Computed Tomography - From basics to clinical use

Diagnosis and Treatment of Valvular Heart Disease

David Messika-Zeitoun

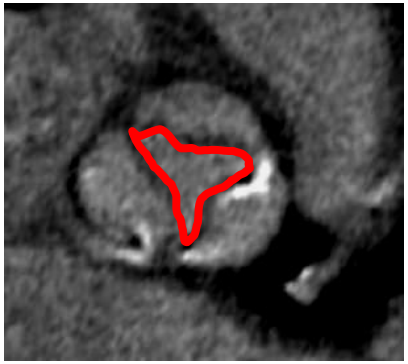
HÔPITAUX UNIVERSITAIRES
PARIS NORD VAL DE SEINE
Bichat - Claude Bernard

Disclosures

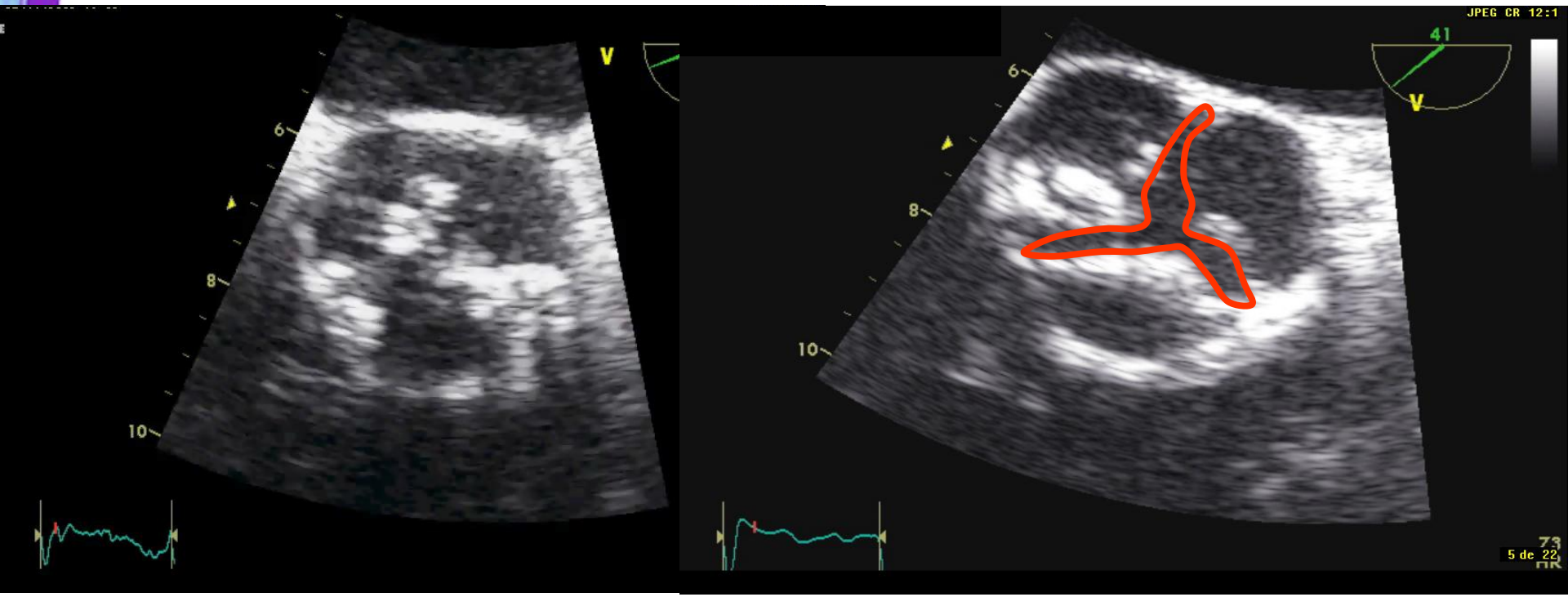
- Lectures fees for Edwards, Abbott
- Consultant fees from Symetis


You know what?
Echo is tough …
www.texavery.com

Planimetry



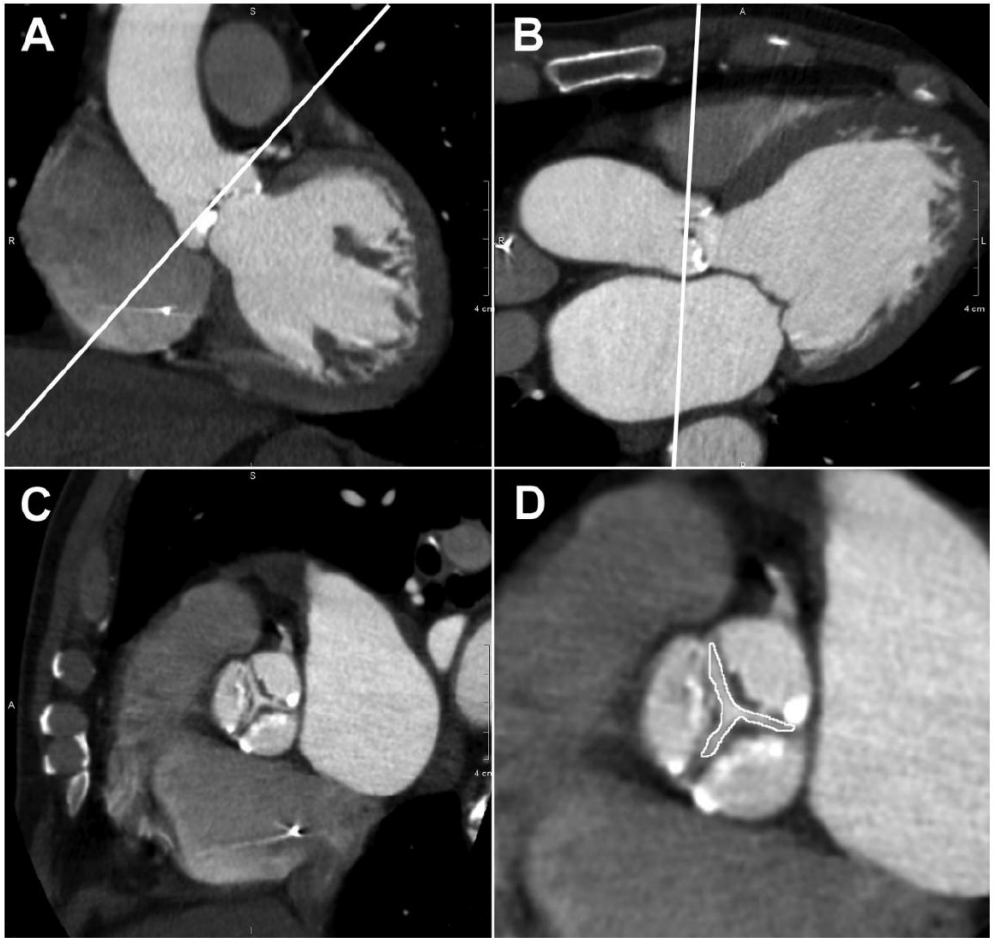
Transoesophageal Echocardiography



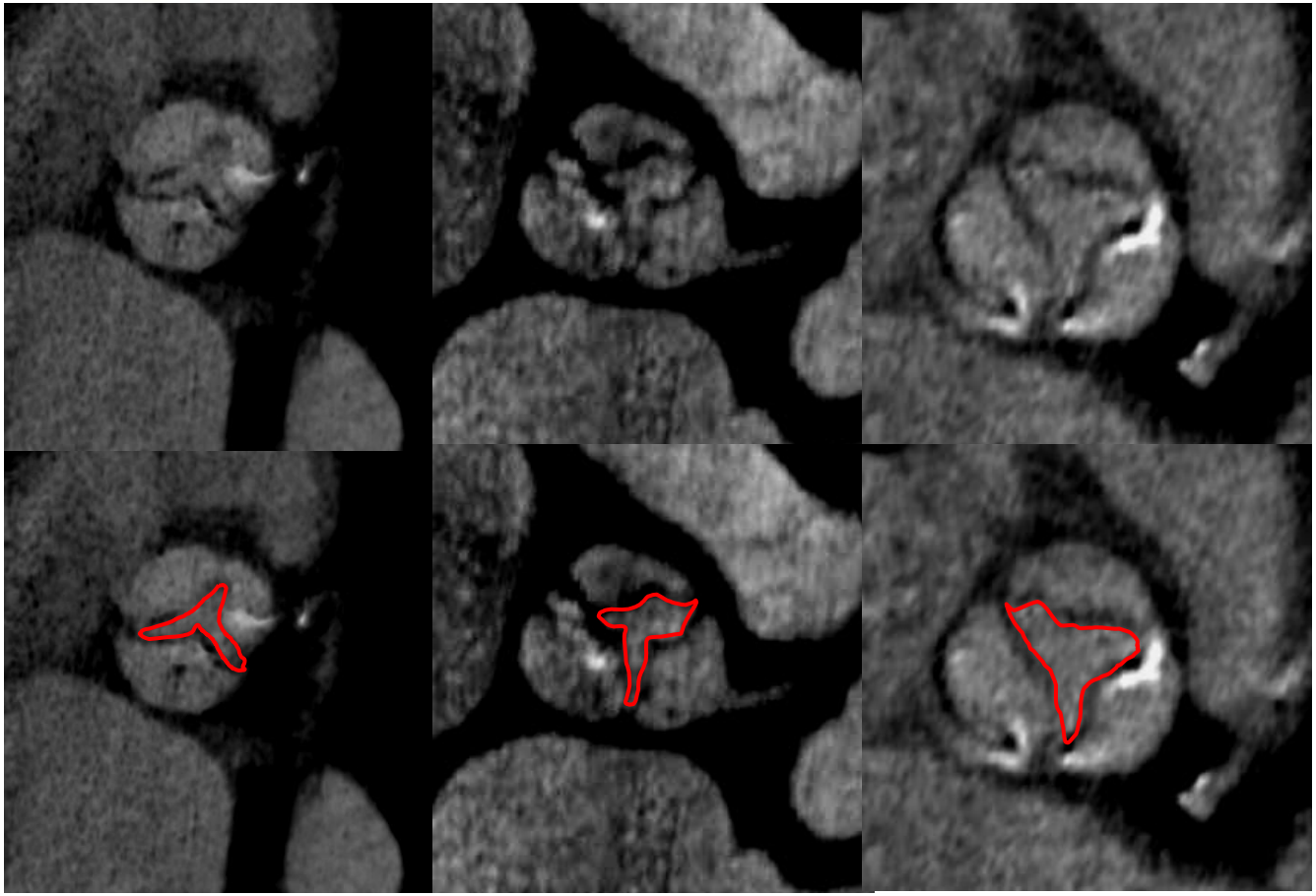
TEE

Computed Tomography
Planimetry

- CT scan
- Iodine contrast agent
- ECG-gating
- Mid-late systolic image reconstruction

