly and independently predictive of valve repairability and postoperative outcome. (*Circulation*. **2007;116[suppl I]:I-264–I-269.**)

TABLE 1. Surgical and TEE Classification of Aortic Regurgitant Lesions

Type 1	Enlargement of the aortic root with normal cusps.
Type 2	Cusp prolapse or fenestration.
Type 3	Poor cusp tissue quality or quantity.

TABLE 2. Grading of Aortic Valve Calcification

Grade 1	No calcification
Grade 2	Isolated small calcification spots
Grade 3	Bigger calcification spots interfering with cusp motion
Grade 4	Extensive calcifications of all cusps with restricted cusp motion



Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Ascending Aortic Aneurysms

Review of 100 Consecutive Cases

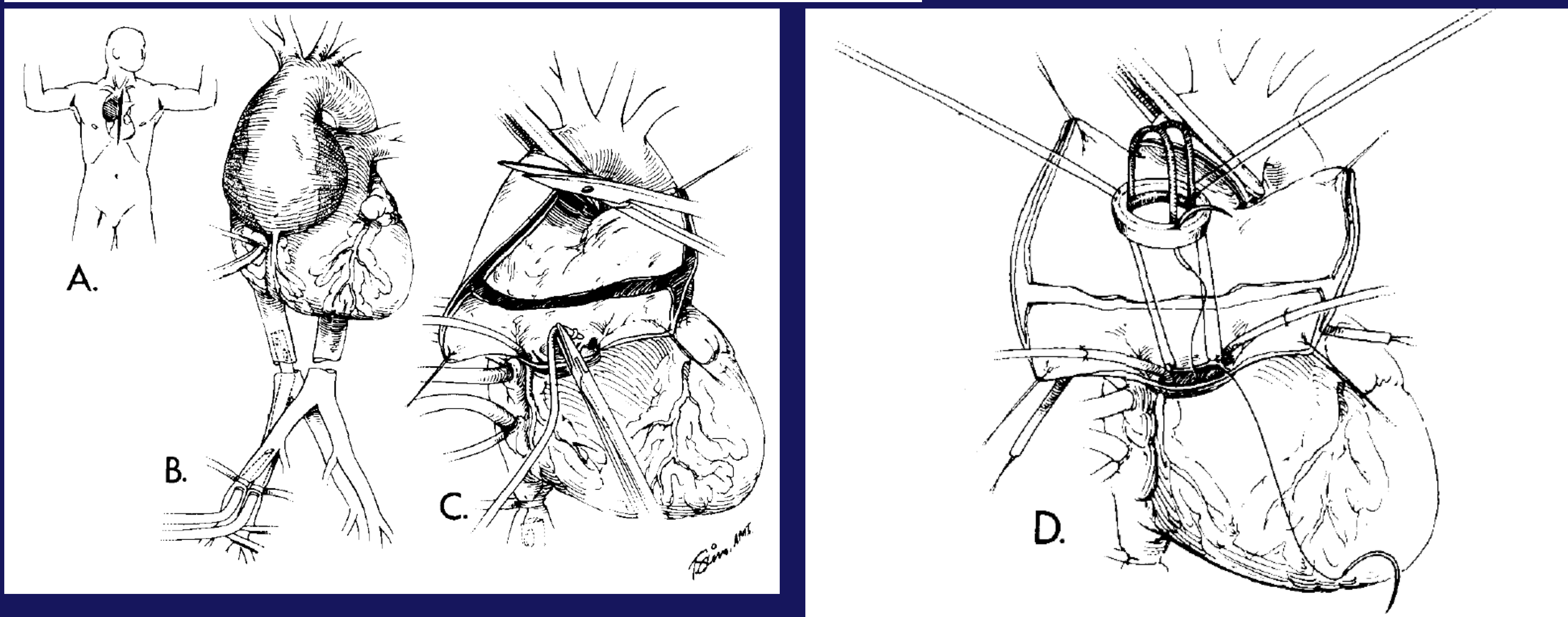
Supplement I to Circulation, Vols. 51 and 52, August 1975

By JOHN E. LIDDICOAT, M.D., SZABOLCS M. BEKASSY, M.D., PEDRO A. RUBIO, M.D., GEORGE P. NOON, M.D., AND MICHAEL E. DEBAKEY, M.D.

AR and Aortic Aneurysm

Figure 3

Drawing showing the surgical technique employed in this series. **A:** *Positioning of patient on the operating table.* **B:** *Cannulation of the common femoral artery and femoral vein.* **C:** *Insertion of coronary artery perfusion cannulas.* **D:** *Insertion of a ball-valve prosthesis.*



Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

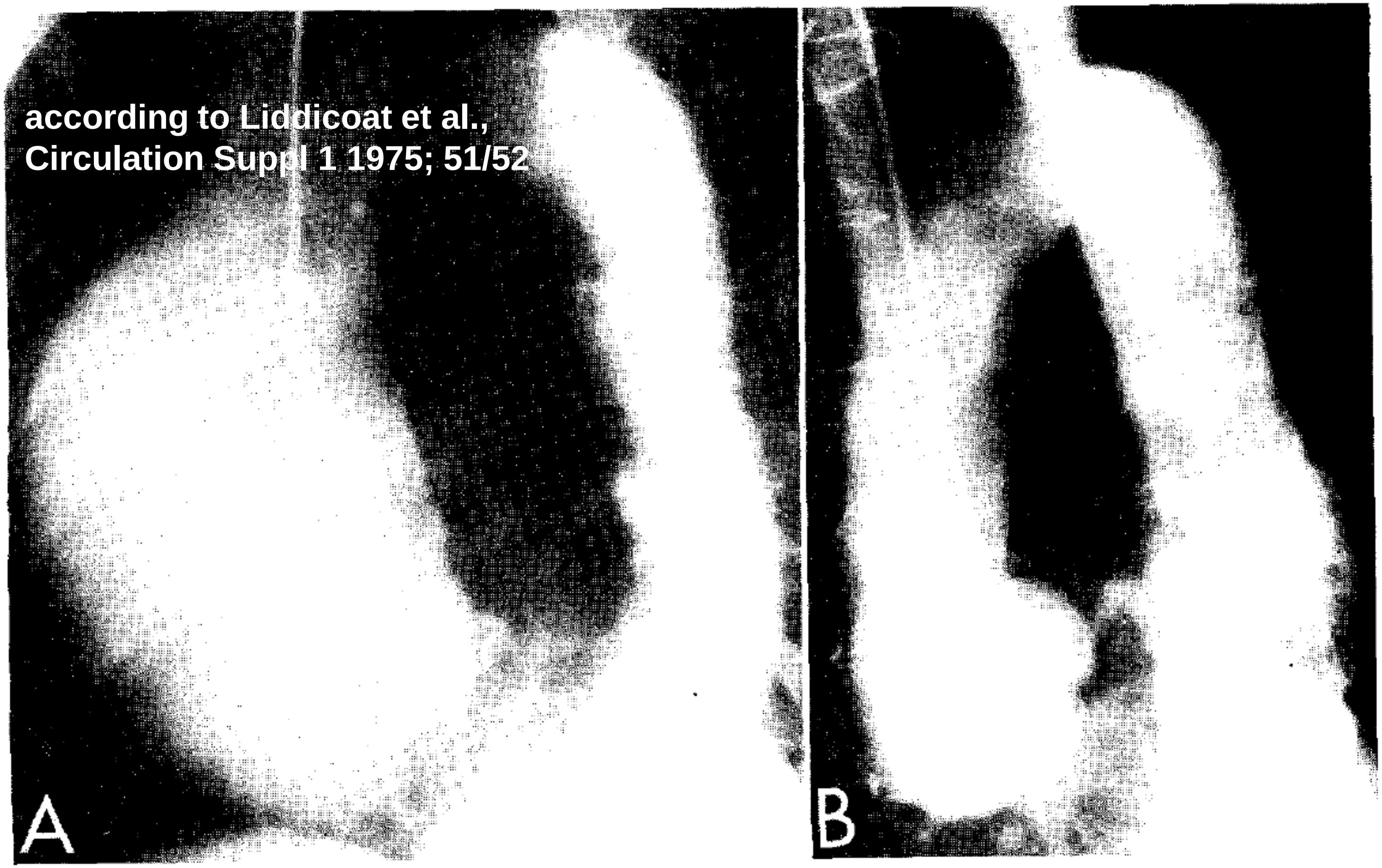


Figure 6

Preoperative aortogram in 60-degree left anterior oblique projection (A) demonstrates aneurysm of the ascending aorta. Postoperative aortogram in 45-degree left anterior oblique projection (B) 39 months after aneurysmal resection and graft replacement demonstrates mild dilatation of the sinuses of Valsalva and the ascending aorta proximal to the graft.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

according to Nienaber, Eur Heart J 2013; 14: 15-23

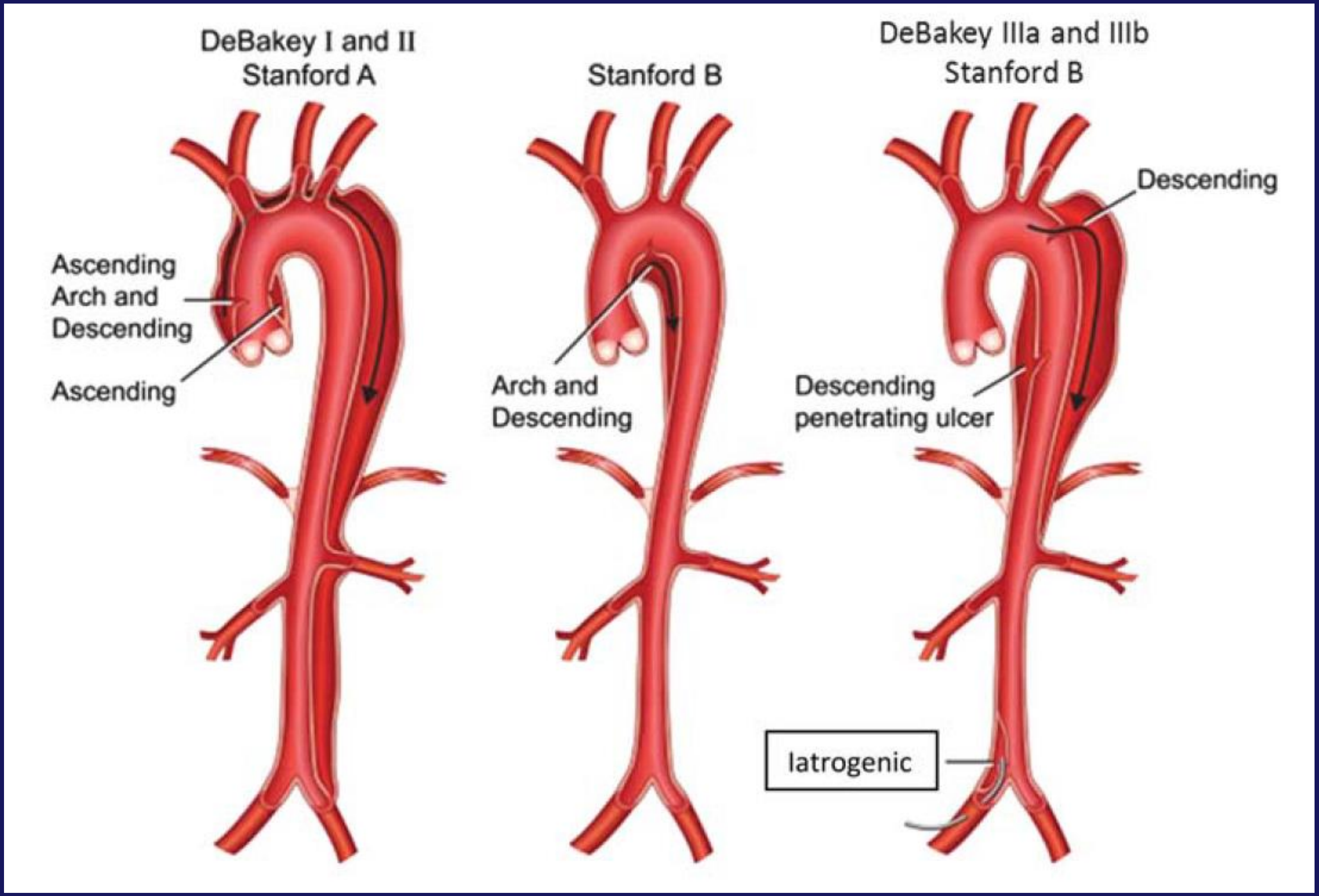


Figure 2 Aortic dissection classification: DeBakey and Stanford classification as the currently most frequently used classification systems for aortic dissection.

Contemporary Reviews in Cardiovascular Medicine

Thoracic and Abdominal Aortic Aneurysms

Eric M. Isselbacher, MD

(*Circulation*. 2005;111:816-828.)

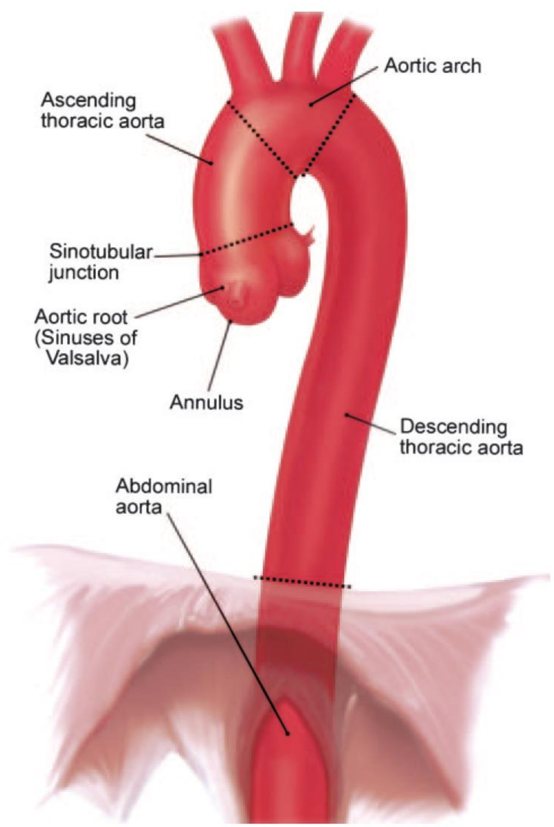
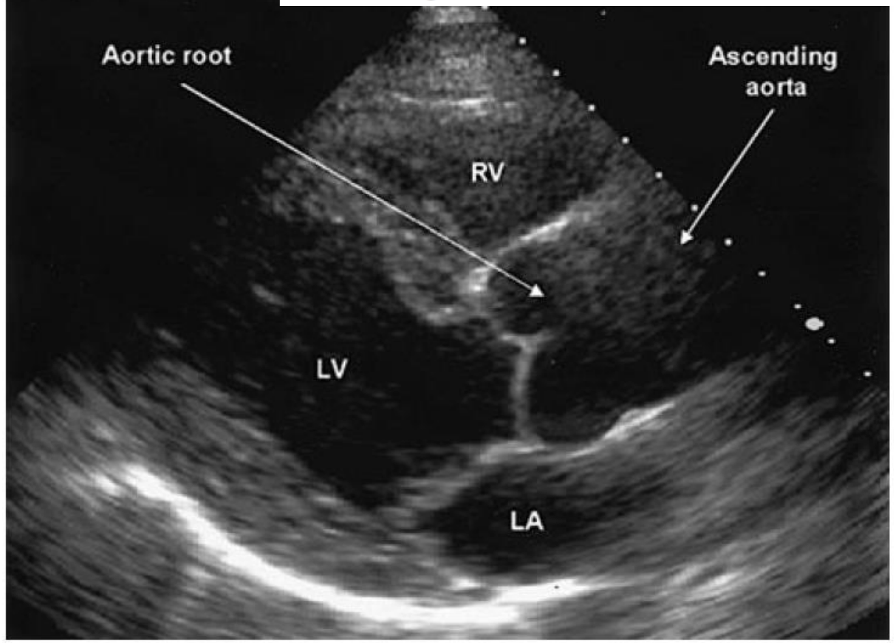


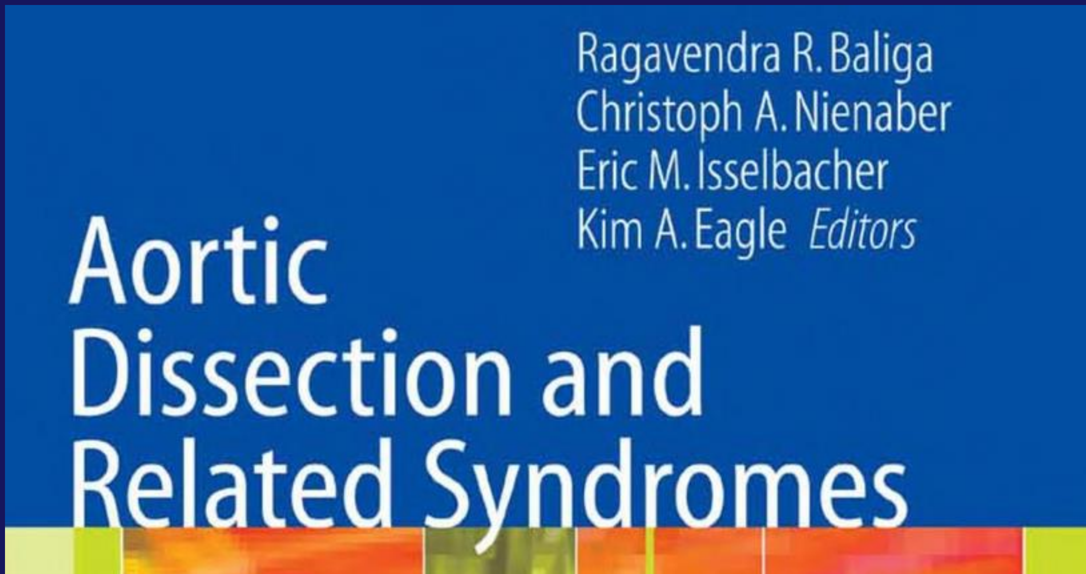
Figure 1. Anatomy of thoracic and proximal abdominal aorta. (©Massachusetts General Hospital Thoracic Aortic Center. Used with permission.)

Figure 5. A transthoracic echocardiogram, in a parasternal long-axis view, demonstrating a dilated aortic root (4.4 cm) and ascending aorta (4.2 cm). Whereas the aortic root is well visualized, the ascending aorta is less so, as is often the case with transthoracic imaging. RV indicates right ventricle; LV, left ventricle; and LA, left atrium.



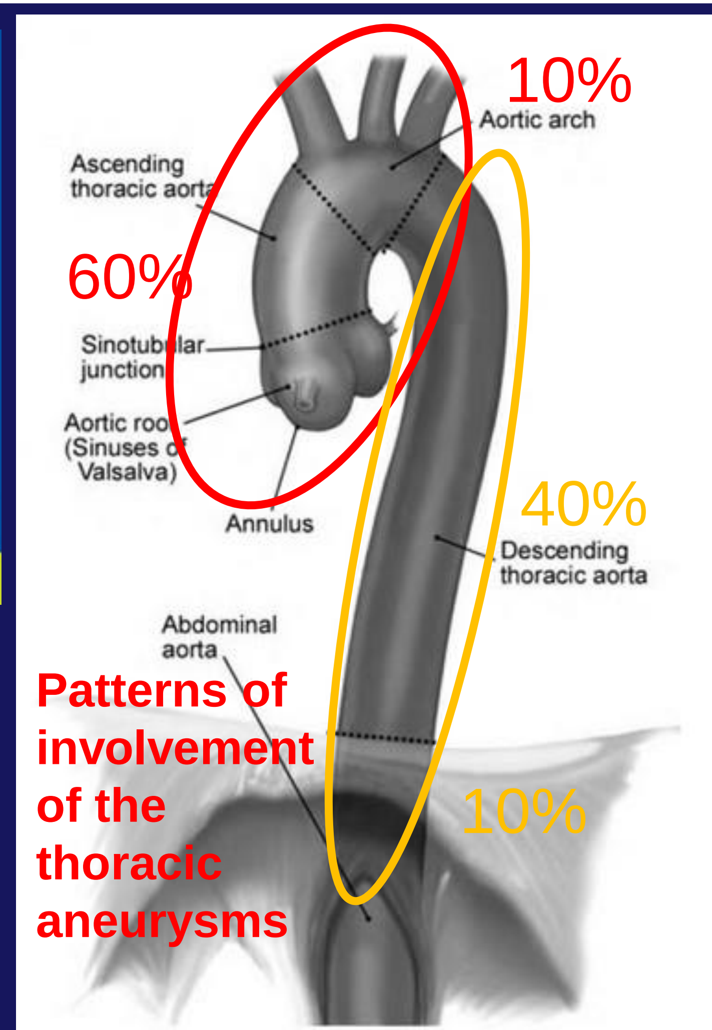
Results about the incidence of TAA

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -



EPIDEMIOLOGY OF THORACIC AORTIC ANEURYSMS, AORTIC DISSECTION, INTRAMURAL HEMATOMA, AND PENETRATING ATHEROSCLEROTIC ULCERS

Eric M. Isselbacher



Incidences: :

Aneurysma of the ascending aorta	**10 per 100.000 per year – m/f = 1.7/1**
Aneurysma of the descending aorta	**3 per 100.000 per year – m/f = 4.1/1**

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

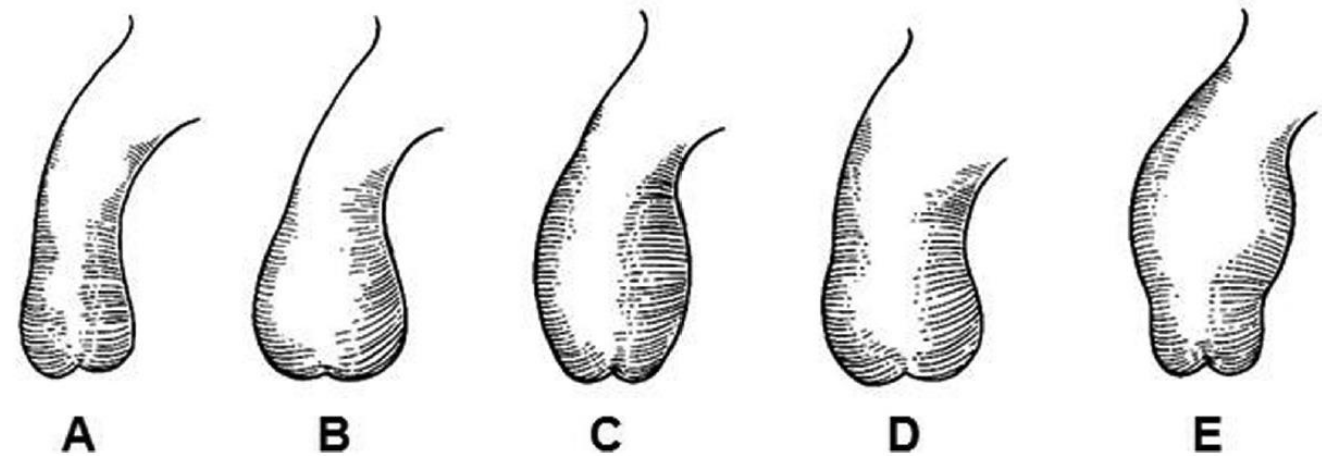
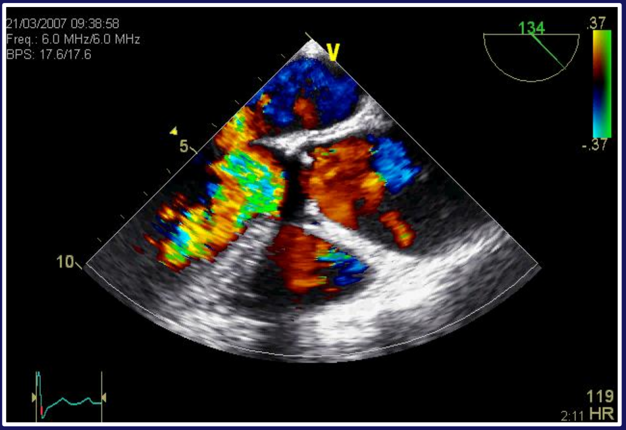


Figure 47 Diagram of some of the various shapes of aortic root and ascending aortic aneurysms. **(A)** Normal. **(B)** Characteristic "marfanoid" or "pear-shaped" aortic root with dilatation localized to the annulus and sinuses of Valsalva. **(C, D)** Two patterns of dilatation involving the annulus, sinuses of Valsalva, and ascending aorta. **(E)** Dilatation beginning at the STJ, but sparing the aortic annulus and sinuses of Valsalva.

Table 16 Goal of imaging of TAAs

1	Confirm diagnosis
2	Measure maximal diameter of the aneurysm
3	Define longitudinal extent of the aneurysm
4	Measure the diameters of the proximal and distal margins of the aneurysm
5	Determine involvement of the aortic valve
6	Determine involvement of the arch vessel(s)
7	Detect periaortic hematoma or other sign of leakage
8	Differentiate from aortic dissection
9	Detect mural thrombus

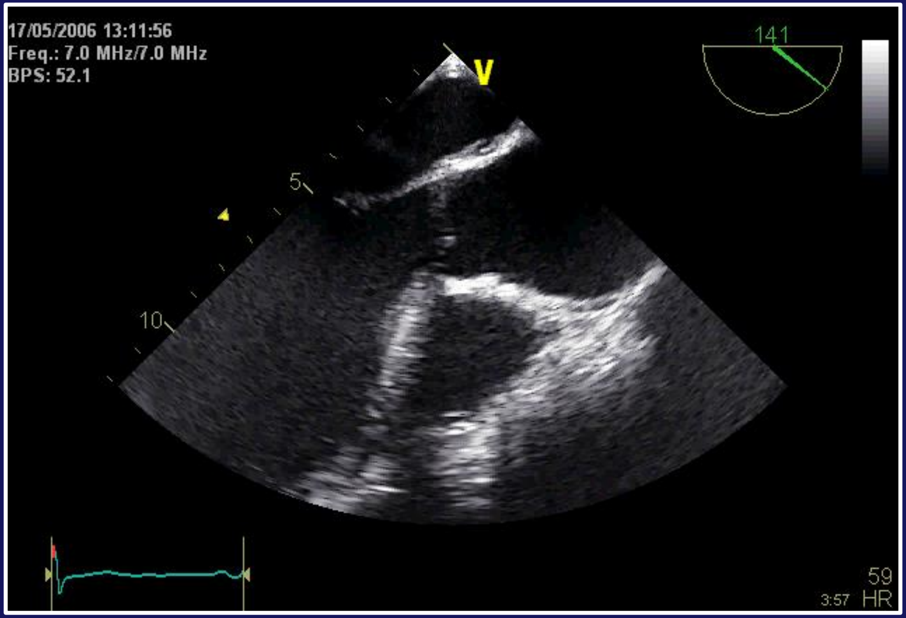
according to Goldstein et al., J Am Soc Echocardiogr 2015; 28: 119-182



Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Table 15 Etiologies of TAAs

1. Marfan syndrome
2. BAV-related aortopathy
3. Familial TAA syndrome
4. Ehlers-Danlos syndrome type IV (vascular type)
5. Loeys-Dietz syndrome
6. Turner syndrome
7. Shprintzen-Goldberg (marfanoid-craniosynostosis) syndrome
8. Noninfectious aortitis (e.g., GCA, TA, nonspecific arteritis)
9. Infectious aortitis (mycotic syndrome)
10. Syphilitic aortitis
11. Trauma
12. Idiopathic



Assessment of AA includes etiology of AA.

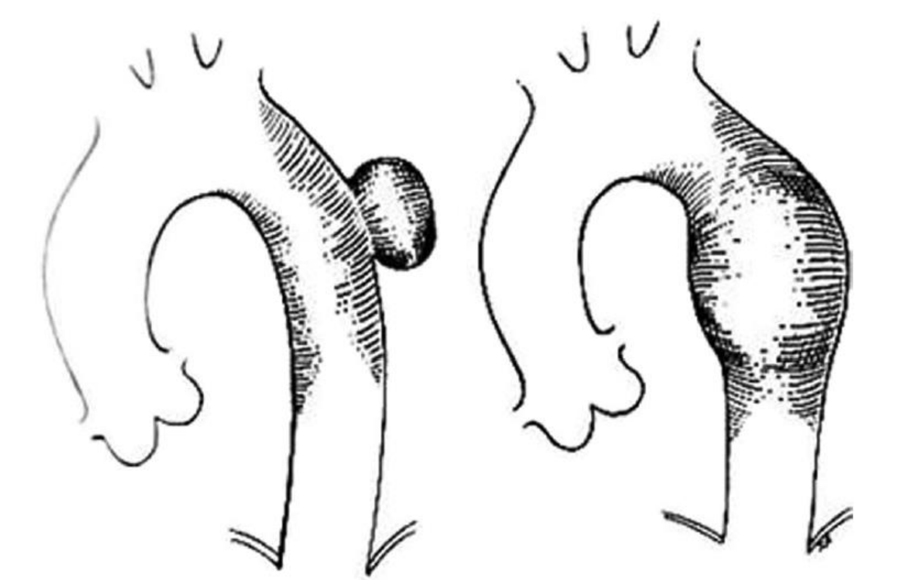


Figure 46 Diagram illustrating the two morphologic types of aortic aneurysms: saccular and fusiform.

according to Goldstein et al.,
J Am Soc Echocardiogr 2015; 28: 119-182

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Repair-oriented classification of aortic insufficiency: Impact on surgical techniques and clinical outcomes

Munir Boodhwani, MD, MMSc, Laurent de Kerchove, MD, David Glineur, MD, Alain Poncelet, MD, Jean Rubay, MD, Parla Astarci, MD, Robert Verhelst, MD, Philippe Noirhomme, MD, and Gébrine El Khoury, MD

Conclusion: Aortic valve repair is an acceptable therapeutic option for patients with aortic insufficiency. This functional classification allows a systematic approach to the repair of AI and can help to predict the surgical techniques required as well as the durability of repair. Restrictive cusp motion (type III), due to fibrosis or calcification, is an important predictor for recurrent AI following AV repair.

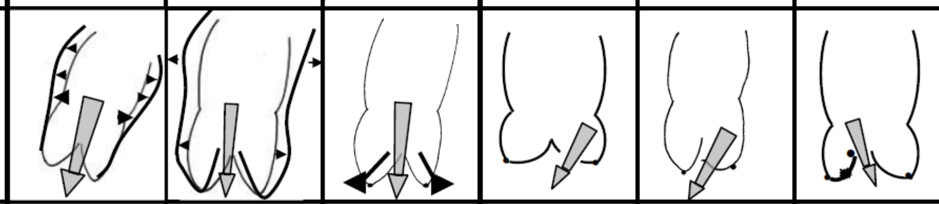
AI Class	Type I Normal cusp motion with FAA dilatation or cusp perforation				Type II Cusp Prolapse	Type III Cusp Restriction
	Ia	Ib	Ic	Id		
Mechanism						
Repair Techniques (Primary)	STJ remodeling *Ascending aortic graft*	Aortic Valve sparing: *Reimplantation or Remodeling with SCA*	SCA	Patch Repair *Autologous or bovine pericardium*	Prolapse Repair *Plication* *Triangular resection* *Free margin Resuspension* *Patch*	Leaflet Repair *Shaving* *Decalcificatio* *Patch*
(Secondary)	SCA		STJ Annuloplasty	SCA	SCA	SCA

FIGURE 1. Repair-oriented functional classification of aortic insufficiency *(AI)* with description of disease mechanisms and repair techniques used. *FAA*, Functional aortic annulus; *STJ*, sinotubular junction; *SCA*, subcommissural annuloplasty.

Aortic Root Dilatation at Sinuses of Valsalva and Aortic Regurgitation in Hypertensive and Normotensive Subjects

The Hypertension Genetic Epidemiology Network Study

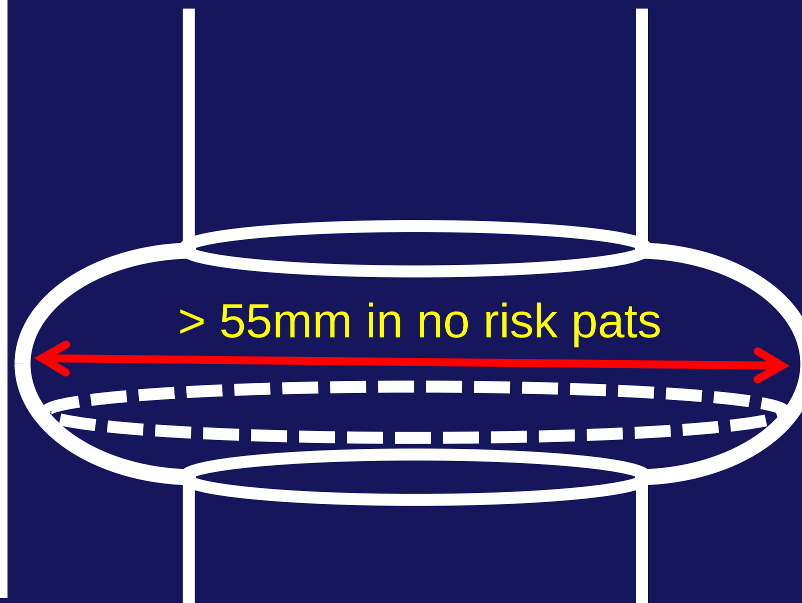
Vittorio Palmieri, Jonathan N. Bella, Donna K. Arnett, Mary J. Roman, Albert Oberman, Dalane W. Kitzman, Paul N. Hopkins, Mary Paranicas, D.C. Rao, Richard B. Devereux

(*Hypertension*. 2001;37:1229-1235.)