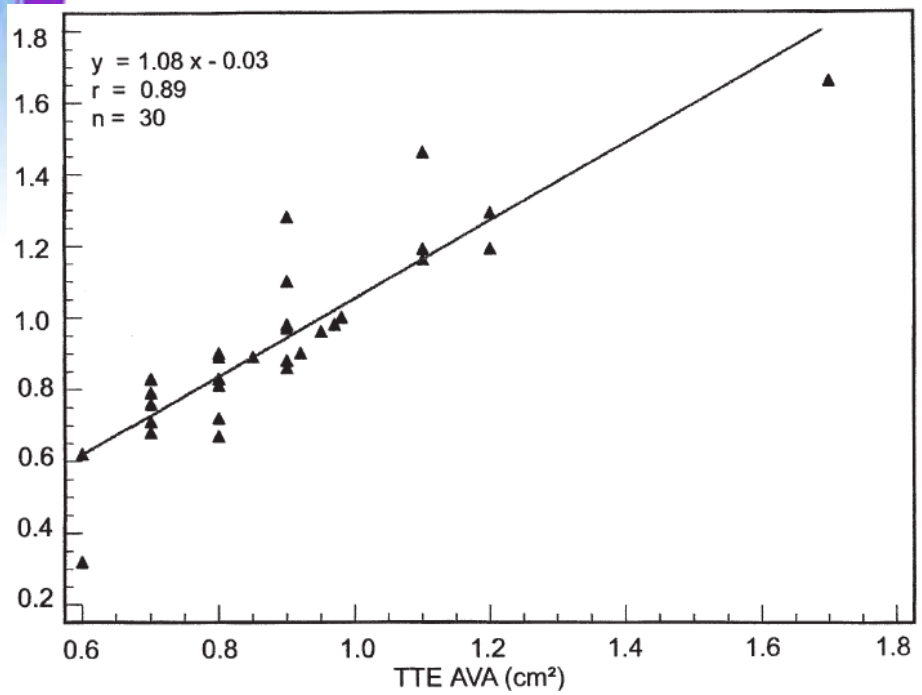


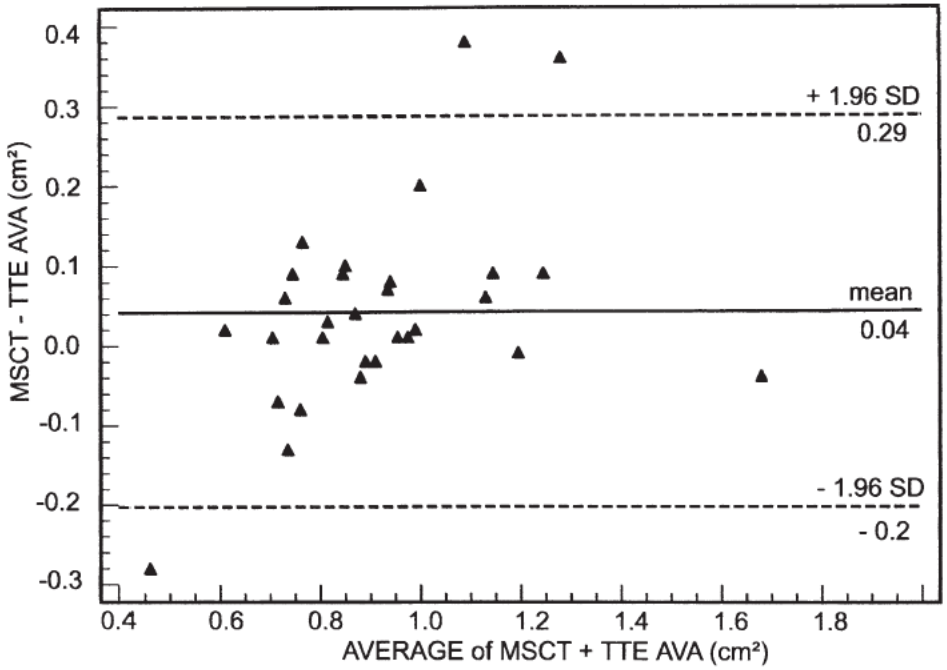
Example of Planimetry of the Aortic Valve Area



Laissy, Heart 2007

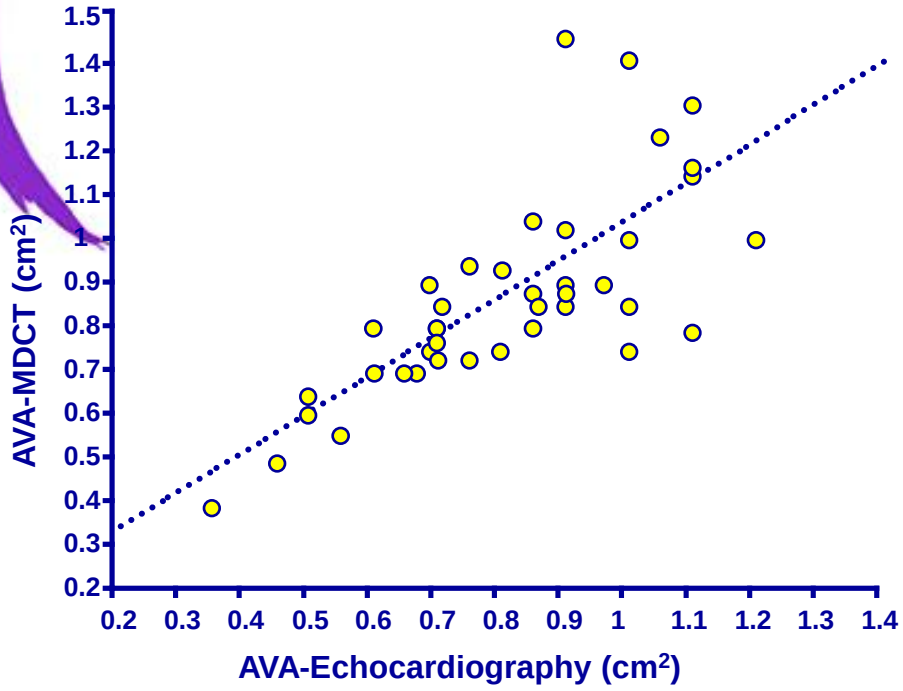
Aortic Valve Area

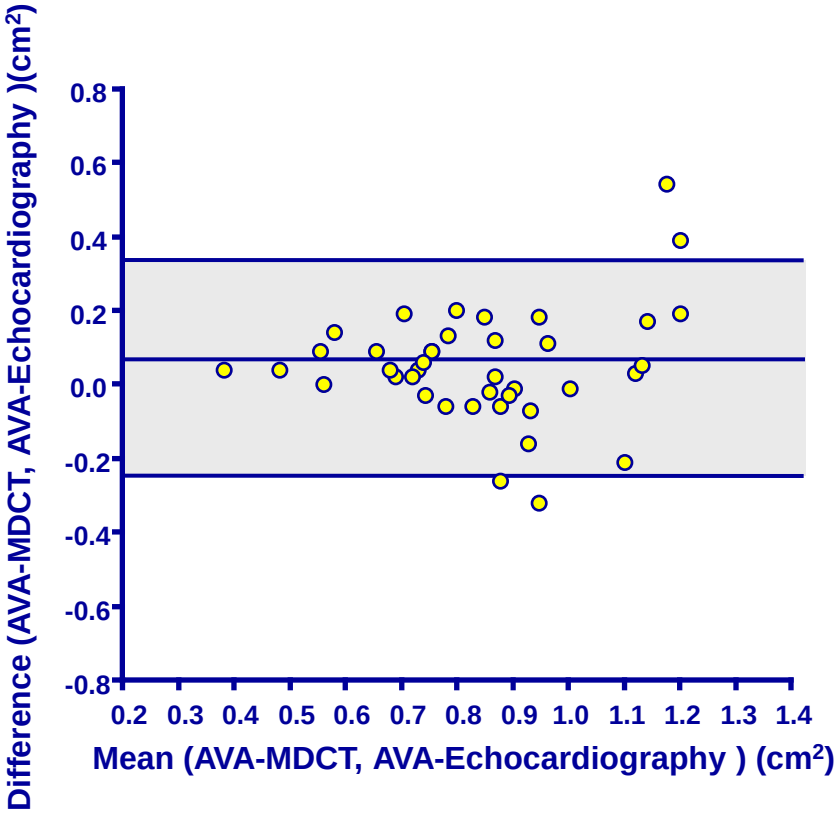




Feuchtner, JACC 2006

Planimetry of Aortic Valve Area





Laissy, Heart 2007

Aortic Valve Area - Results

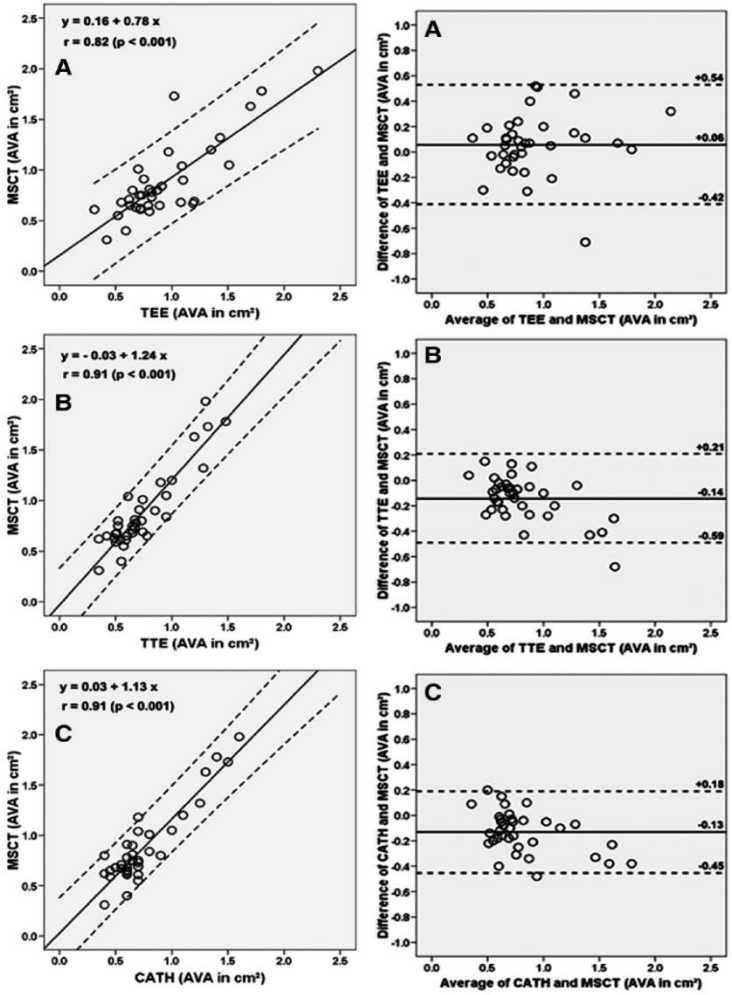
	N	AVA echo (cm^2)	AVA CT (cm^2)	Correlation Coefficient	SD of the difference (cm^2)
Feuchtner	30	0.90±0.22 0.6 – 1.7	0.94±0.27 0.6 – 1.7	0.89	0.13
Bouvier	30	0.80±0.27	0.87±0.33	-	0.16
Alkadhi	20	0.83±0.33 0.4 – 1.6	0.89±0.35 0.44 – 1.53	0.95	0.10
Laissy	40	0.81±0.20 0.35 - 1.2	0.87±0.23 0.40 - 1.45	0.77	0.15
Pouleur	48	2.0±1.5 0.5 – 6.1	2.5±1.7 0.5 – 6.3	0.96	0.5
Lembecke	36	0.74±0.28 0.3 – 1.6	0.88±0.39 0.3 – 2.0	0.91	0.18

Aortic Valve Area - Results

- 36 patients with AS
- CT = 0.88±0.39 cm²
- TEE = 0.94 ± 0.41 cm²
- TTE = 0.74 ± 0.28 cm²
- CATH = 0.75 ± 0.31 cm²