TABLE 1. Prevalence of Aortic Root Dilatation at Sinuses of Valsalva Within Subjects Divided According to Hypertension, Diabetes, Gender, Body Size, and Smoking Habit

Categories	Aortic Root Dilatation		Aortic Regurgitation	
Study population	4.6% (n=112)		6.7% (n=165)	
Hypertension				
Yes	4.2%		6.6%	
No	5.8%	*P*=NS	6.9%	*P*=NS
Diabetes				
Yes	4.2%		6.9%	
No	4.6%	*P*=NS	6.5%	*P*=NS
Men	8.3%		7.0%	
Women	2.0%	*P*<0.001	6.4%	*P*=NS
Normal body weight	7.0%		9.1%	
Overweight	3.4%	*P*<0.001	5.5%	*P*<0.005
Smoker	5.3%		7.0%	
Never smoked	3.8%	*P*=NS	6.3%	*P*=NS

2096 hypertensive participants
361 normotensive participants



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Aortic root dilatation of the sinuses is correlated with

- **Calcified AV**
- **Left ventricular motion abnormalities**
- **male gender**

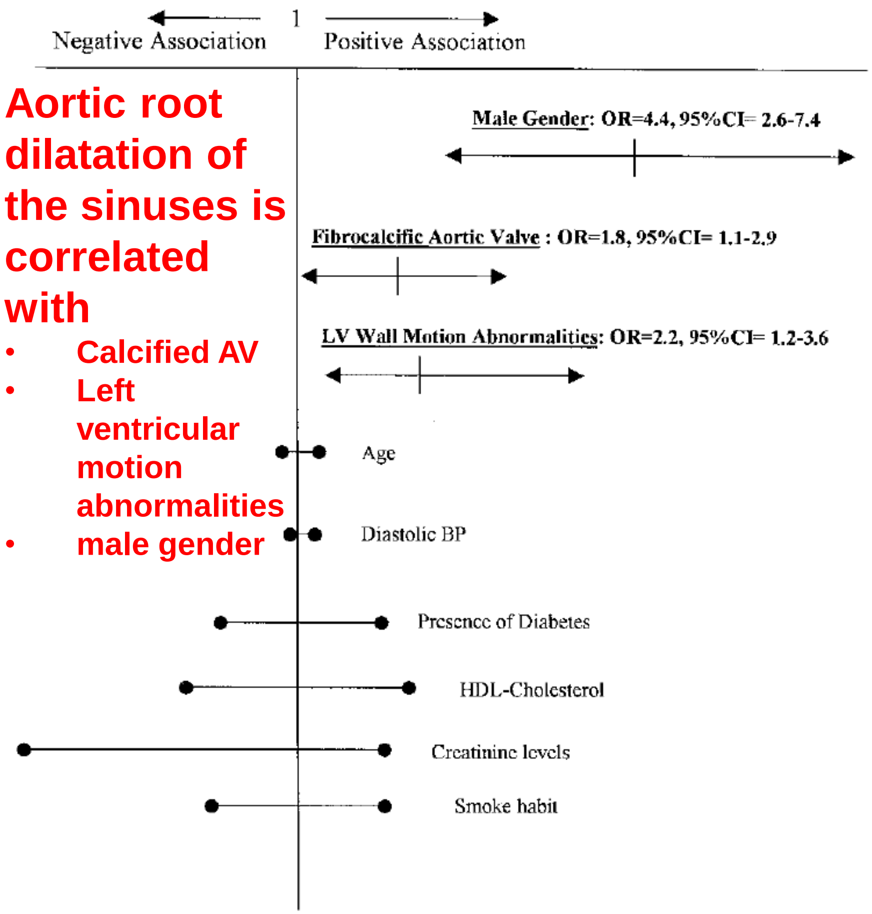
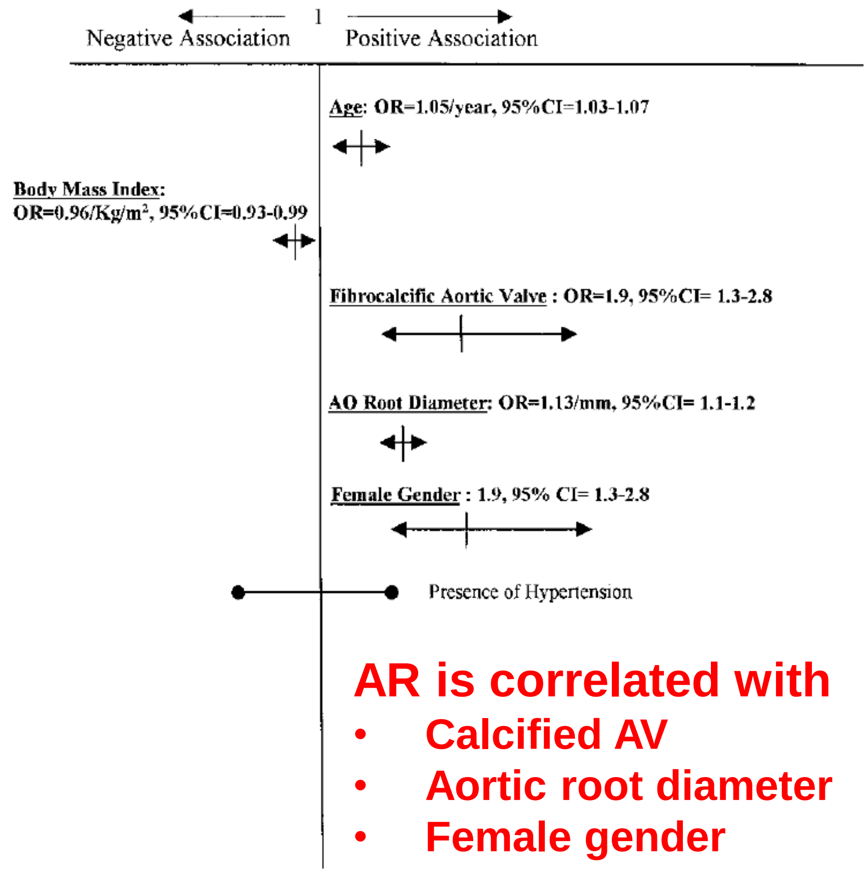


Figure 1. Correlates of aortic root dilatation at sinuses of Valsalva. Adjusted OR and 95% CI, derived by multivariate logistic regression analysis, are reported for variables associated with aortic root dilatation at sinuses of Valsalva. Statistical significance is indicated by horizontal lines not crossing the vertical line.



AR is correlated with

- **Calcified AV**
- **Aortic root diameter**
- **Female gender**

Figure 2. Correlates of aortic regurgitation. Adjusted OR and 95% CI, derived by multivariate logistic regression analysis, are reported for variables associated with aortic regurgitation. Statistical significance is indicated by horizontal lines not crossing the vertical line.

according to Palmieri et al., Hypertension 2001;37:1229-1235

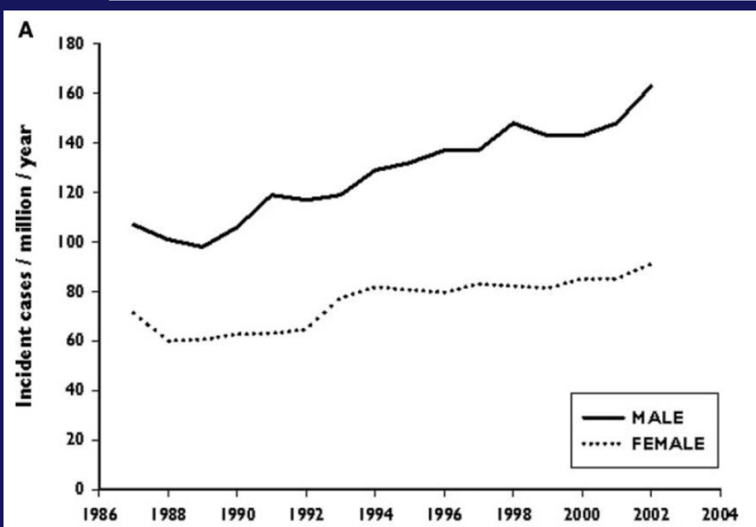
Epidemiology

Thoracic Aortic Aneurysm and Dissection

Increasing Prevalence and Improved Outcomes Reported in a Nationwide Population-Based Study of More Than 14 000 Cases From 1987 to 2002

Christian Olsson, MD; Stefan Thelin, MD, PhD; Elisabeth Ståhle, MD, PhD;
Anders Ekbom, MD, PhD; Fredrik Granath, PhD

Conclusions—The prevalence and incidence of thoracic aortic disease was higher than previously reported and increasing. The annual number of operations increased substantially. Surgical (30-day) and long-term survival improved significantly over time to form a growing cohort of patients needing counseling, management decisions, operations, and extended postoperative surveillance. (***Circulation*. 2006;114:2611-2618.**)



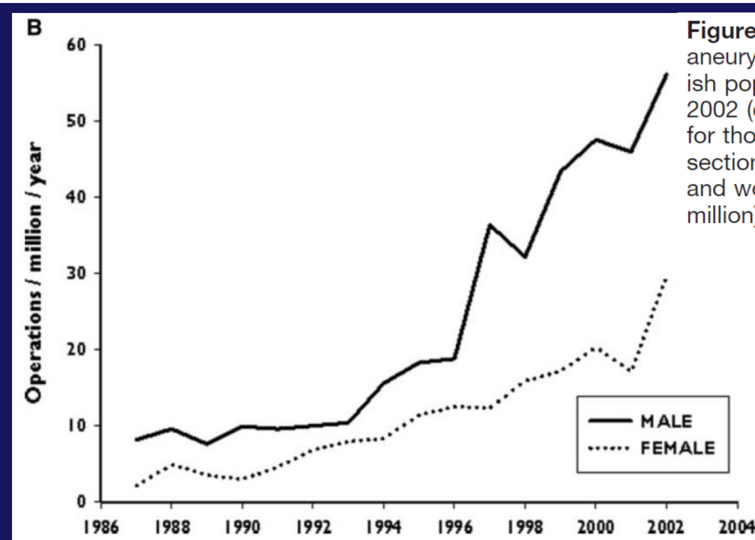


Figure 1. A, Incidence of thoracic aortic aneurysms and dissection in the Swedish population (men and women), 1987–2002 (cases per million). B, Operations for thoracic aortic aneurysms and dissection in the Swedish population (men and women), 1987–2002 (operations per million).

Incidence of thoracic aortic disease:
16.3 per 100.000 per year in men and 9.1 per 100.000 per year in women

Two-dimensional transthoracic echocardiographic normal reference ranges for proximal aorta dimensions: results from the EACVI NORRE study

European Heart Journal – Cardiovascular Imaging
doi:10.1093/ehjci/jew053

Daniel Saura[1], Raluca Dulgheru[2], Luis Caballero[1], Anne Bernard[2,3], Seisyou Kou[4], Natalia Gonjilashvili[5], George D. Athanassopoulos[6], Daniele Barone[7], Monica Baroni[8], Nuno Cardim[9], Andreas Hagendorff[10], Krasimira Hristova[11], Teresa Lopez[12], Gonzalo de la Morena[1], Bogdan A. Popescu[13], Martin Penicka[14], Tolga Ozyigit[15], Jose David Rodrigo Carbonero[16], Nico Van De Veire[17], Ralph Stephan Von Bardeleben[18], Dragos Vinereanu[19], Jose Luis Zamorano[20], Ann-Stephan Gori[2], Bernard Cosyns[21,22], Erwan Donal[23], Gilbert Habib[24,25], Karima Addetia[26], Roberto M. Lang[26], Luigi P. Badano[27], and Patrizio Lancellotti[2,28]*

To report normal reference ranges for echocardiographic dimensions of the proximal aorta obtained in a large group of healthy volunteers recruited using state-of-the-art cardiac ultrasound equipment, considering different measurement conventions, and taking into account gender, age, and body size of individuals.

A total of 704 (mean age: 46.0 ± 13.5 years) healthy volunteers (310 men and 394 women) were prospectively recruited from the collaborating institutions of the Normal Reference Ranges for Echocardiography (NORRE) study.

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- Epidemiology and Guidelines -

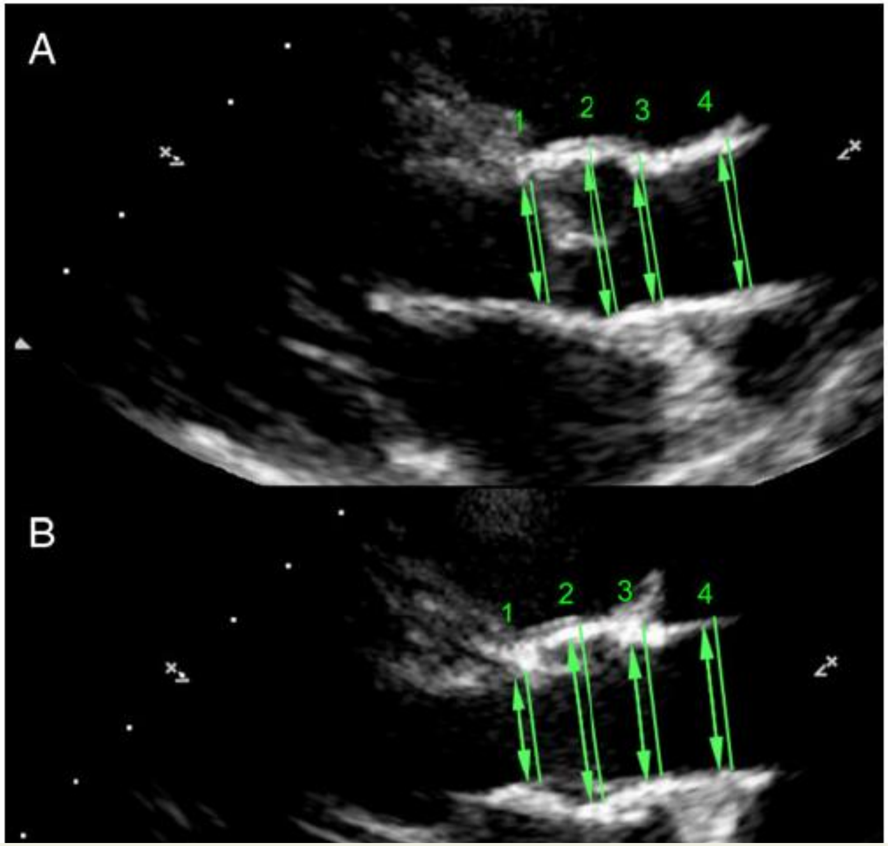


Figure 1 Echocardiographic parasternal long-axis views centered in the LVOT and proximal aorta, showing measurement methods. (*A*) End-diastolic image. (*B*) Mid-systolic image. (1) Ventriculo-arterial junction level; (2) sinuses of valsalva level; (3) STJ level; (4) TAA level. Lines ended in arrowheads show inner-edge to inner-edge convention. Lines without specific ending represent leading-edge to leading-edge measurement convention.

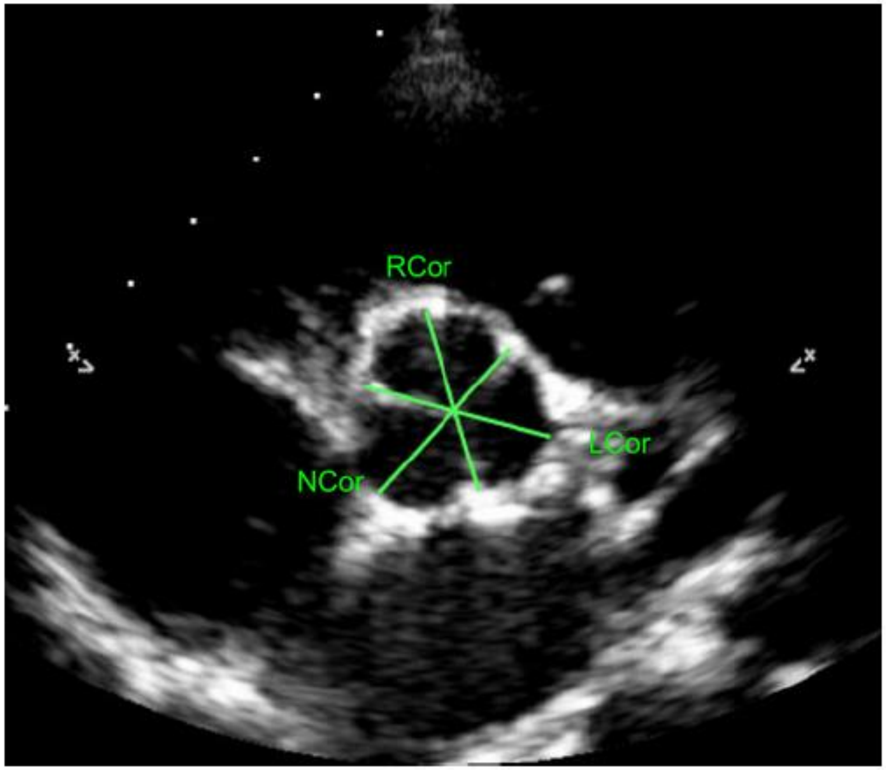


Figure 2 Diastolic still frame of echocardiographic parasternal zoomed short-axis view of aortic root, showing measurement of diameters corresponding to each aortic sinus and the facing commisural line. RCor, right coronary sinus; LCor, left coronary sinus; NCor, non-coronary sinus.

according to Saura et al., Eur Heart J Cardiovasc Img 2016 – doi:10.1093/ehjci/jew053

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Table 3 Proximal aorta echocardiographic measurements indexed by body size

Parameters	Total (n = 704) Mean ± SD	Total (n = 704) IQR	Total (n = 704) 95% CI of mean	Male (n = 310) Mean ± SD	Female (n = 394) Mean ± SD	P^*
Ratios to BSA						
L–L end-diastole						
VAJ/BSA (mm/m²)	11.7 ± 1.8	10.6–12.4	11.6–11.9	11.6 ± 1.8	11.8 ± 1.8	0.34
SV/BSA (mm/m²)	18.0 ± 2.6	16.2–19.1	17.8–18.2	17.9 ± 2.7	18.1 ± 2.6	0.293
STJ/BSA (mm/m²)	15.5 ± 2.4	13.9–16.7	15.3–15.7	15.2 ± 2.5	15.8 ± 2.3	0.004
TAA/BSA (mm/m²)	16.3 ± 2.8	14.4–17.6	16.1–16.5	15.9 ± 2.8	16.6 ± 2.8	0.001
I–I end-diastole						
VAJ/BSA (mm/m²)	11.0 ± 1.8	9.9–11.7	10.8–11.2	10.9 ± 1.7	11.1 ± 1.8	0.363
SV/BSA (mm/m²)	16.8 ± 2.5	15.2–17.9	16.6–16.9	16.7 ± 2.5	16.8 ± 2.4	0.375
STJ/BSA (mm/m²)	14.3 ± 2.3	12.8–15.5	14.1–14.5	14.0 ± 2.3	14.4 ± 2.2	0.009
TAA/BSA (mm/m²)	15.2 ± 2.7	13.3–16.5	15.0–15.4	14.7 ± 2.6	15.5 ± 2.7	<0.001
L–L mid-systole						
VAJ/BSA (mm/m²)	12.4 ± 1.7	11.3–13.0	12.2–12.5	12.1 ± 1.7	12.5 ± 1.7	0.005
SV/BSA (mm/m²)	18.6 ± 2.6	17.0–20.0	18.4–18.8	18.4 ± 2.7	18.8 ± 2.6	0.03
STJ/BSA (mm/m²)	16.1 ± 2.4	14.4–17.2	15.9–16.3	15.8 ± 2.4	16.4 ± 2.4	0.002
TAA/BSA (mm/m²)	17.2 ± 2.8	15.3–18.7	17.0–17.4	16.7 ± 2.8	17.6 ± 2.7	<0.001
I–I mid-systole						
VAJ/BSA (mm/m²)	11.5 ± 1.6	10.5–12.2	11.4–11.7	11.3 ± 1.6	11.7 ± 1.6	0.002
SV/BSA (mm/m²)	17.4 ± 2.5	15.8–18.7	17.2–17.6	17.2 ± 2.6	17.5 ± 2.4	0.07
STJ/BSA (mm/m²)	14.8 ± 2.3	13.3–16.0	14.6–15.0	14.5 ± 2.3	15.1 ± 2.2	<0.001
TAA/BSA (mm/m²)	16.0 ± 2.7	14.2–17.4	15.8–16.2	15.5 ± 2.6	16.4 ± 2.6	<0.001
Short-axis end-diastole						
RCor/BSA (mm/m²)	16.0 ± 2.4	14.4–17.0	15.8–16.2	15.8 ± 2.5	16.1 ± 2.4	0.058
LCor/BSA (mm/m²)	16.1 ± 2.5	14.4–17.4	15.9–16.3	15.7 ± 2.5	16.4 ± 2.5	<0.001
NCor/BSA (mm/m²)	16.1 ± 2.5	14.5–17.4	15.9–16.3	15.8 ± 2.4	16.4 ± 2.6	0.001

Ht, height; BSA, body surface area; SD, standard deviation; IQR, interquartile range; CI, confidence interval; L–L, leading edge to leading edge convention; I–I, inner-edge to inner-edge convention; RCor, diameter of aortic root at the level of the right coronary sinus; LCor, diameter of aortic root at the level of the left coronary sinus; NCor, diameter of aortic root at the level of the non-coronary sinus.
*P differences between male vs. female.

according to Saura et al., Eur Heart J Cardiovasc Img 2016 – doi:10.1093/ehjci/jew053

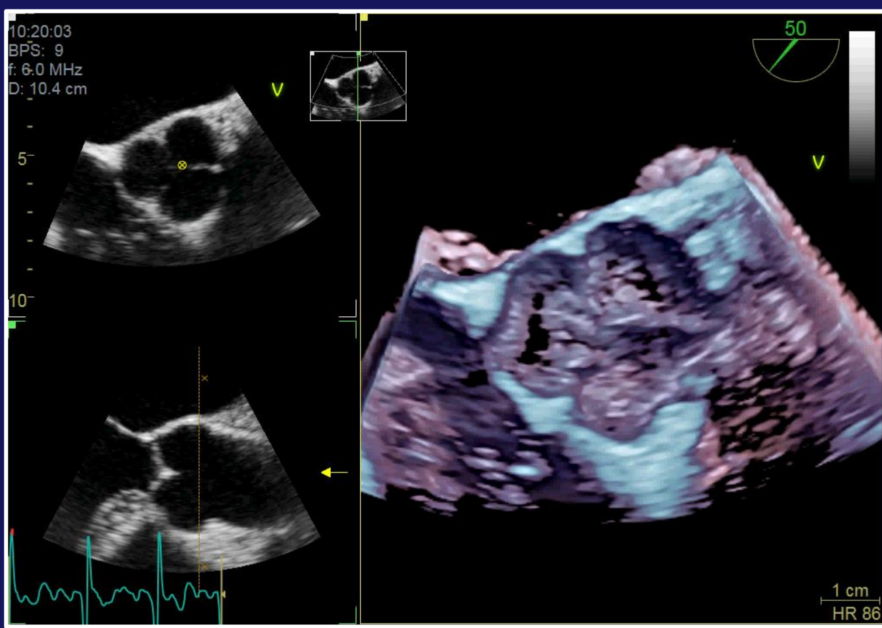
Discussion about echocardio-graphic measurements of the aortic dimensions: leading-edge-to-leading edge or inner-edge-to inner-edge

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

If your image is correct, inner-edge-to-inner edge is correct.

Conclusion

The NORRE study yielded reference ranges for proximal aorta dimensions as assessed by transthoracic echocardiography, based on data of a large population of normal subjects of broad European origin. Normal reference values considering measurement method, time of heart cycle, and anatomical levels are provided. Gender, age, and body size need to be considered, as are major determinants of aortic dimensions.



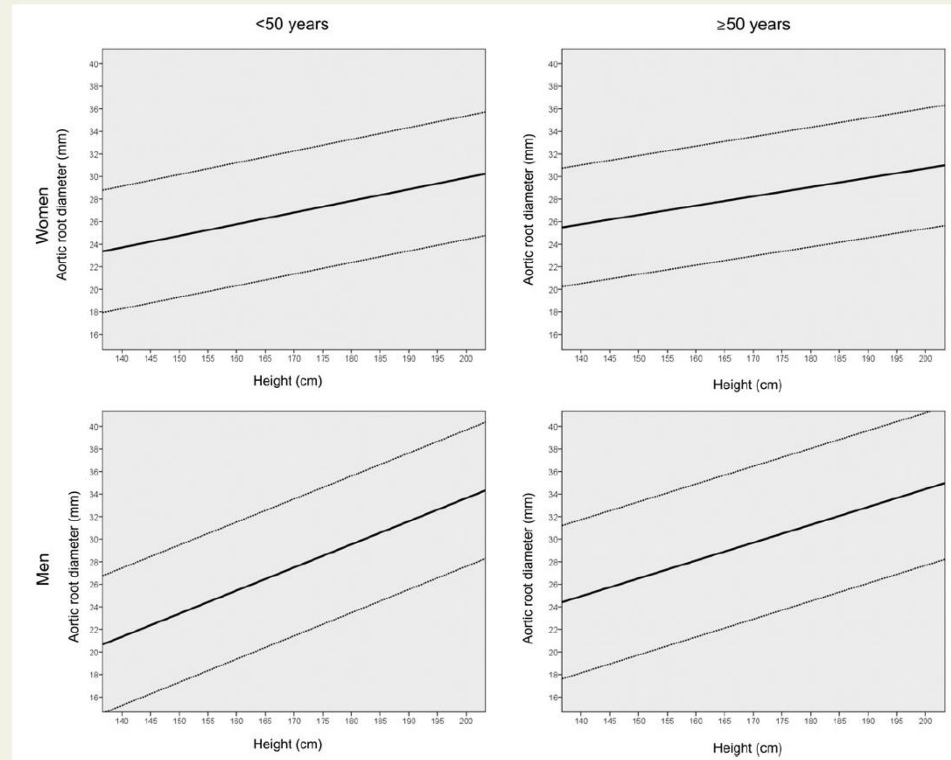


Figure 4 Nomograms of aortic root dimensions (SV level) according to different heights for both genders and two age groups (younger or older than 50 years). X-axis represents height in centimeters. Y-axis represents aortic root diameter in millimeters.

according to Saura et al., Eur Heart J Cardiovasc Img 2016 - doi:10.1093/ehjci/jew053

Echocardiography in aortic diseases: EAE recommendations for clinical practice

European Journal of Echocardiography (2010) **11**, 645–658

Arturo Evangelista[1*], Frank A. Flachskampf[2], Raimund Erbel[3], Francesco Antonini-Canterin[4], Charalambos Vlachopoulos[5], Guido Rocchi[6], Rosa Sicari[7], Petros Nihoyannopoulos[8], and Jose Zamorano[9] on behalf of the European Association of Echocardiography

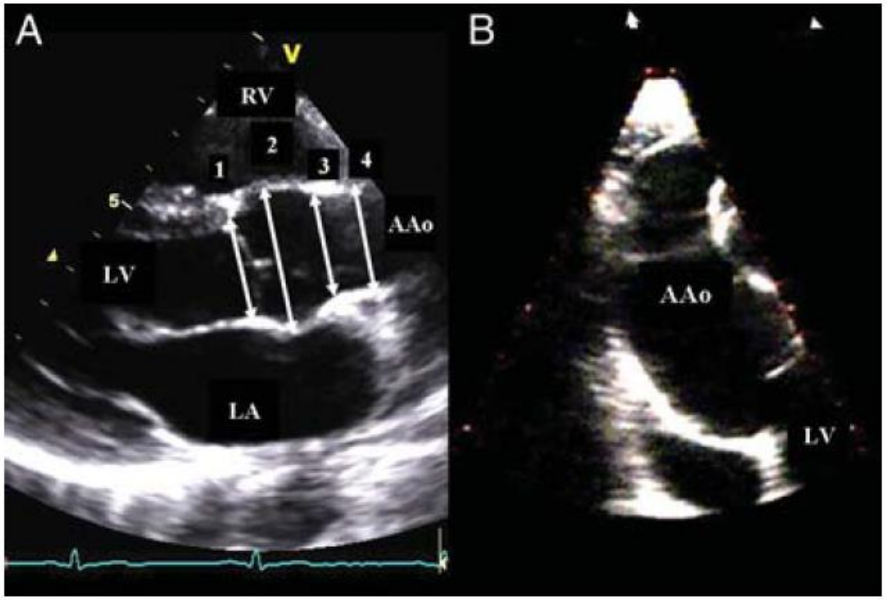
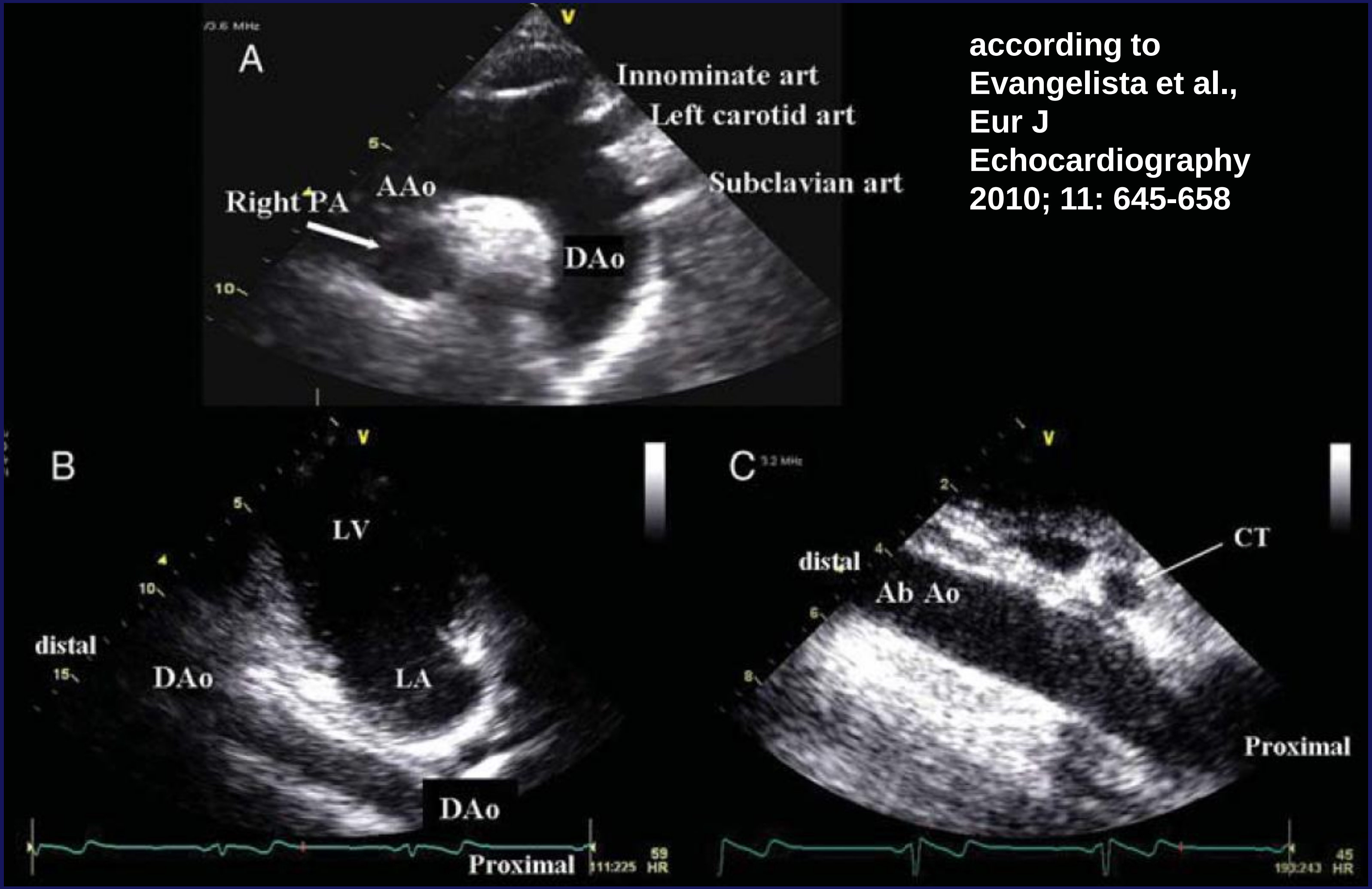


Figure 1 Transthoracic echocardiography. (*A*) Parasternal long-axis view (transthoracic echocardiography). The following diameters are shown: outflow tract diameter (1), sinuses of Valsalva (2), sinotubular junction (3), and tubular ascending aorta (4). (*B*) Right parasternal long-axis view, mid and distal parts of ascending aorta may be visualized. AAo, ascending aorta; LA, left atrium; LV, left ventricle; RV, right ventricle.



according to Evangelista et al., Eur J Echocardiography 2010; 11: 645-658

Figure 2 (*A*) Suprasternal view of aortic arch and supra-aortic great arteries. (*B*) Mid part of the descending thoracic aorta visualized by long-axis view from apical window. (*C*) Abdominal aorta visualized by subcostal view. In non-obese patients, it is not difficult to visualize distal abdominal aorta. art, artery; PA, pulmonary artery; AAo, ascending aorta; DAo, descending aorta; CT, coeliac trunk.