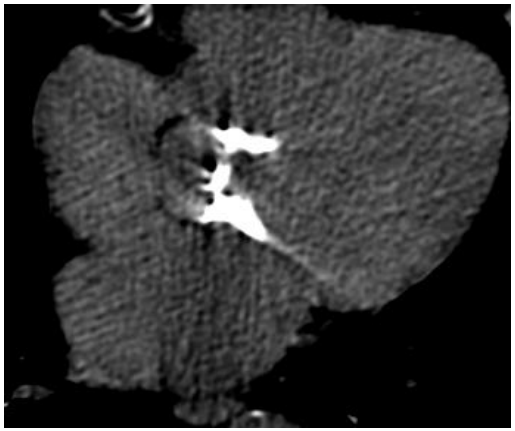
Effective area

Anatomic area



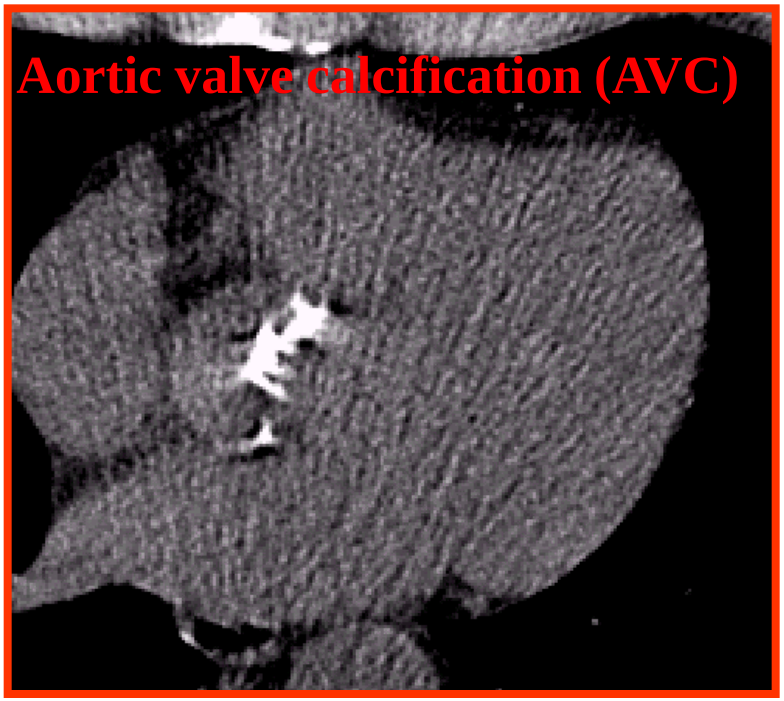
Lembcke 2009 Invest Radiol

Aortic Valve Calcifications



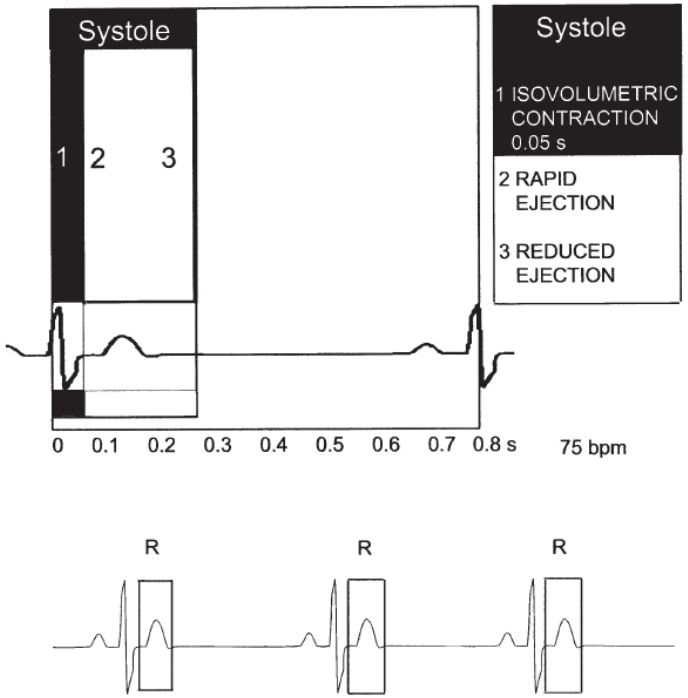
Aortic Valve Calcification (AVC)

CT is ideally suited to objectively and quantitatively assessed calcifications



CT scanner - Acquisition

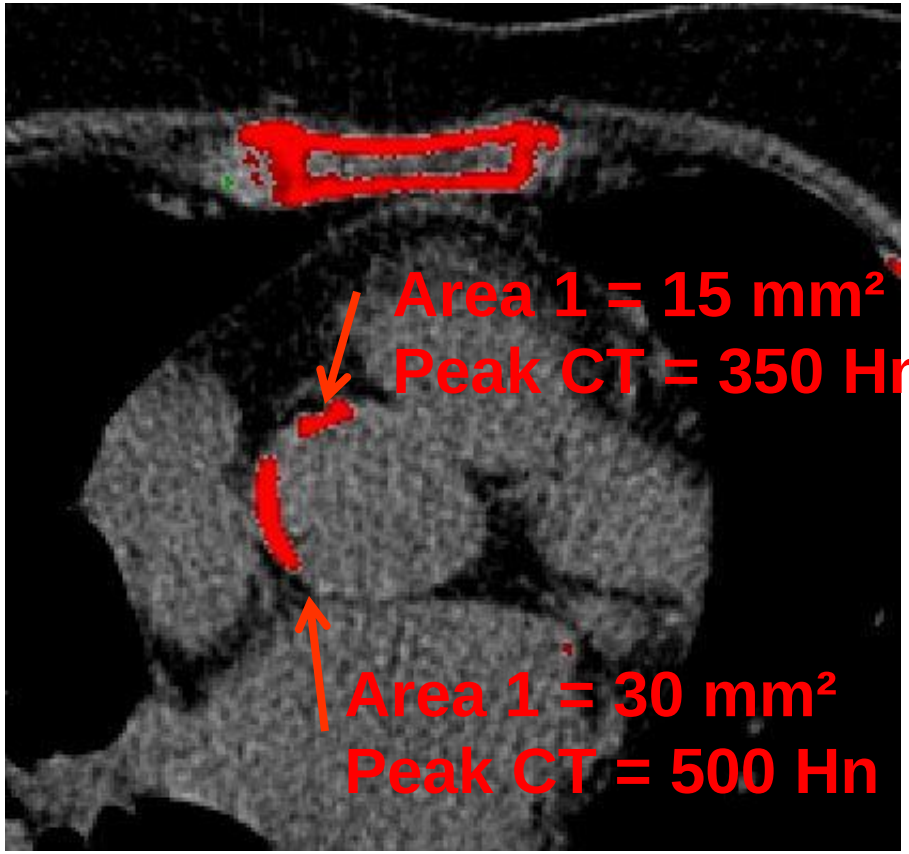
- Forty 3-mm-thick contiguous transverse slices with 3-mm table incrementation
- Covering the ascending aorta to the apex
- Acquisition triggered by electrocardiography at 80% of the RR interval (prospective ECG-gating)
- 2 independent runs
- No contrast agent



CT Scanner – Measurements of Calcifications

- Automated operator-independent image-processing software
- Calcification are defined as 4 adjacent pixels with density 130 Hounsfield units
- Radiologist affect the selected area to the coronary arteries, the aortic valve….

The Agatston Score



Peak density score

Hn	X Factor
130-199	1
200-299	2
300-399	3
> 400	4

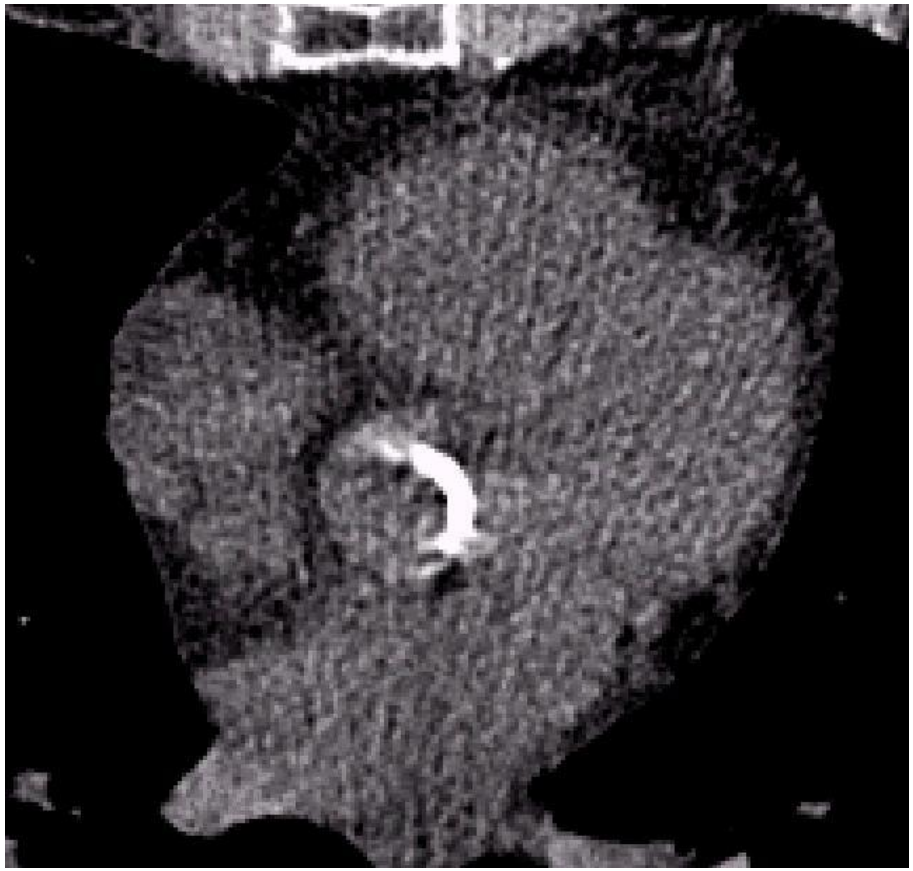
Region 1. Score = 15 * 3 = 45

Region 2. Score = 30 * 4 = 120

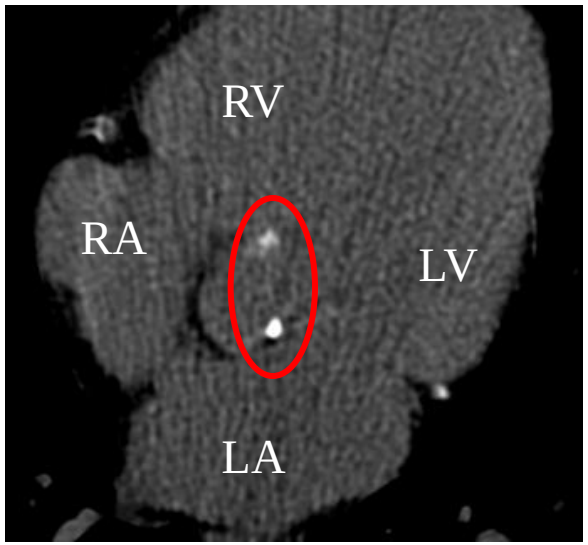
- For each region of interrest, score = density score * area
- Total score: sum of score of each region of interest in all slices