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Table 1 **Echocardiographic views of the aorta**

View	Part of aorta
Transthoracic echo	
Parasternal long + short axis	Ascending + descending thoracic
Apical four-chamber	Descending thoracic
Apical two-chamber and/or long axis	Descending thoracic
Suprasternal	Arch, descending + ascending thoracic
Subcostal	Abdominal (+ascending thoracic)
Transoesophageal echo	
Upper oesophageal long + short axis	Ascending thoracic
Aortic (long + short axis)	Descending thoracic + arch

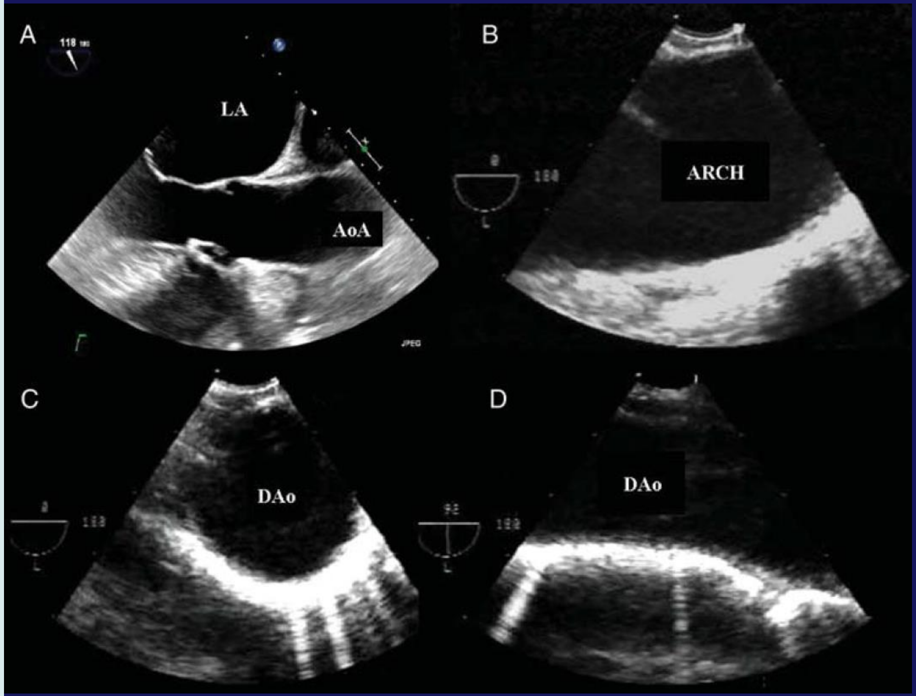
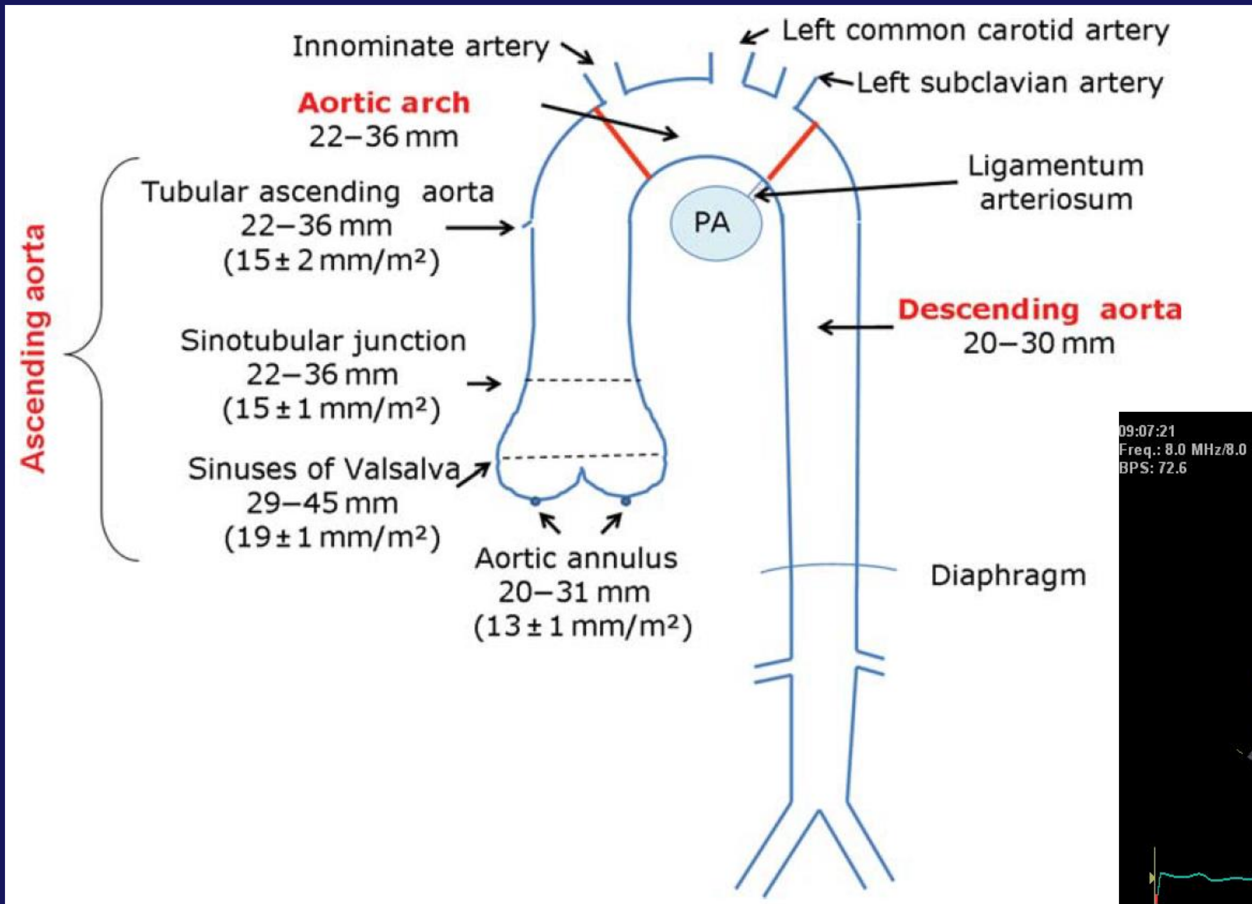


Figure 3 Transoesophageal echocardiography. (*A*) Ascending aorta in long-axis view at 120°. (*B*) Aortic arch in transverse view. (*C*) Descending aorta visualized by transverse view. (*D*) Descending aorta visualized by longitudinal view.

according to Evangelista et al.,
Eur J Echocardiography 2010; 11: 645-658

Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

according to Evangelista et al., Eur J Echocardiography 2010; 11: 645-658



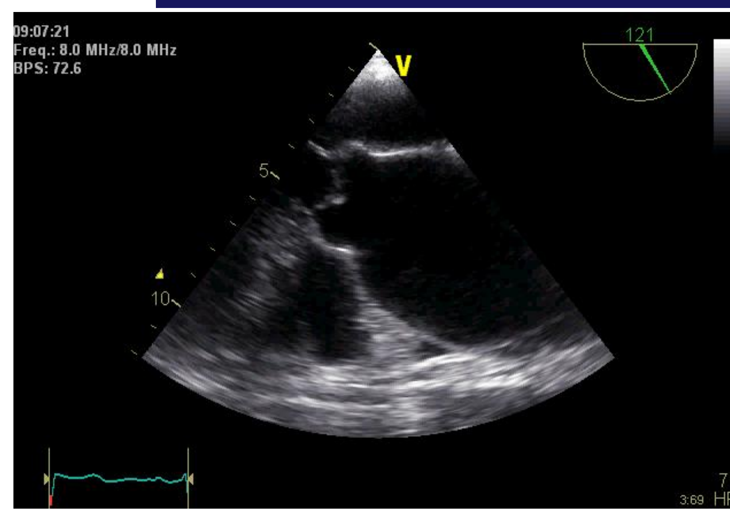


Figure 4 Normal size of thoracic aortic segments. The thoracic aorta can be divided into three segments: the ascending aorta that extends from the aortic annulus to the innominate artery and is typically measured at the level of the aortic annulus, the sinuses of Valsalva, the sinotubular junction, and the proximal (tubular) ascending aorta; the aortic arch that extends from the innominate artery to the ligamentum arteriosum; and the descending aorta that extends from the ligamentum arteriosum to the level of the diaphragm. PA, right pulmonary artery. Modified from Diseases of the aorta. In: Feigenbaum H, Armstrong WF, Ryan T, eds. *Feigenbaum's Echocardiography*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2005. p673; Ascending aorta values from Erbel *et al.*[46]

GUIDELINES AND STANDARDS

Multimodality Imaging of Diseases of the Thoracic Aorta in Adults: From the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Endorsed by the Society of Cardiovascular Computed Tomography and Society for Cardiovascular Magnetic Resonance

Steven A. Goldstein, MD, Co-Chair, Arturo Evangelista, MD, FESC, Co-Chair, Suhny Abbara, MD, Andrew Arai, MD, Federico M. Asch, MD, FASE, Luigi P. Badano, MD, PhD, FESC, Michael A. Bolen, MD, Heidi M. Connolly, MD, Hug Cuéllar-Calàbria, MD, Martin Czerny, MD, Richard B. Devereux, MD, Raimund A. Erbel, MD, FASE, FESC, Rossella Fattori, MD, Eric M. Isselbacher, MD, Joseph M. Lindsay, MD, Marti McCulloch, MBA, RDCS, FASE, Hector I. Michelena, MD, FASE, Christoph A. Nienaber, MD, FESC, Jae K. Oh, MD, FASE, Mauro Pepi, MD, FESC, Allen J. Taylor, MD, Jonathan W. Weinsaft, MD, Jose Luis Zamorano, MD, FESC, FASE, Contributing Editors: Harry Dietz, MD, Kim Eagle, MD, John Elefteriades, MD, Guillaume Jondeau, MD, PhD, FESC, Hervé Rousseau, MD, PhD, and Marc Schepens, MD, *Washington, District of Columbia; Barcelona and Madrid, Spain; Dallas and Houston, Texas; Bethesda and Baltimore, Maryland; Padua, Pesaro, and Milan, Italy; Cleveland, Ohio; Rochester, Minnesota; Zurich, Switzerland; New York, New York; Essen and Rostock, Germany; Boston, Massachusetts; Ann Arbor, Michigan; New Haven, Connecticut; Paris and Toulouse, France; and Brugge, Belgium*

(J Am Soc Echocardiogr 2015;28:119-82.)

Aortic Regurgitation and Aortic Aneurysm
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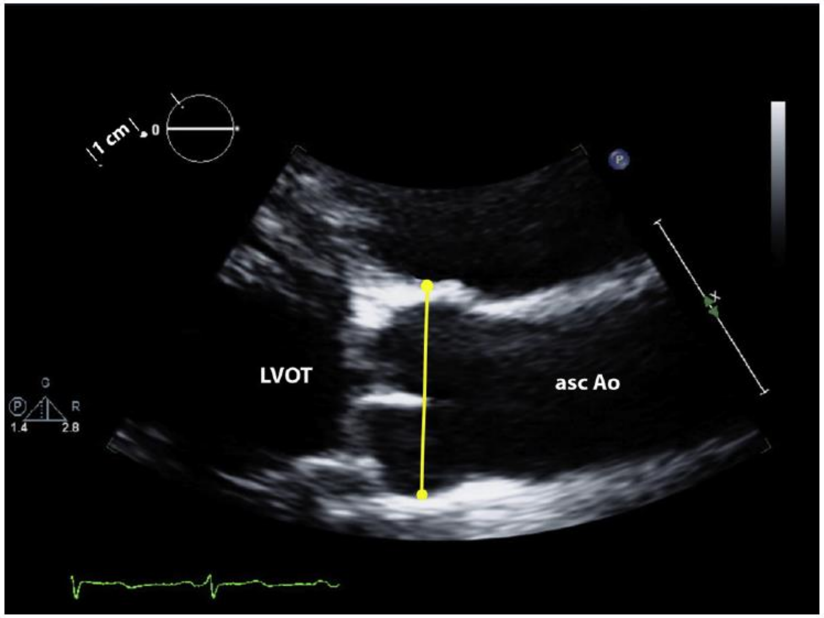

Figure 2 Transthoracic echocardiogram in the parasternal long-axis view (zoomed on aortic root and ascending aorta) illustrating measurement of the aortic root diameter at sinus of Valsalva level at end-diastole using the leading edge–to–leading-edge method. *asc Ao*, Ascending aorta; *LVOT*, left ventricular outflow tract.

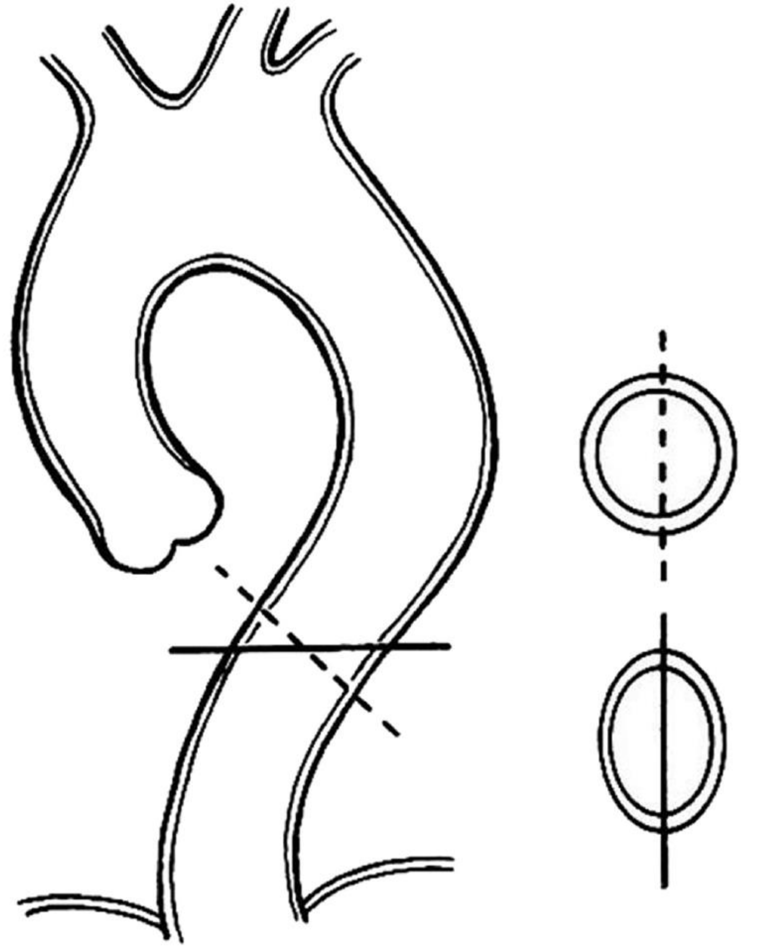

Figure 9 Diagram illustrating the potential pitfall of obtaining an oblique cut resulting in an "ellipsoid" cross-section that overestimates the true diameter. This is especially a problem when the descending aorta is tortuous.

according to Goldstein et al.,
J Am Soc Echocardiogr 2015; 28: 119-182

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

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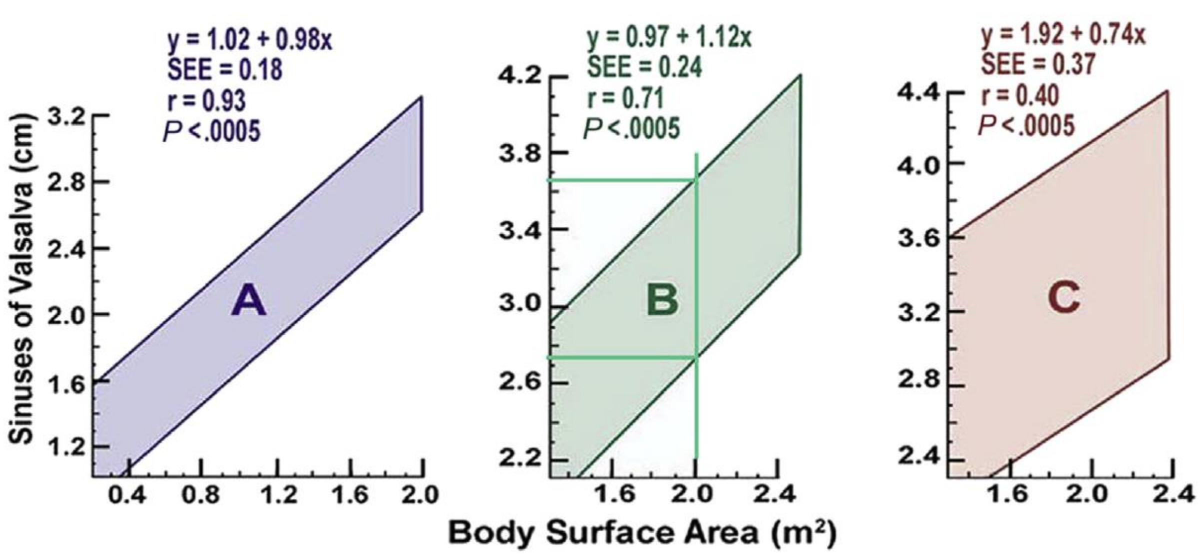


Figure 3 Aortic root diameter (*vertical axis*) in relation to BSA (*horizontal axis*) in apparently normal individuals aged 1 to 15 (*left panel, blue*), 20 to 39 (*center panel, green*), and ≥40 (*right panel, pink*) years. For example, an individual between the ages of 20 and 39 years (*center panel, green*) who has a BSA of 2.0 m^2 (*vertical green line*) has a normal root diameter range (2 SDs) between 2.75 and 3.65 cm, as indicated by the intersections of the *two horizontal green lines* with the *green-shaded* parallelogram.