Definition of AVC

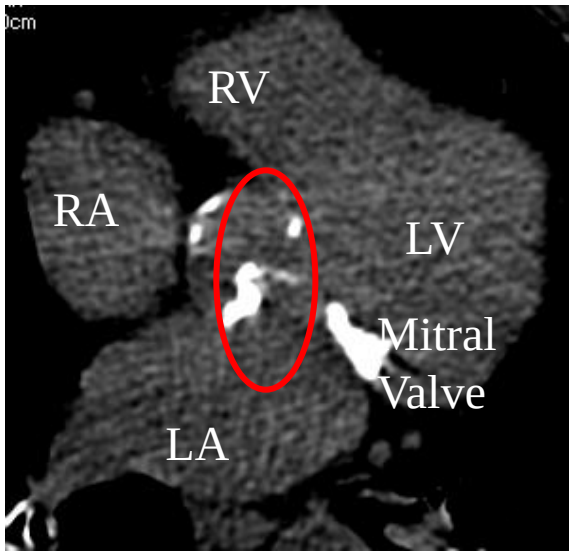
- **Aortic valve calcifications are defined as calcifications within valve leaflets, aortic annulus, or aortic wall immediately adjacent to leaflet or annular calcification.**



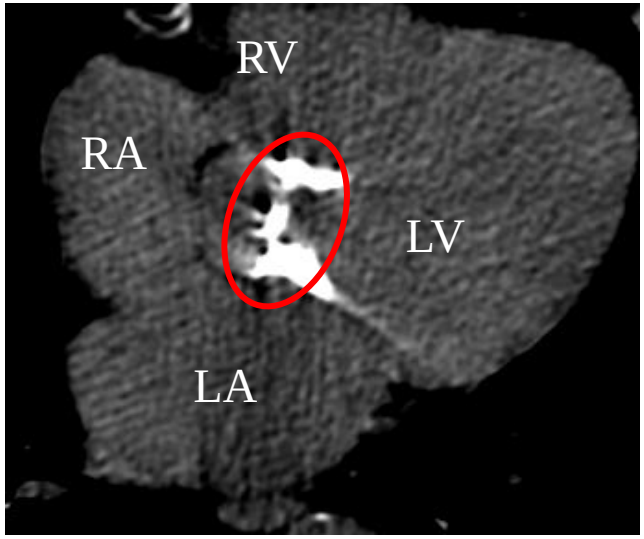
Examples of degree of AVC



Mild AVC. Score = 200 AU

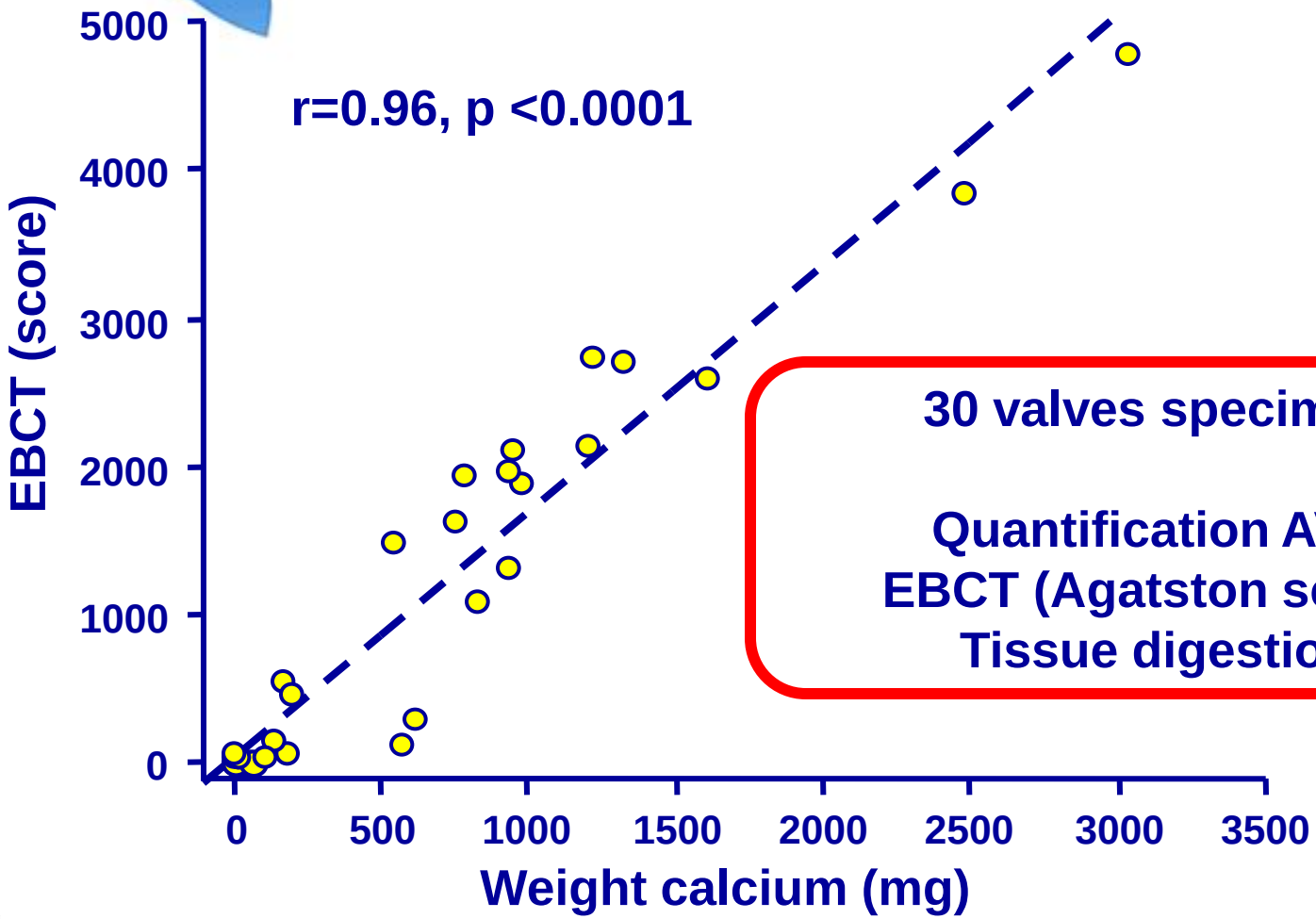


Moderate AVC. score = 800



Severe AVC. Score = 2000

Anatomic validation for AVC

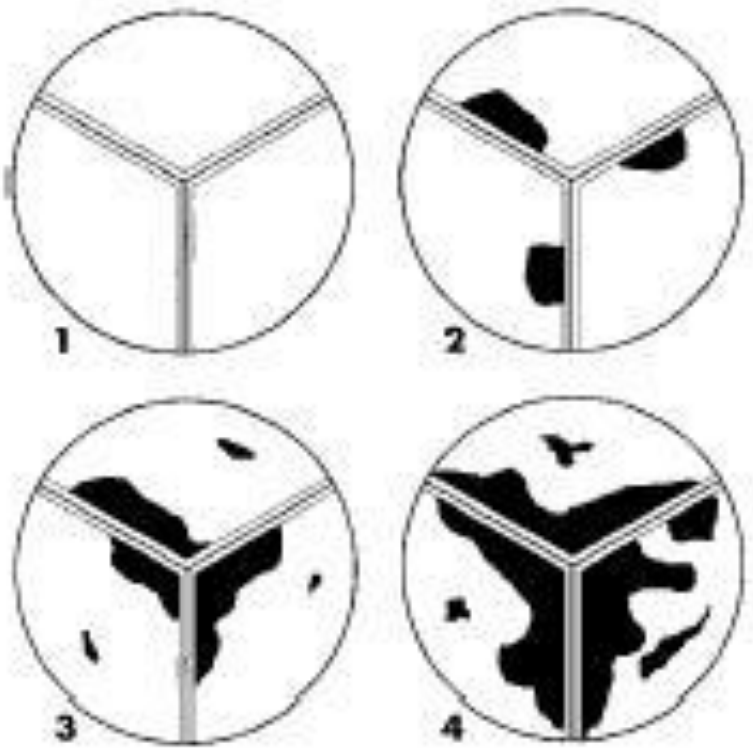


30 valves specimen

Quantification AVC
EBCT (Agatston score)
Tissue digestion

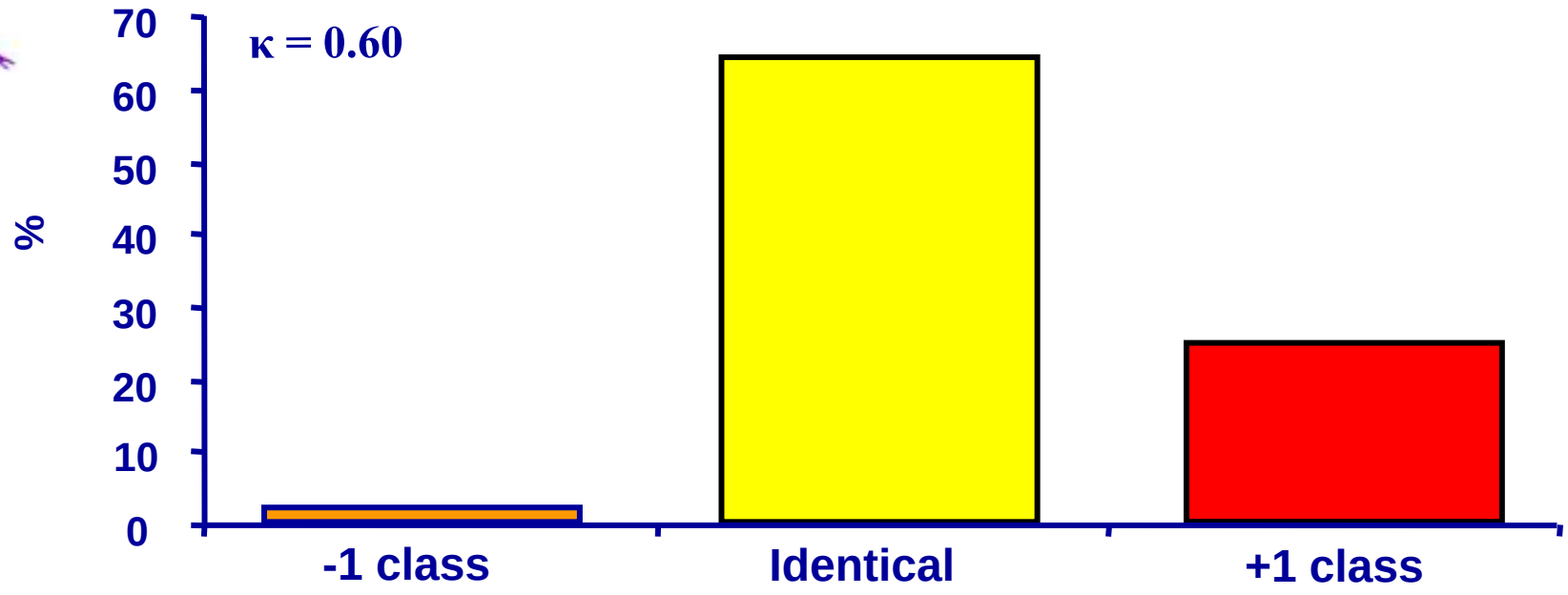
Echocardiographic Evaluation of Aortic Valve Calcifications

- None
- Mild: isolated spots
- Moderate: Multiples spots
- Severe : Large and diffuse calcifications



Echocardiographic Evaluation of Aortic Valve Calcifications

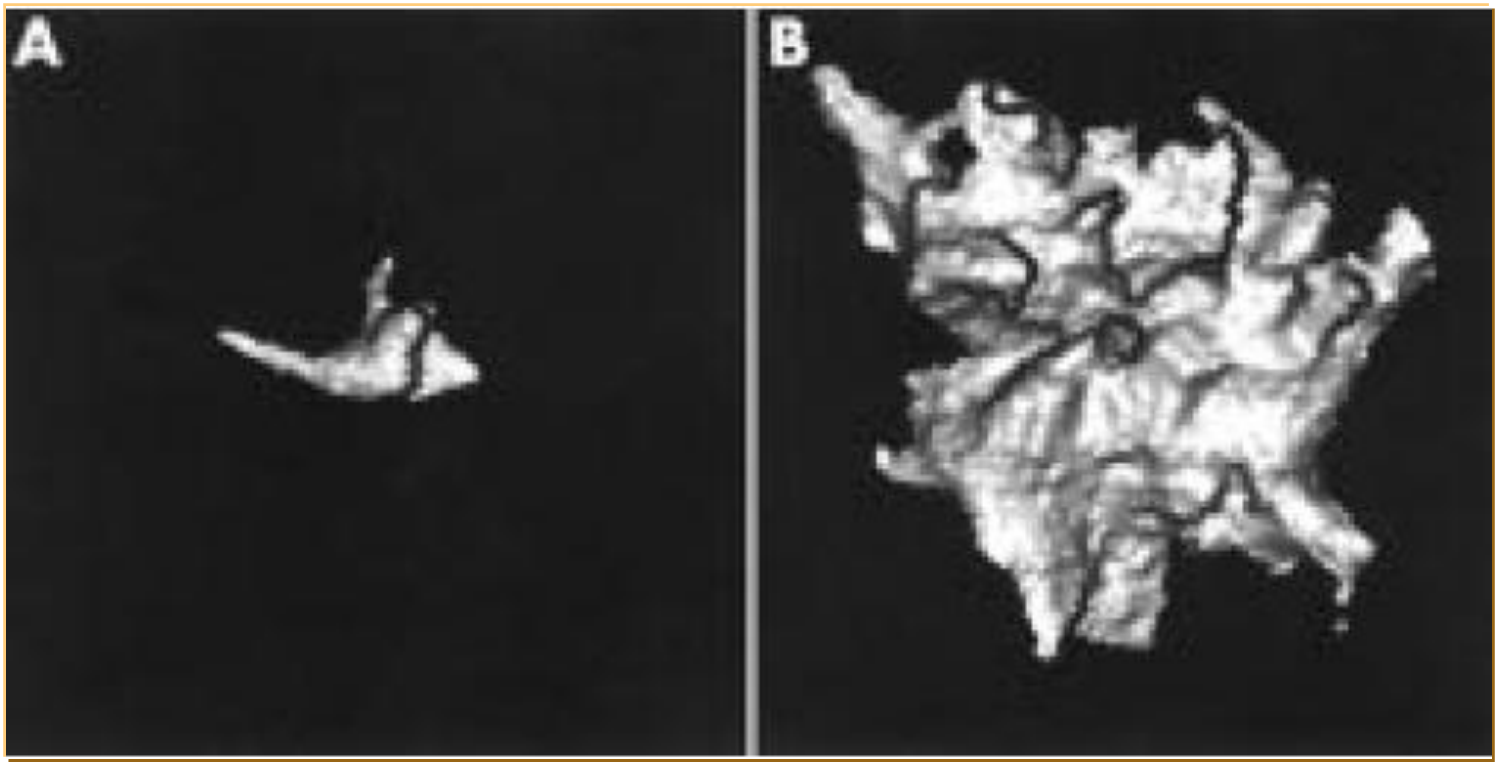
Classification subjective and inaccurate



Three dimensional volume quantification of aortic valve calcification using multislice computed tomography

G J Morgan-Hughes, P E Owens, C A Roobottom, A J Marshall

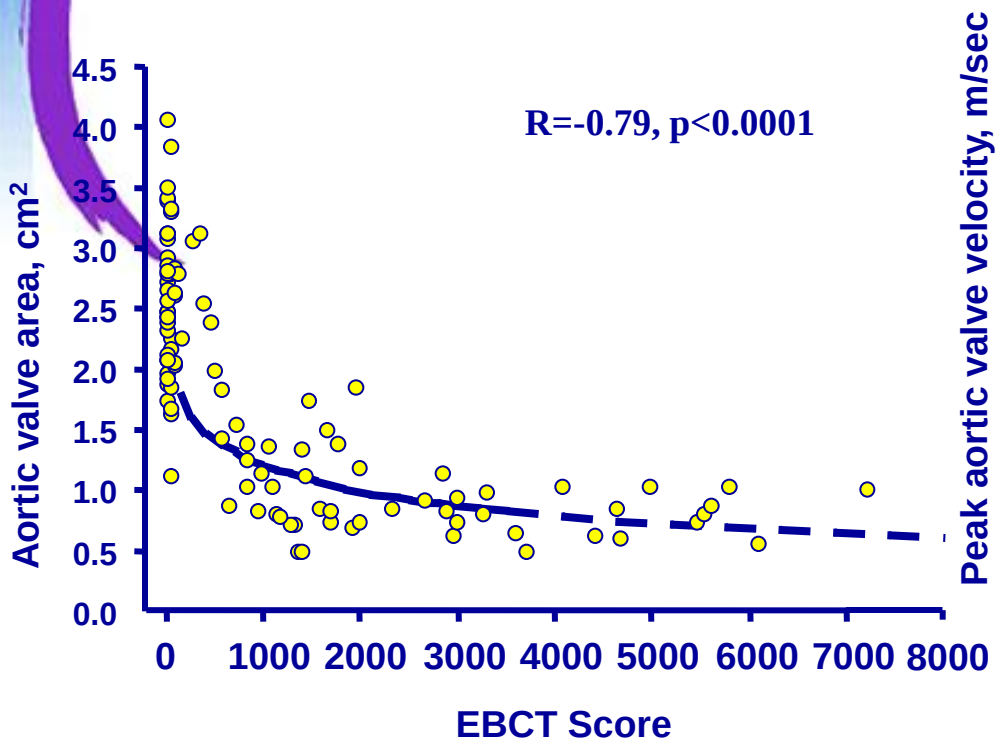
Heart 2003;**89**:1191–1194

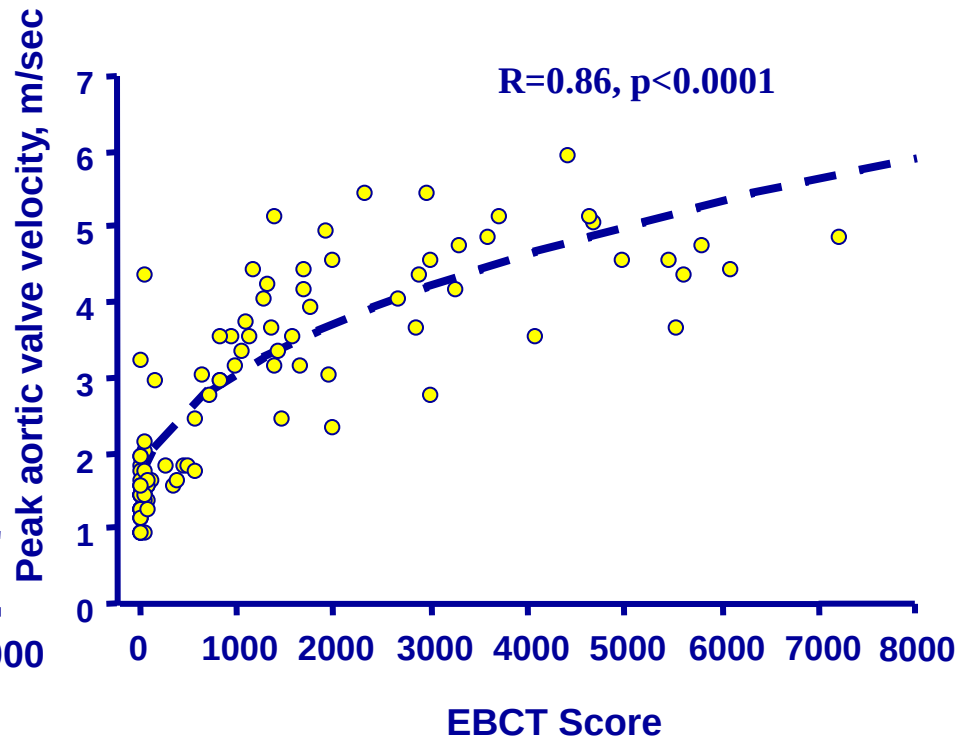


(A) Mild calcification of the left coronary cusp (Volume 74 mm3, aortic valve area 2.4 cm²).

(B) Severe calcification (Volume 5044 mm3, aortic valve area 0.4 cm²)

AVC and Hemodynamic Severity





Messika-Zeitoun Circulation 2004

EBCT Thresholds

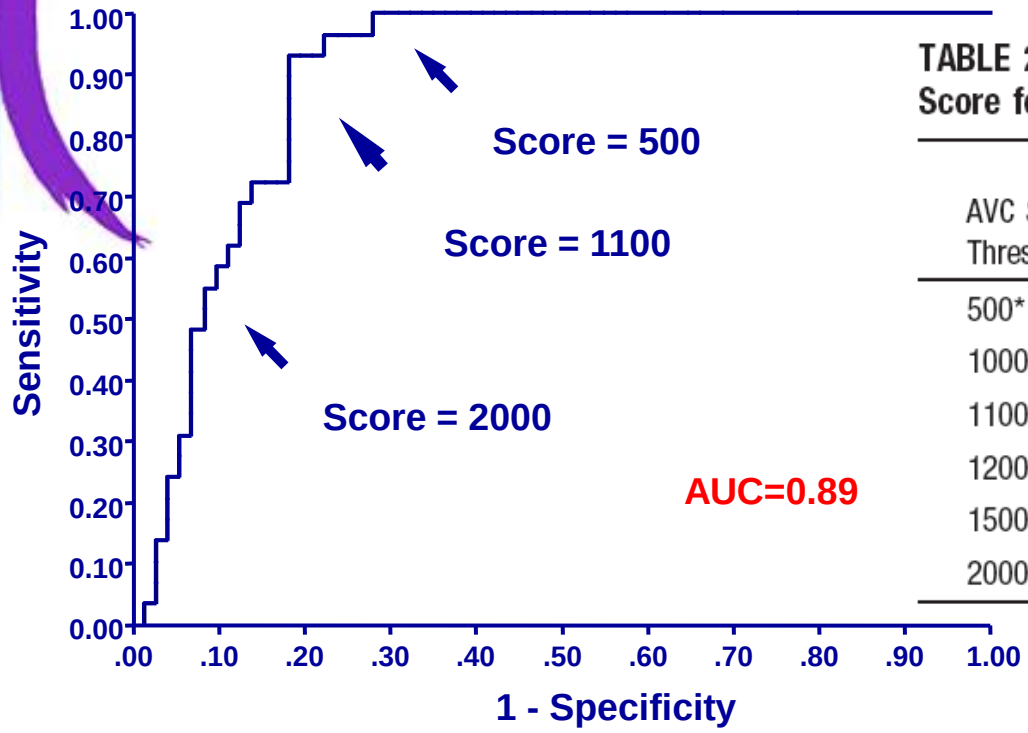
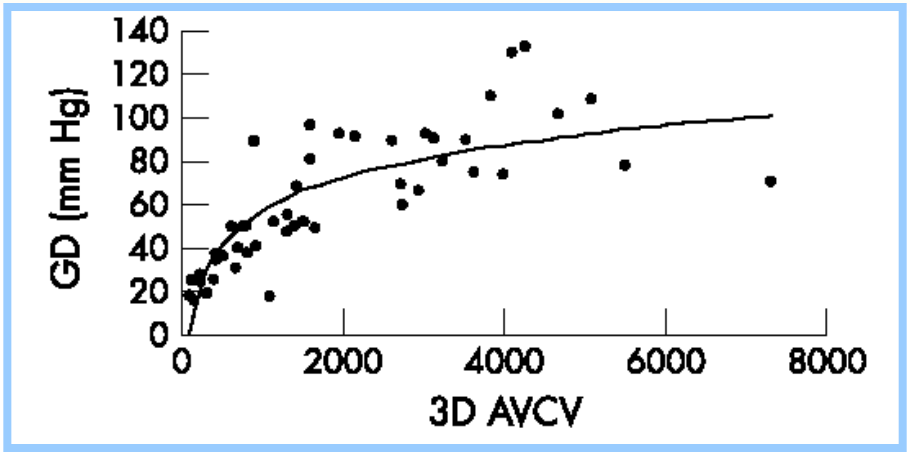
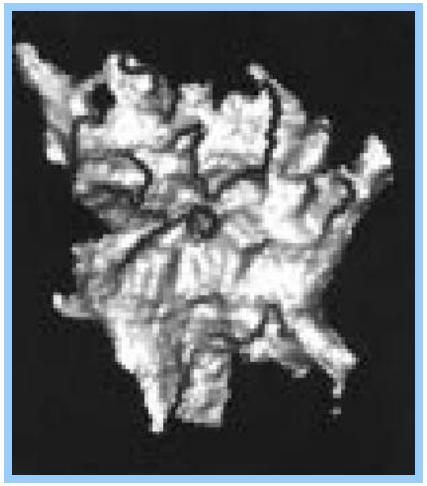