Table 1 Normal aortic root diameter by age for men with BSA of 2.0 m^2

	Age (y)					
	15–29	30–39	40–49	50–59	60–69	≥70
Mean normal (cm)	3.3	3.4	3.5	3.6	3.7	3.8
Upper limit of normal (cm) (95% CI)	3.7	3.8	3.9	4.0	4.1	4.2

Add 0.5 mm per 0.1 m^2 BSA above 2.0 m^2 or subtract 0.5 mm per 0.1 m^2 BSA below 2.0 m^2.[6]
CI, Confidence interval.

Table 2 Normal aortic root diameter by age for women with BSA of 1.7 m^2

	Age (y)					
	15–29	30–39	40–49	50–59	60–69	≥70
Mean normal (cm)	2.9	3.0	3.2	3.2	3.3	3.4
Upper limit of normal (cm)	3.3	3.4	3.6	3.6	3.7	3.9

Add 0.5 mm per 0.1 m^2 BSA above 1.7 m^2 or subtract 0.5 mm per 0.1 m^2 BSA below 1.7 m^2.[6]

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Measurements of the Aortic Root: during diastole or duringf systole?
In the actual recommendation (EACVI 2010 and 2013) measurements should be performed during systole – dimensions are larger during systole than during diastole

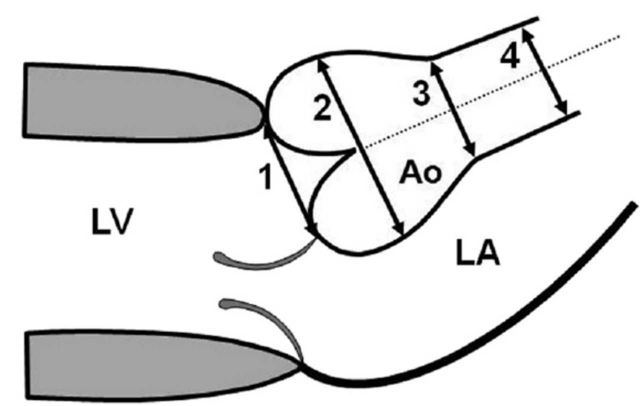


Figure 10 Sites for measurements of the aortic root and ascending aorta. This diagram illustrates the four sites at which measurements are recommended: 1 = aortic valve annulus (hinge point of aortic leaflets), 2 = aortic root at sinuses of Valsalva (maximal diameter, usually midpoint), 3 = STJ, 4 = proximal tubular portion of the ascending aorta. *Ao*, Aorta; *LA*, left atrium; *LV*, left ventricle.

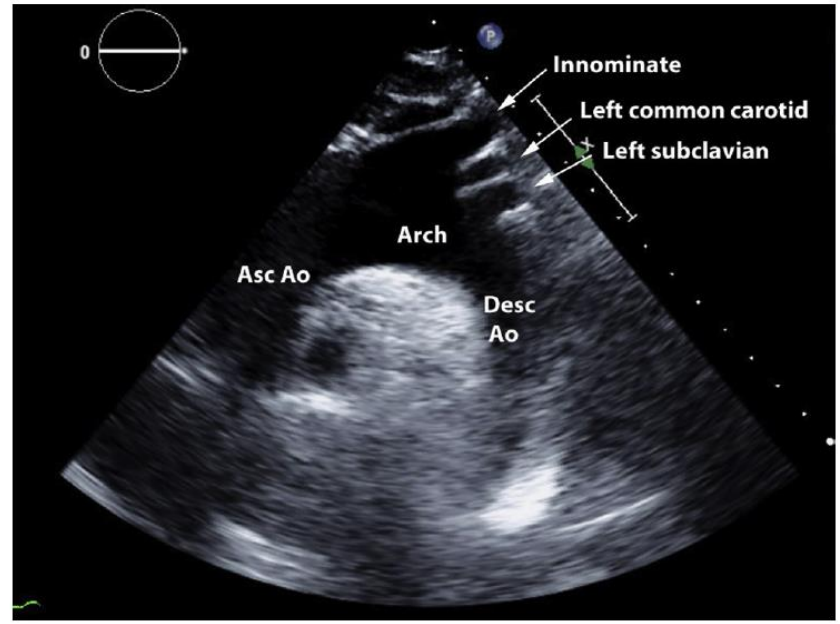


Figure 11 Transthoracic echocardiographic suprasternal notch view of the distal ascending aorta (Asc Ao), aortic arch, supra-aortic vessels (*arrows*), and proximal descending thoracic aorta (Desc Ao).

according to Goldstein et al., J Am Soc Echocardiogr 2015; 28: 119-182

Ascending Aortic Dilatation Associated With Bicuspid Aortic Valve

Pathophysiology, Molecular Biology, and Clinical Implications

Thomas M. Tadros, MD, MPH; Michael D. Klein, MD; Oz M. Shapira, MD

(*Circulation*. 2009;119:880-890.)

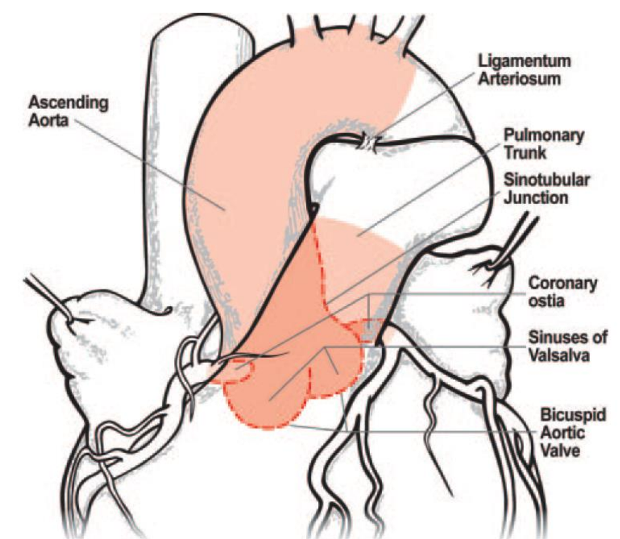


Figure 1. Schematic diagram of the anatomic boundaries of BAV disease. The structures involved in BAV disease (highlighted in pink) include the aortic valve; aortic annulus (not labeled); sinuses of Valsalva; sinotubular junction; ascending aorta; aortic arch; pulmonary trunk; and coronary ostia.

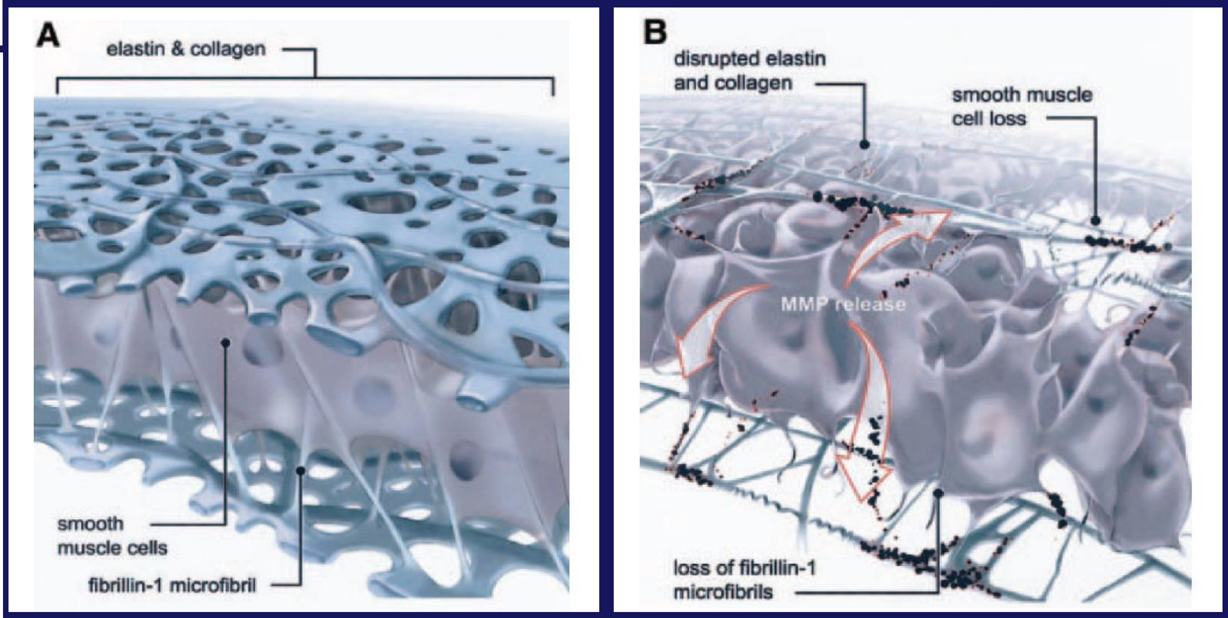
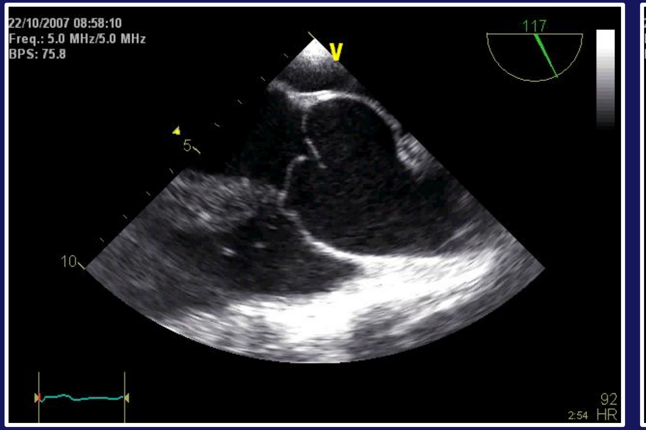


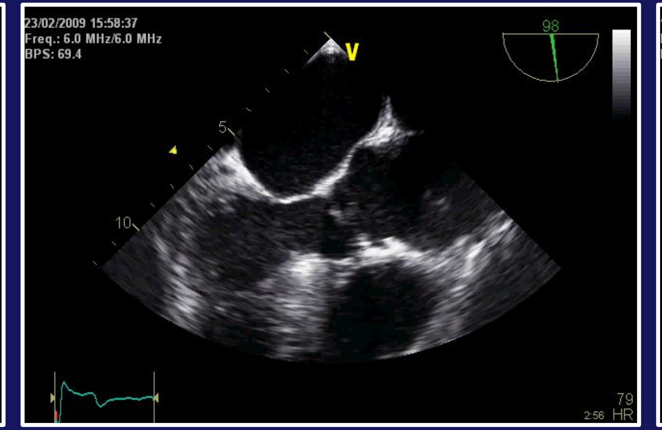
Figure 3. Schematic diagram of the ascending aortic media. In a normal aorta with TAV (A), fibrillin-1 microfibrils tether VSMCs to adjacent elastin and collagen matrix components. In patients with BAV (B), deficiency of fibrillin-1 leads to VSMC detachment, MMP release, matrix disruption, and apoptosis of VSMCs, resulting in loss of structural support and elasticity. Reprinted from Fedak et al,[42] with permission from Lippincott Williams & Wilkins. Copyright 2002, American Heart Association.

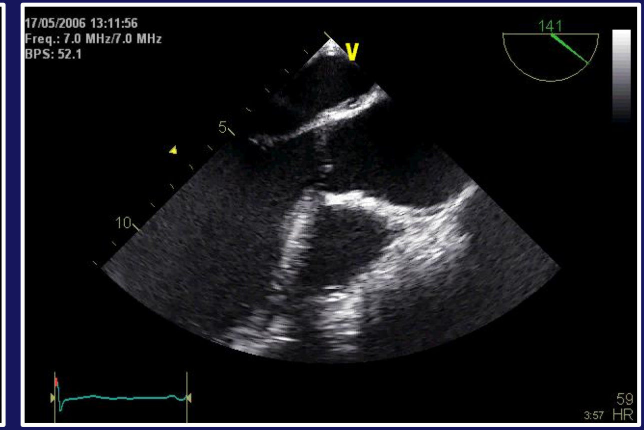
Bicuspid Aortic Cusp Fusion Morphology Alters Aortic Three-Dimensional Outflow Patterns, Wall Shear Stress, and Expression of Aortopathy

Riti Mahadevia, MD; Alex J. Barker, PhD; Susanne Schnell, PhD; Pegah Entezari, MD; Preeti Kansal, MD; Paul W.M. Fedak, MD; S. Chris Malaisrie, MD; Patrick McCarthy, MD; Jeremy Collins, MD; James Carr, MD; Michael Markl, PhD

Conclusions—The presence and type of BAV fusion was associated with changes in regional wall shear stress distribution, systolic flow eccentricity, and expression of BAV aortopathy. Hemodynamic markers suggest a physiological mechanism by which the valve morphology phenotype can influence phenotypes of BAV aortopathy. (***Circulation*. 2014;129:673-682.**)







Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

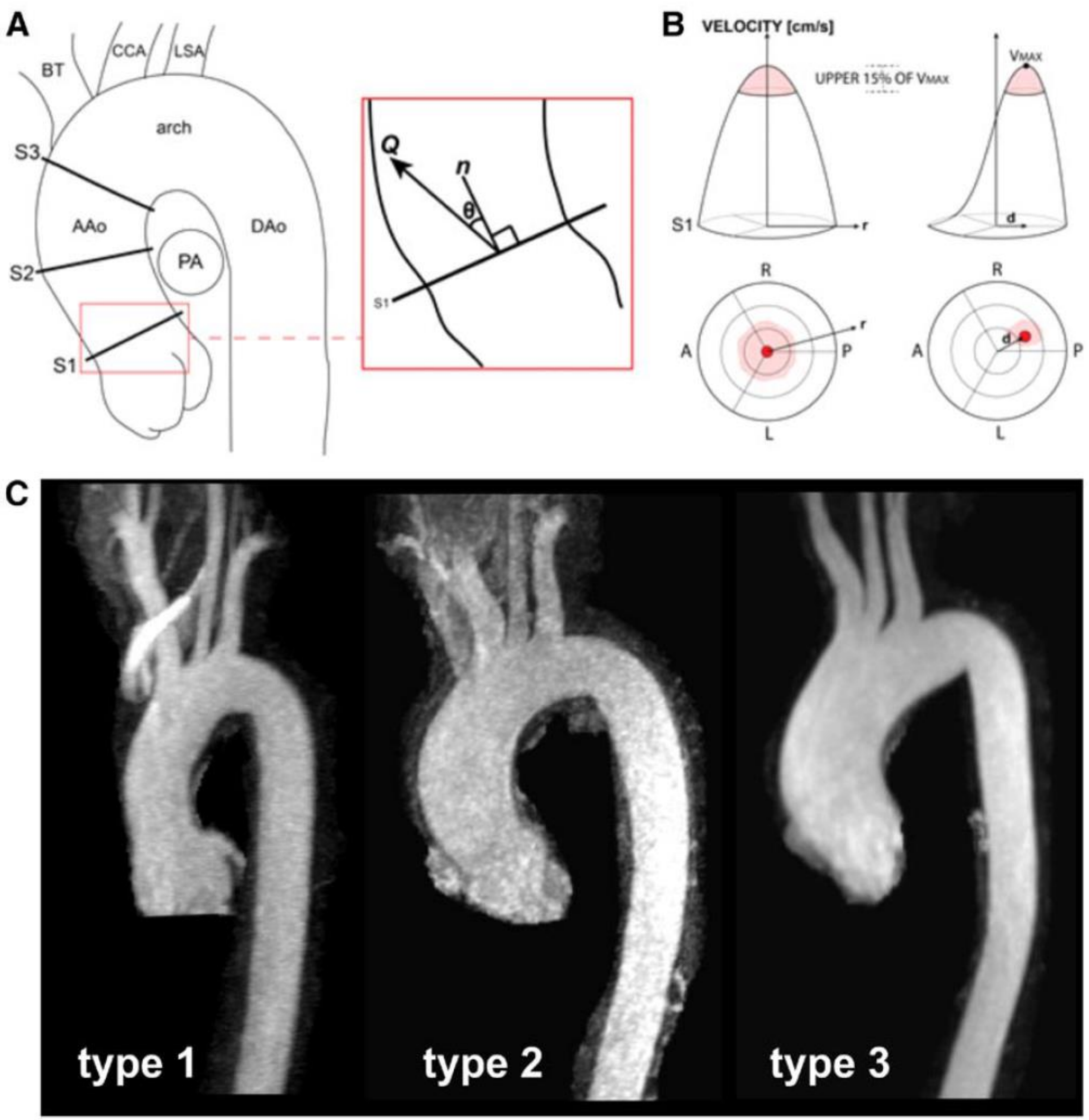


Figure 1. A, Quantification of ascending aorta (AAo) hemodynamics in 3 analysis planes (S1, S2, S3) to compute the systolic flow angle, θ, between the net systolic flow, *Q*, and unit normal vector, n. **B,** The location of the top 15% of velocities at peak systole was mapped onto an aortic lumen chart. A symmetrical flow profile is reflected by a central location of the maximum velocities (red-shaded area) with the highest velocity (V_{Max}) at the center of the vessel. Flow profile asymmetry results in an off-center location of the top 15% of velocities. The flow displacement, *d*, was calculated as the distance (in millimeters) from the vessel centroid to the velocity-weighted centroid. **C,** Example images illustrating the 3 different aortopathy types in our patient cohort. A indicates anterior; BT, brachiocephalic trunk; CCA, common carotid artery; DAo, descending aorta; L, left; LSA, left subclavian artery; P, posterior; PA, pulmonary artery; and R, right.

according to Mahadevia et al., Circulation 2014; 129:673-682

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

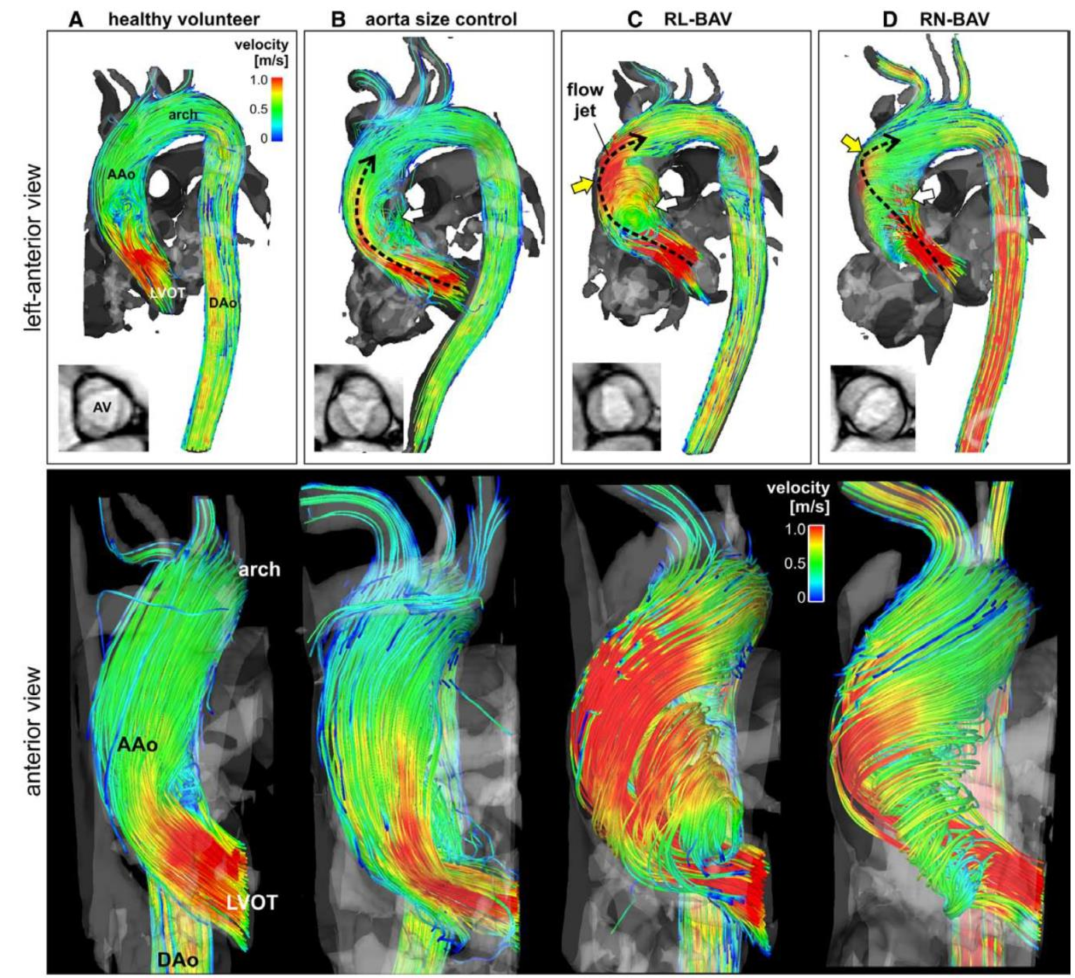
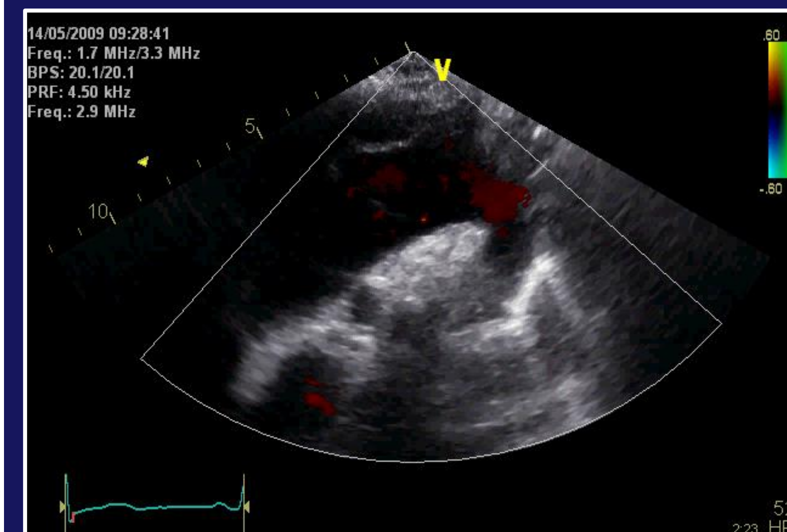


Figure 2. Top, 3D streamline visualization of peak systolic blood flow in patients with BAV (**C** and **D**) in comparison with an aorta size–matched control subject (**B**) and a healthy volunteer (**A**). Note the presence of distinctly different 3D outflow flow jet patterns (black dashed arrows) in the ascending aorta (AAo) for patients **B** and **C**. **Bottom,** 3D flow patterns in the left ventricular outflow tract (LVOT) an AAo distal to the aortic valve. Note the different systolic aortic valve outflow flow jet patterns (red indicating high velocities > 1 m/s) and wall impingement zones that correspond to variable exertion of high wall shear forces between different valve groups (**C** and **D**) and aorta size–matched controls (**B**) and healthy volunteers (**A**). BAV indicates bicuspid aortic valve; RL, right and left coronary leaflet; and RN, righ and noncoronary leaflet.

Conclusion

Our study shows that the presence and type of BAV fusion was associated with changes in regional WSS distribution, systolic outflow asymmetry, and the expression of BAV aortopathy. Of the parameters measured, flow displacement was most sensitive to differences in BAV aortopathy phenotype and may represent a new and easily accessible metric for the quantification of hemodynamic abnormalities in aortic valve disease. Future longitudinal studies are warranted to evaluate the impact of BAV valve morphology and the associated hemodynamic alterations in determining the risk for aortopathy development and progression.



according to Mahadevia et al., Circulation 2014; 129:673-682

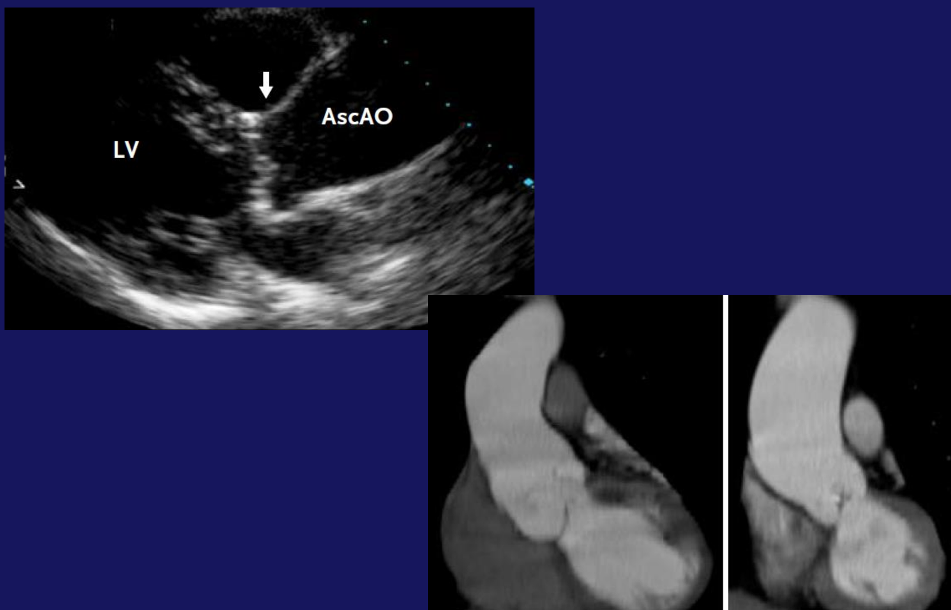
Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Aortic Dilatation in Patients with Bicuspid Aortic Valve

N Engl J Med 2014;370:1920-9.

Subodh Verma, M.D., Ph.D., and Samuel C. Siu, M.D.

B Echocardiographic and magnetic resonance examples of bicuspid aortopathy



A Patterns of bicuspid aortopathy

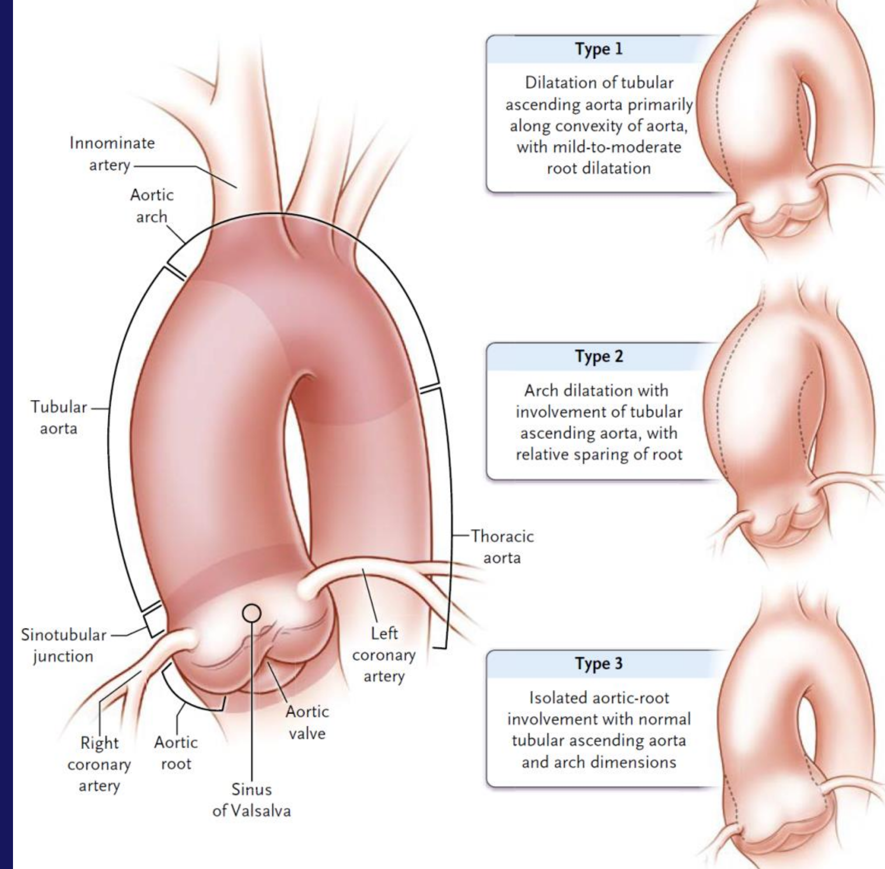


Figure 1. Patterns of Bicuspid Aortopathy, with Representative Findings on Echocardiography and Computed Tomography (CT).

Panel A shows the biologic features of the aorta and the three types of bicuspid aortopathy. The transthoracic echocardiogram at the left in Panel B shows normal dimensions of the sinuses of Valsalva (arrow) and a dilated ascending aorta. AscAO denotes proximal ascending aorta, and LV left ventricle. The CT images in the middle and at the right show dilatation of the aortic root and dilatation of the ascending aorta and proximal arch, respectively.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

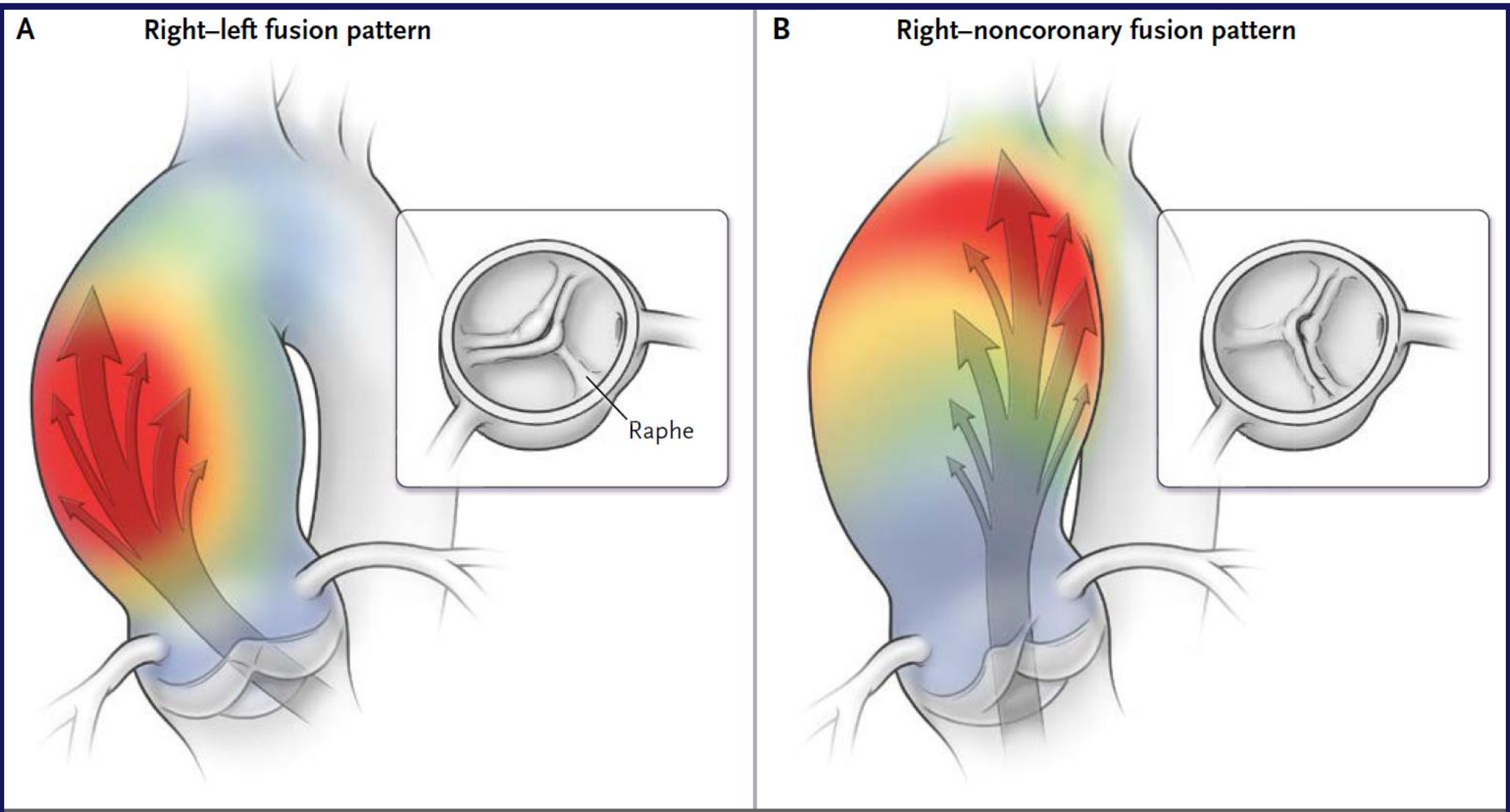


Figure 3. Morphologic Features of the Bicuspid Aortic Valve That Influence the Pattern of Aortopathy.