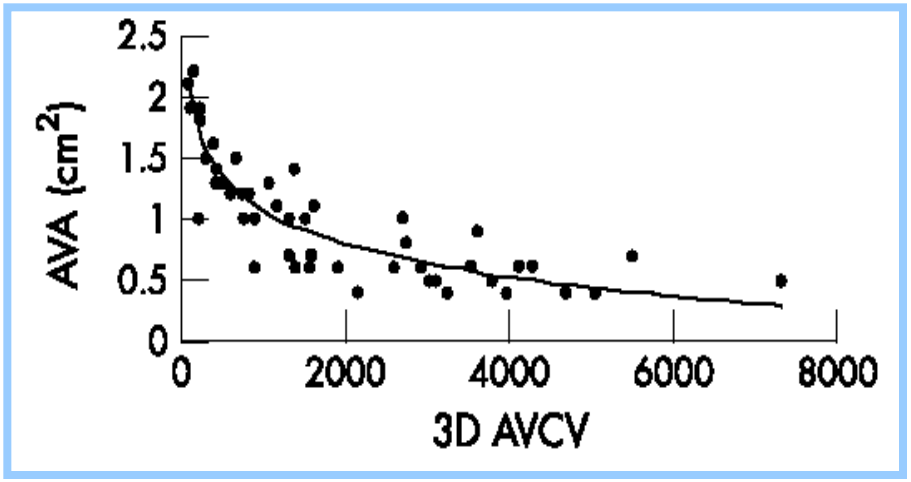
TABLE 2. Diagnostic Value of Various Thresholds of AVC Score for Severe AS (Valve Area <1 cm²)

AVC Score Threshold, AU	Sensitivity, %	Specificity, %	Positive Predictive Value, %	Negative Predictive Value, %
500*	100	69	57	100
1000	93	77	63	96
1100*	93	82	68	97
1200	86	82	66	94
1500	72	85	66	88
2000*	55	92	73	83

Volumetric Assessment







Morghan-Hughes Heart 2003

EBCT = MSCT ?

Measurement of aortic valve calcification using multislice computed tomography: correlation with haemodynamic severity of aortic stenosis and clinical implication for patients with low ejection fraction

Caroline Cueff,[1] Jean-Michel Serfaty,[2,3] Claire Cimadevilla,[1] Jean-Pierre Laissy,[2] Dominique Himbert,[1] Florence Tubach,[4] Xavier Duval,[5] Bernard Iung,[1] Maurice Enriquez-Sarano,[6] Alec Vahanian,[1] David Messika-Zeitoun[1,3]

[1]Cardiology Department, AP-HP, Bichat Hospital, Paris, France
[2]Radiology Department, AP-HP, Bichat Hospital, Paris, France
[3]INSERM U698, University Paris 7, Paris, France
[4]Département d'Epidémiologie Biostatistique et Recherche Clinique, AP-HP, Bichat Hospital, Paris, France
[5]Centre d'Investigation Clinique 007, AP-HP, Bichat Hospital, Paris, France
[6]Division of Cardiovascular Disease, Mayo Clinic, Rochester, Minnesota, USA

Correspondence to
Dr David Messika-Zeitoun, Cardiovascular division, Bichat Hospital, 46 rue Henri Huchard, 75018 Paris, France; david.messika-zeitoun@bch.aphp.fr

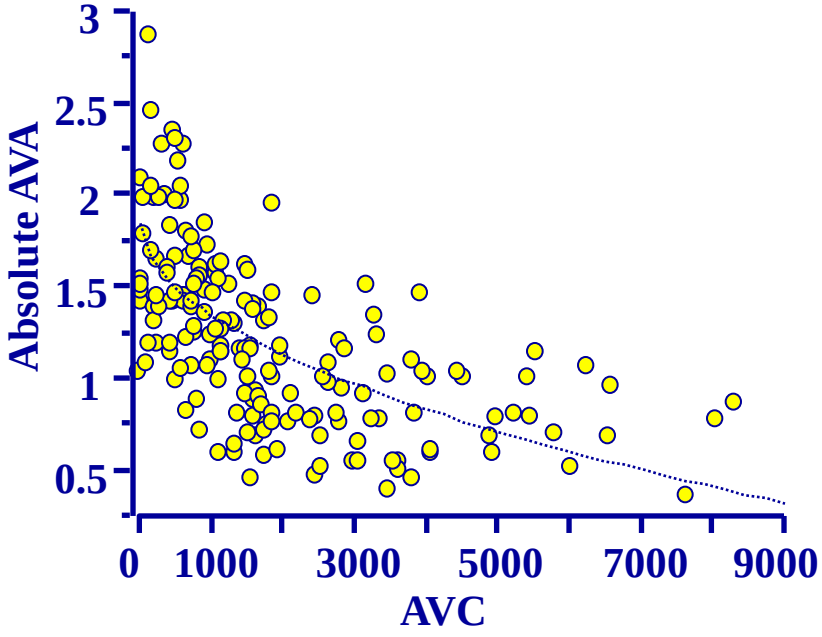
ABSTRACT

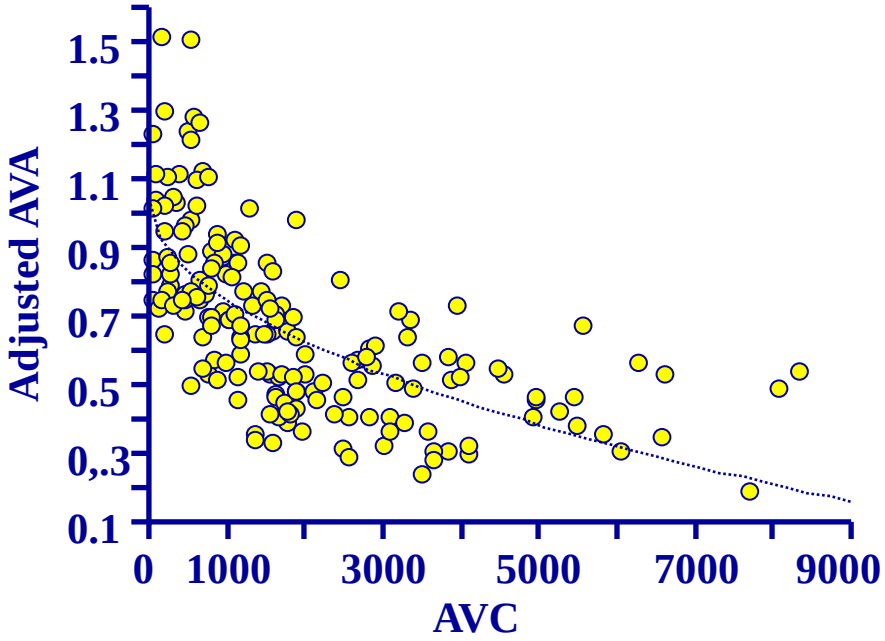
Background Measurement of the degree of aortic valve calcification (AVC) using electron beam computed tomography (EBCT) is an accurate and complementary method to transthoracic echocardiography (TTE) for assessment of the severity of aortic stenosis (AS). Whether threshold values of AVC obtained with EBCT could be extrapolated to multislice computed tomography (MSCT) was unclear and AVC diagnostic value in patients with low ejection fraction (EF) has never been specifically evaluated.

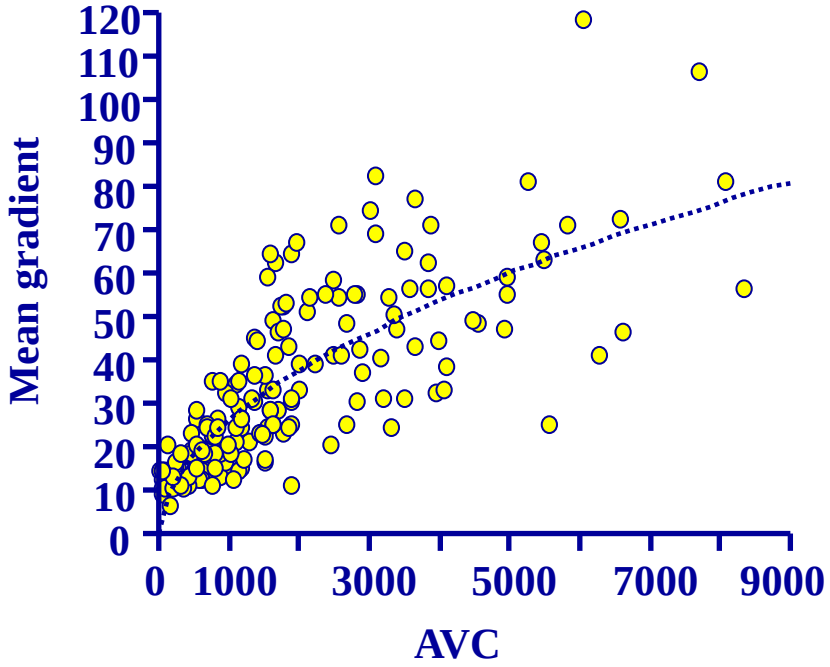
Methods Patients with mild to severe AS underwent prospectively within 1 week MSCT and TTE. Severe AS was defined as an aortic valve area (AVA) of less than 1 cm^2. In 179 patients with EF greater than 40% (validation set), the relationship between AVC and AVA was evaluated. The best threshold of AVC for the diagnosis of severe AS was then evaluated in a second subset (testing set) of 49 patients with low EF (≤40%). In this subgroup, AS severity was defined based on mean gradient, natural history or dobutamine stress