The fusion configuration of the aortic-valve cusps lays the foundation for changes in aortic wall shear stress and the resultant flow pattern. In the right–left fusion pattern (Panel A), the jet is directed toward the right anterior wall of the ascending aorta, where it travels in a right-handed helical direction to promote dilatation predominantly of the ascending aorta. In the pattern with fusion of the right and noncoronary cusps (Panel B), the jet is directed toward the posterior wall of the aorta, whereby the pattern of wall shear stress it causes may promote aortic dilatation within the proximal arch. Further details regarding the influence of morphologic features of bicuspid aortic valve on patterns of aortopathy are provided in Figure S1 in the Supplementary Appendix.

according to Verma and Siu, N Engl J Med 2014; 370:1920-1928

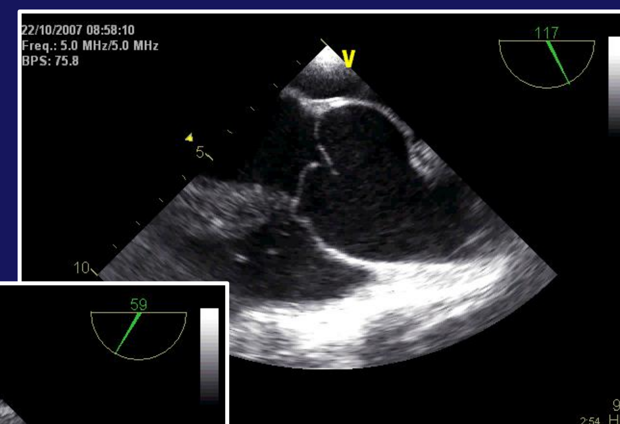
Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Aortic regurgitation | Indications for surgery

B. Indications for surgery in aortic root disease (whatever the severity of AR)			
Surgery is indicated in patients who have aortic root disease with maximal ascending aortic diameter[e] ≥50 mm for patients with Marfan syndrome.	I	C	
Surgery should be considered in patients who have aortic root disease with maximal ascending aortic diameter: ≥45 mm for patients with Marfan syndrome with risk factors[f] ≥50 mm for patients with bicuspid valve with risk factors[g] ≥55 mm for other patients	IIa	C	

The rationale for surgery in patients with ascending aortic and root dilatation has been best defined in Marfan patients. In borderline cases, the individual and family history, the patient's age, and the anticipated risk of the procedure should be taken into consideration. In patients with Marfan syndrome, surgery should be performed with a lesser degree of dilatation (≥50 mm). In previous guidelines, surgery was considered when aortic diameter was >45 mm. The rationale for this aggressive approach is not justified by clinical evidence in all patients. However, in the presence of risk factors (family history of dissection, size increase >2 mm/year in repeated examinations using the same technique and confirmed by another technique; severe AR; desire to become pregnant), surgery should be considered for a root diameter ≥45 mm.[61]

according to Vahanian et al., Eur Heart J 2012; 33: 2451-2496



Aortic Regurgitation and Aortic Aneurysm - Epidemiology and Guidelines -

Aortic dilatation patterns and rates in adults with bicuspid aortic valves: a comparative study with Marfan syndrome and degenerative aortopathy

Delphine Detaint,[1,2] Hector I Michelena,[3] Vuyisile T Nkomo,[3] Alec Vahanian,[1,4] Guillaume Jondeau,[1,2,4] Maurice Enriquez Sarano[3]

Conclusions In patients with BAV, tubular ascending aorta dilatation is the most common pattern and exhibits the fastest growing rate, irrespective of valve morphology and function. Dilatation of the Valsalva sinuses is less common and associated with typical BAV morphology and male gender. Aortic dilatation progresses equally fast in BAV (tubular segment) and MFS (Valsalva sinuses), but a significantly higher proportion of BAV patients does not progress at all, irrespective of BAV type. Baseline aortic diameter does not proportionally predict progression rate; systematic follow-up is therefore warranted in patients with BAV.

according to Detaint et al., Heart 2010; 100: 126-134

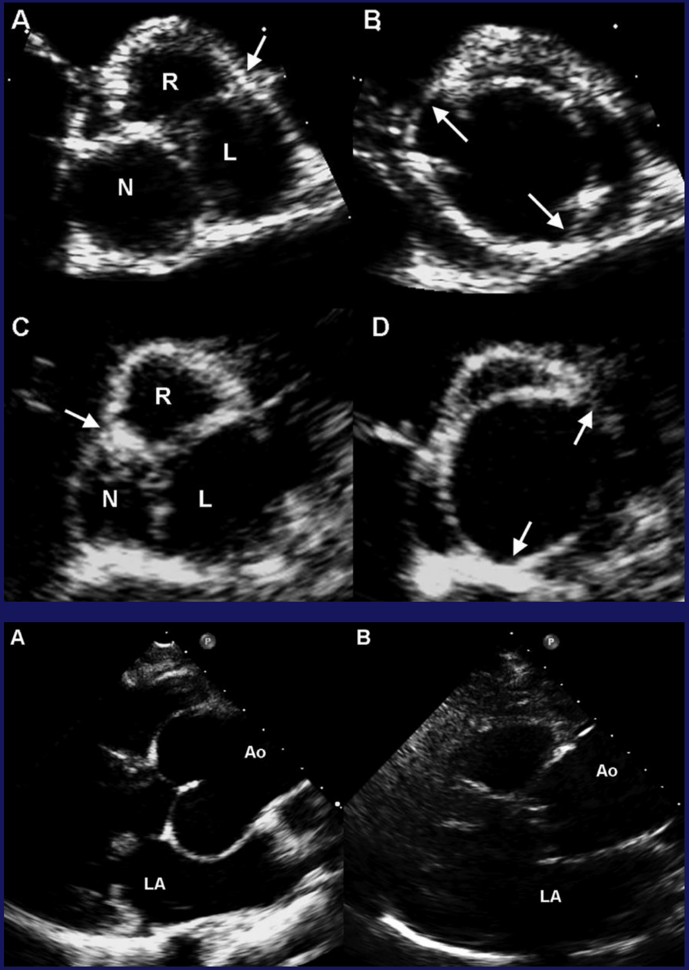
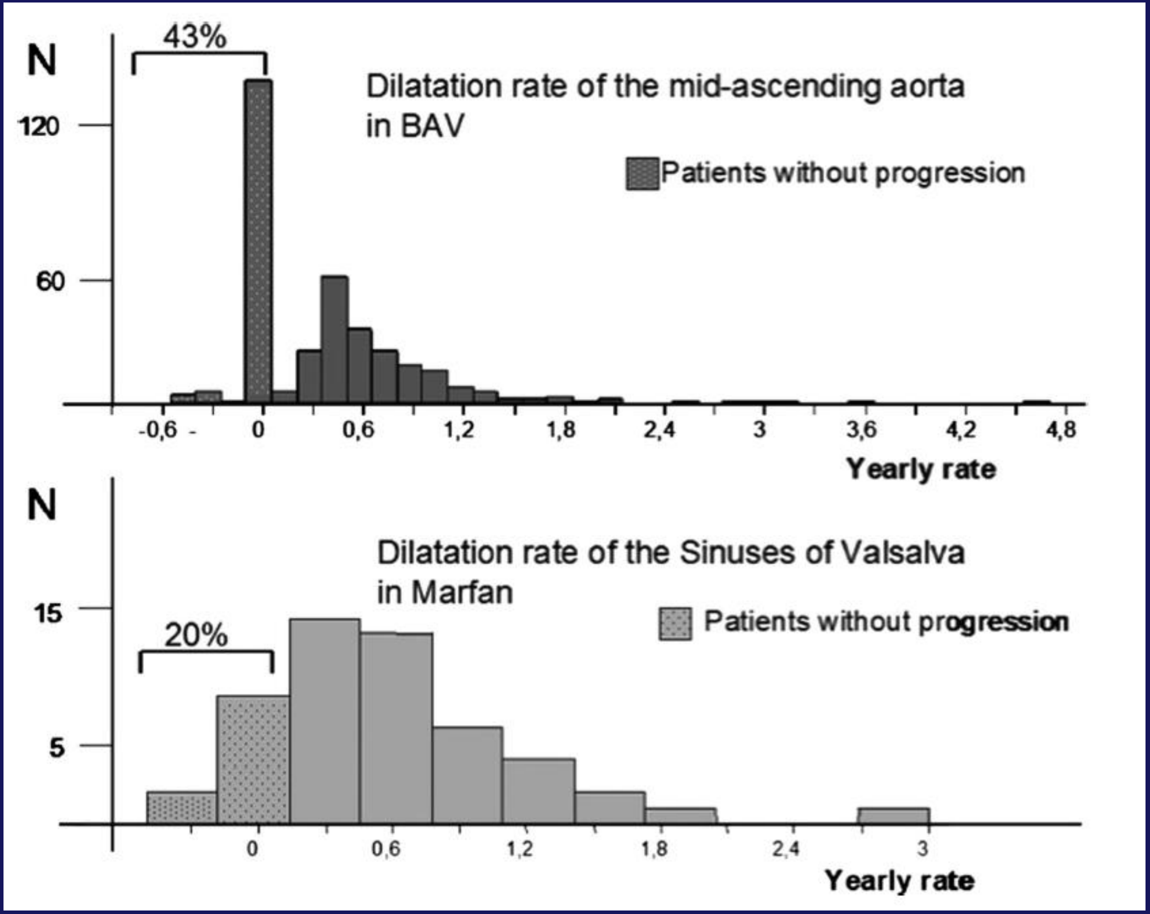


Figure 1 (A) Basic morphologies of bicuspid aortic valve (BAV). Panel A shows a typical BAV in diastole with a small raphe (arrow) between the right (R) and left (L) coronary cusps. In systole (panel B), commissures are located at 10 and 4 o'clock (arrows). Panel C depicts an atypical BAV in diastole with a prominent raphe (arrow) between the right (R) and non-coronary (N) cusps. In systole (panel D), commissures are located at 1 and 7 o'clock (arrows). (B) Aortic dilatation phenotypes. Panel A depicts a patient with Marfan syndrome and predominant dilatation of the sinuses of Valsalva. Panel B depicts a patient with BAV and predominant dilatation of the tubular ascending aorta. LA, left atrium; Ao, ascending aorta.

Aortic Regurgitation and Aortic Aneurysm
- Epidemiology and Guidelines -

Figure 3 Comparative distribution of the aortic dilatation rate in the segment of the aorta more prone to dilatation. Tubular ascending aorta for patients with bicuspid aortic valve (BAV) and sinuses of Valsalva in patients with Marfan syndrome. Although the mean value is similar (0.42 and 0.49 mm/year respectively), the distribution of the population is very different.



Follow Up: 3.6 years±1.2

Dilatation rate:

BAV:	353 pts	0.42mm/year
Marfan:	50 pts	0.49mm/year
Degenerative:	51 pts	0.20mm/year

according to Detaint et al., Heart 2010; 100: 126-134

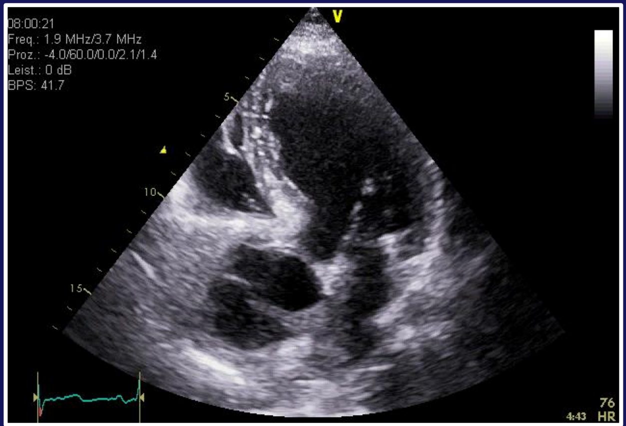
Echocardiographic diagnostics: Impact on prevention of TAA rupture

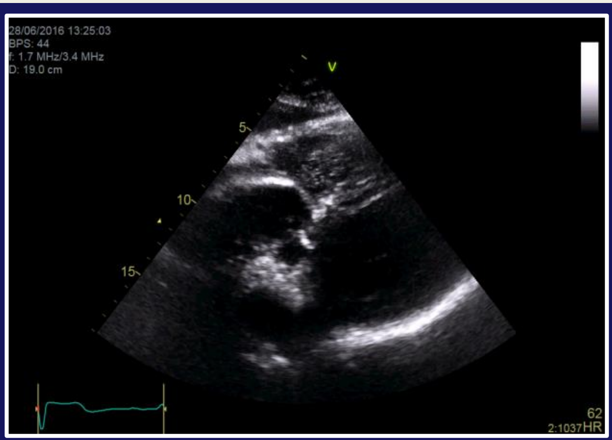
Impact of contrast-enhanced echocardiography on the diagnostic algorithm of acute aortic dissection

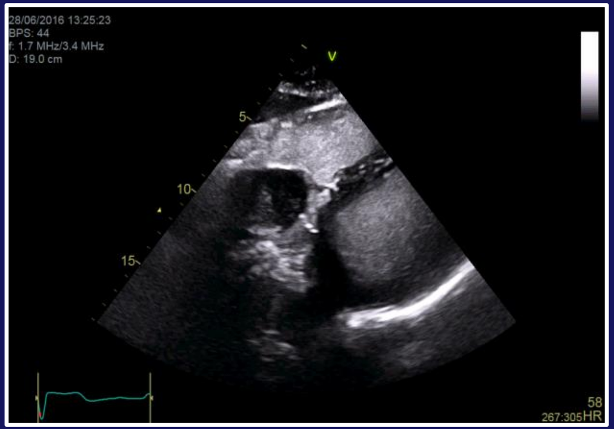
European Heart Journal (2010) **31**, 472–479

Artur Evangelista[1*], Gustavo Avegliano[1], Rio Aguilar[1], Hug Cuellar[2], Albert Igual[3], Teresa González-Alujas[1], Jose Rodríguez-Palomares[1], Patricia Mahia[1], and David García-Dorado[1]

Contrast enhancement substantially improves TTE in the diagnosis of AD and should be considered as the initial imaging modality in the emergency setting. Contrast enhancement also has significant value for obtaining critical morphological and haemokinetic information by TOE useful for adequate patient management.







Summary: AR - Epidemiology and Guidelines

- Epidemiological data about incidence and prevalence of aortic regurgitation are rare.
- The prevalence and incidence of aortic regurgitation is age-dependent.
- The qualitative evidence of aortic regurgitation is about 5% of the total population.
- The prevalence of severe aortic regurgitation is about 0.5% of the total population.
- In the elderly > 75 years it is about 5%.
- Indications for surgery in patients with aortic regurgitation are primarily symptoms, enlargement of LV-dimensions and impairment of LV-function as well as progression of symptoms and deterioration of LV-indices.
- Impaired LV-function in pts with AR is a significant risk factor of surgical therapy.
- Symptoms have to be identified in relation to the valvular defect.
- Thus, the grading of the severity of AR is the crucial factor for the therapeutical decision making.

Summary: TAA - Epidemiology and Guidelines

- Epidemiological data about incidence and prevalence of thoracic aortic aneurysms (TAA) are rare.
- The incidence of aortic regurgitation is about 10 per 100.000 per year.
- There are various shapes of aortic root and thoracic aortic aneurysms, which have been classified due to different mechanisms.
- Aortic root aneurysm is related to calcified aortic valves, left ventricular wall motion abnormalities and male gender.
- The normal values for the aortic root and the proximal thoracic aorta are recently published in the NORRE study.
- Indications for surgery in patients with TAA are aortic diameter > 45mm in pts with Marfan syndrome, > 50mm in BAV pts with risk factors and > 55mm in allother patients.
- In BAV pts cusp fusion morphology alters outflow patterns and consecutive aortopathy due to different wall shear-stress
- TAA has to be monitored to detect aortic enlargement and to prevent aortic dissection.

Thank You for Your Attention