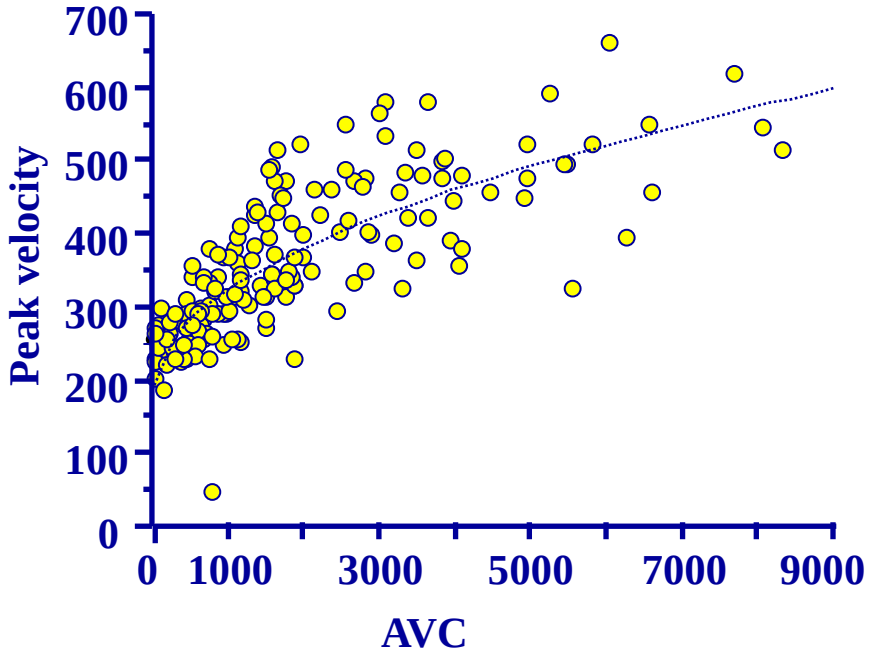
continuity equation.[5] According to current recommendations, severe AS is defined as an AVA less than 1 cm^2 (or 0.6 cm^2/m^2 of body surface area), an MPG greater than 40 or 50 mm Hg and a peak aortic velocity greater than 4.0 m/s.[6] However, echocardiographic evaluation of AS severity may be technically challenging in patients with poor echocardiographic windows such as obese patients or patients with severe chronic obstructive pulmonary disease. Furthermore, in patients with depressed EF and low-flow/low-gradient (LF/LG) AS, transthoracic echocardiography (TTE) at rest is not conclusive requiring additional testing such as dobutamine stress echocardiography (DSE) to differentiate severe from pseudo-severe AS.[7–10]

Aortic valve calcification (AVC) is the leading process to aortic valve stenosis. Measurement of the degree of AVC using electron beam computed tomography (EBCT) has previously been validated as a complementary method for the evaluation of AS severity.[11] However, whether thresholds defined

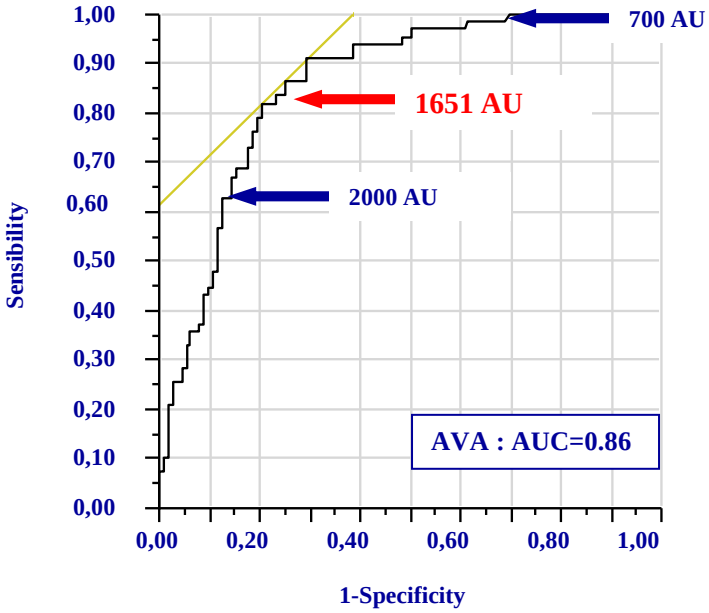








Cueff Heart 2011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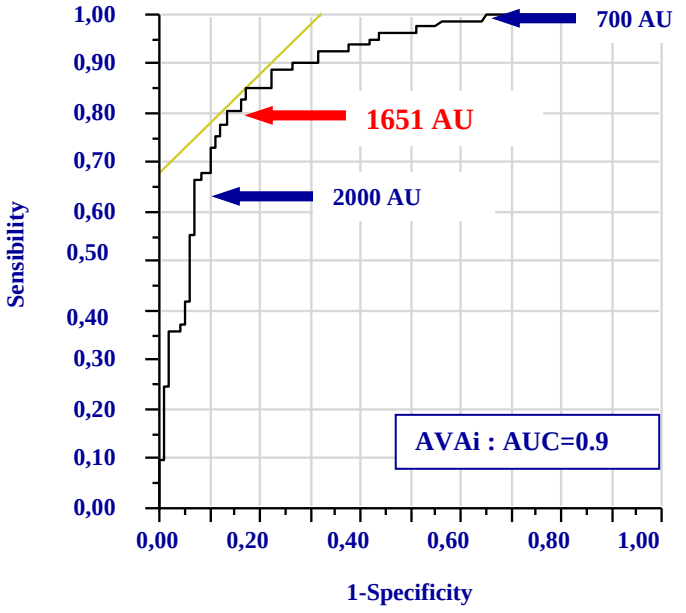
1651 AU
2000 AU
AVA : AUC=0.86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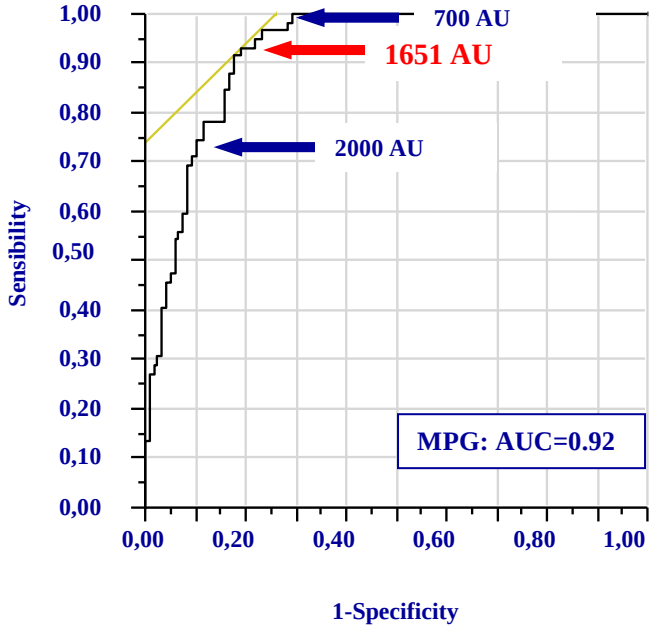
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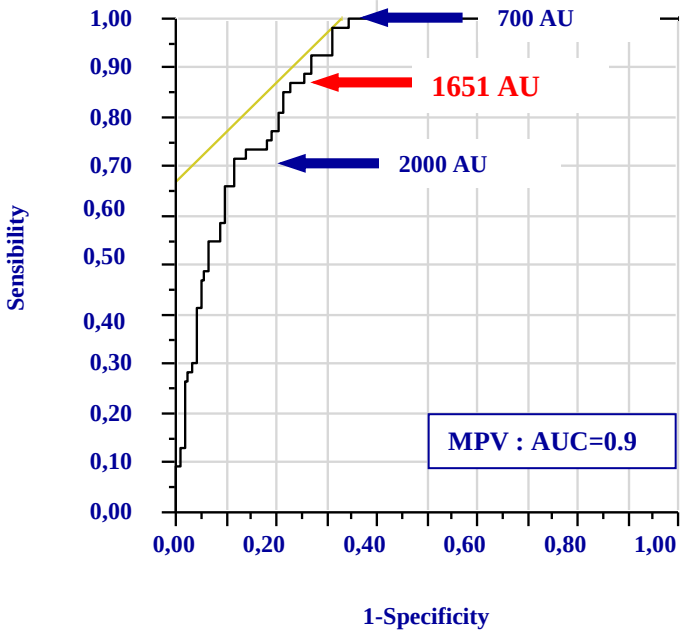
Sensibility
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1,00
1-Specificity
700 AU
1651 AU
2000 AU
MPV : AUC=0.9

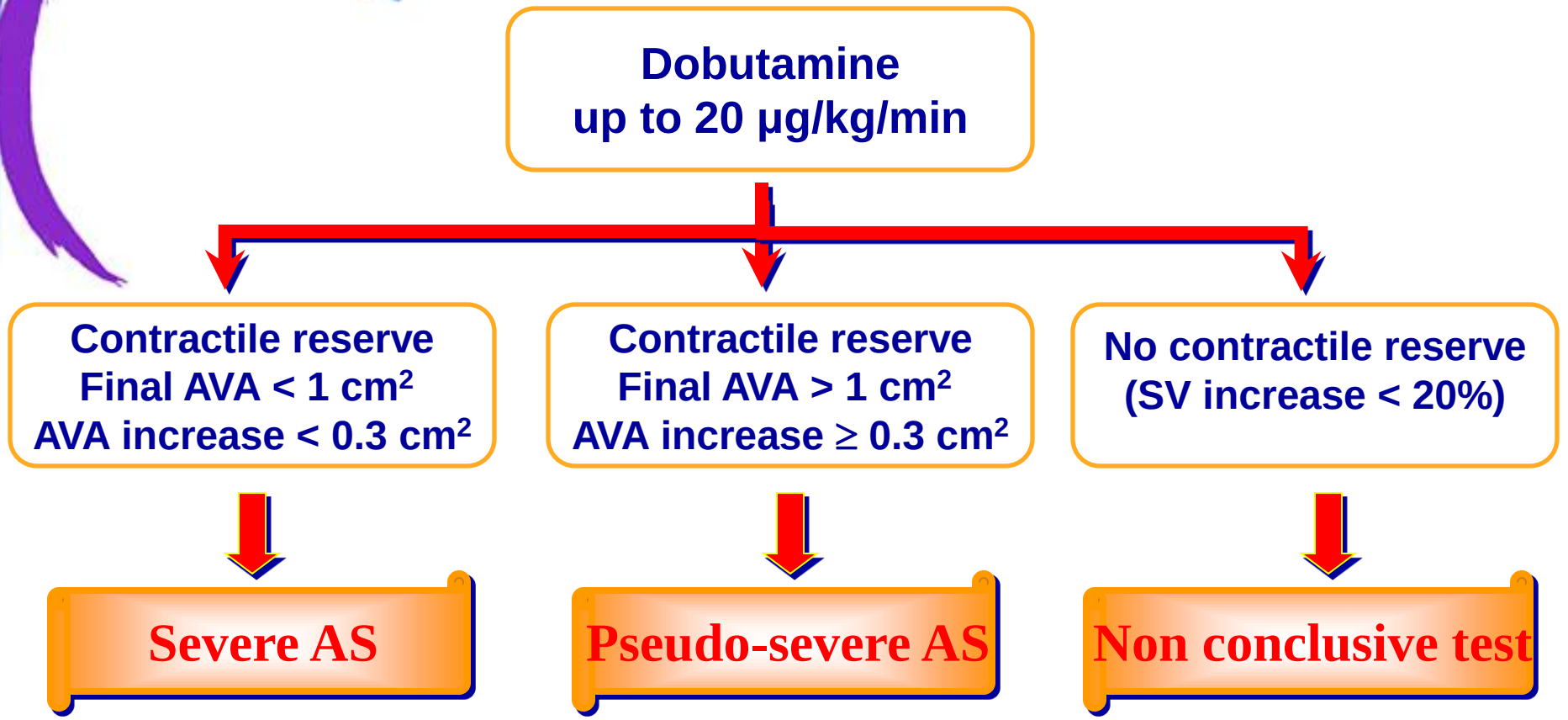
Scanner MSCT Thresholds

Calcium Score	Sensitivity, %	Specificity, %	PPV, %	NPV, %
500	100	31	46	100
700	98	49	49	98
1000	94	65	55	94
1200	91	65	59	92
1651	**82**	**80**	**70**	**88**
2000	62	86	72	79
3000	57	91	74	72

Clinical Implications

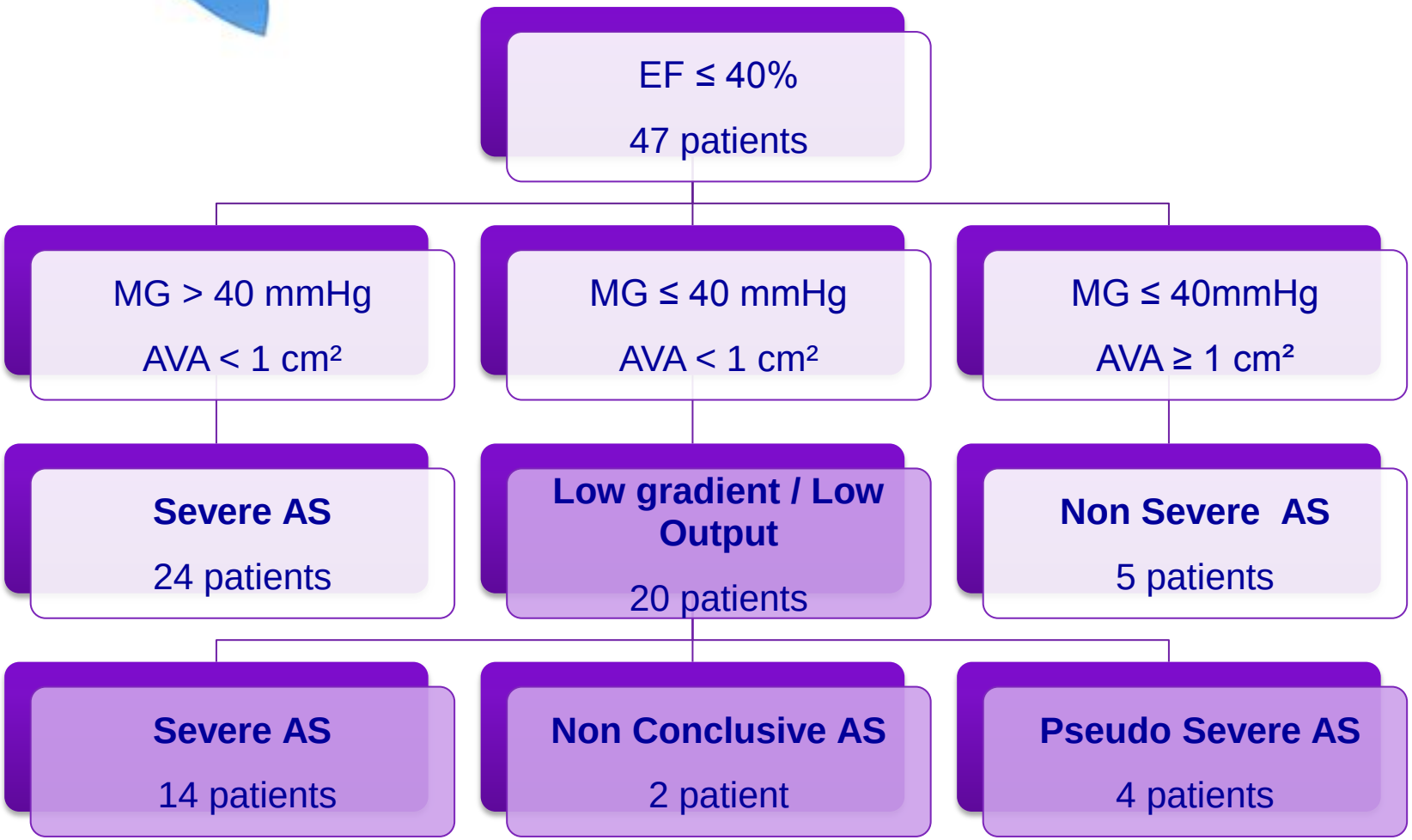
- **Discrepancies between symptoms and echocardiographic measurements**
- **Poor echogenicity**
- **Low gradient – low output**

Low Gradient – Low Output



Monin Circulation; 108: 319-324

47 patients with Low EF



Cueff Heart 2011

Indications for chest CT included evaluation of thoracic and extrathoracic malignant tumor, pulmonary or pleural infection, pulmonary embolism, postoperative and posttraumatic abnormalities, and assessment of thoracic aortic aneurysm or dissection. No CT scan was obtained specifically to evaluate aortic valve disease. Indications for

Aortic valve calcification was noted in 18% of multi-detector row CT scans as an incidental finding.

Prevalence and Clinical Importance of Aortic Valve Calcification Detected Incidentally on CT Scans:

Comparison with Echocardiography[1]

Radiology

Purpose: To evaluate retrospectively the prevalence and grade of aortic valve calcification incidentally detected on chest multi-detector row computed tomographic (CT) scans and to compare the grade of calcification with the severity of aortic valve disease as assessed with echocardiography.

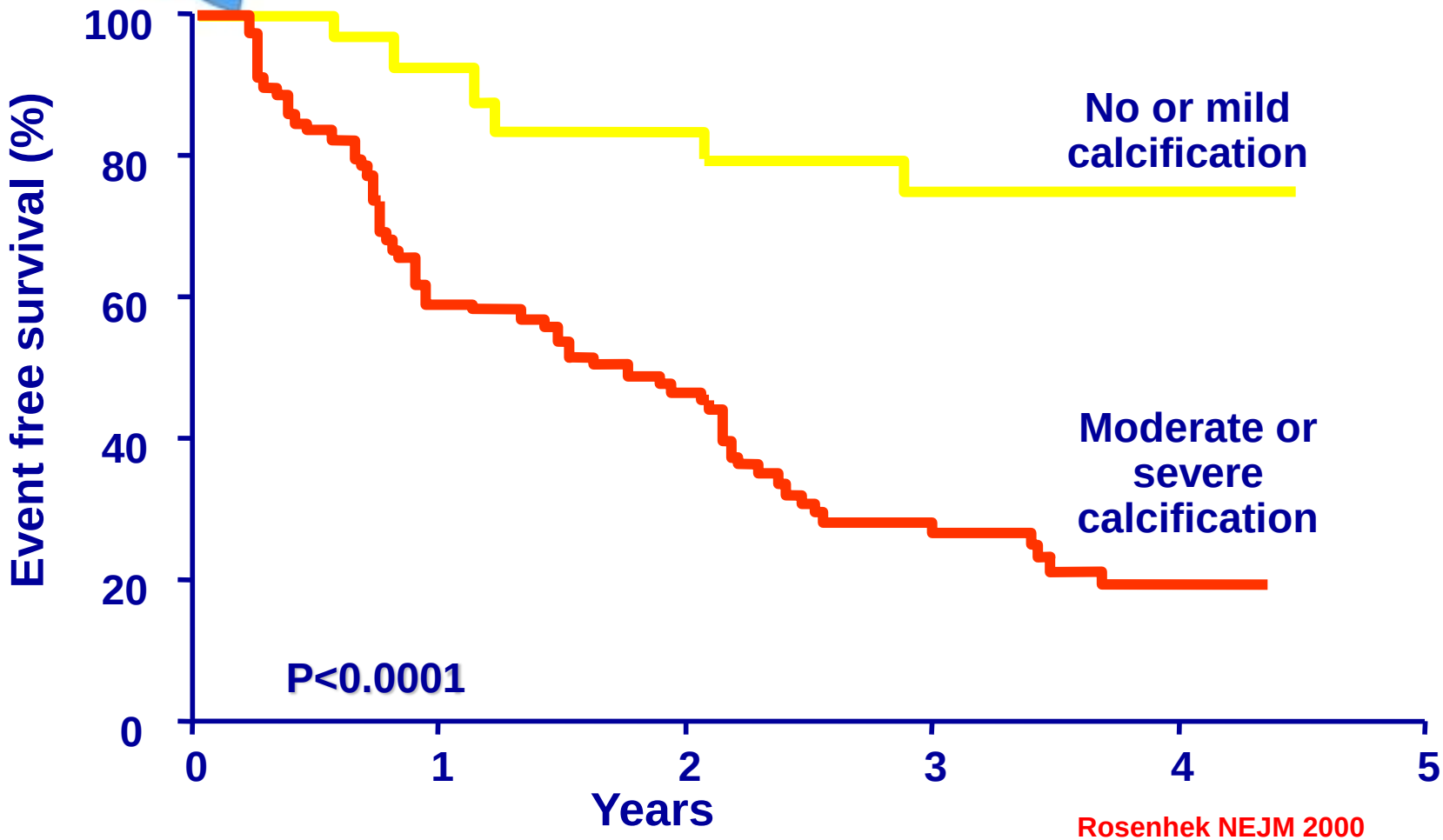
Materials and Methods: Patient informed consent was waived by the institutional board on medical ethics that approved this study. The authors identified 402 patients (231 men and 171 women; mean age, 62.5 years ± 12.1) of 1820 patients who underwent chest multi-detector row CT between July 2001 and August 2004 and also underwent echocardiography. Aortic valve calcification at multi-detector row CT was visually graded on a scale ranging from 0 to 4 (0 = no calcification, 4 = severe calcification). CT findings were correlated with hemodynamic data obtained at echocardiography. Patients without aortic stenosis were compared with patients with aortic stenosis. The Student *t* test, Spearman correlation coefficient, χ^2 analysis, and an unweighted κ test were used to compare results.

Results: Aortic valve calcification was noted on multi-detector row CT scans in 72 of the 402 patients (18%). Twelve of 20 patients (60%) with grade 3 or grade 4 calcification on CT scans had aortic stenosis at echocardiography, compared with only nine of 382 patients (2.4%) with grade 0–2 calcification ($P < .001$). Significant correlations were observed between the grade of aortic valve calcification and the echocardiographically determined mean ($r = 0.45$, $P = .03$) and peak transvalvular gradient ($r = 0.47$, $P = .03$). There was substantial agreement between the grade of valve calcification at multi-detector row CT and the severity of aortic valve disease at echocardiography ($\kappa = 0.67$).

Conclusion: Aortic valve calcification was an incidental finding on 18% of multi-detector row CT scans. The grade of aortic valve calcification is correlated with the hemodynamic severity of aortic valve disease as determined with echocardiography.

Koos Radiology 2006

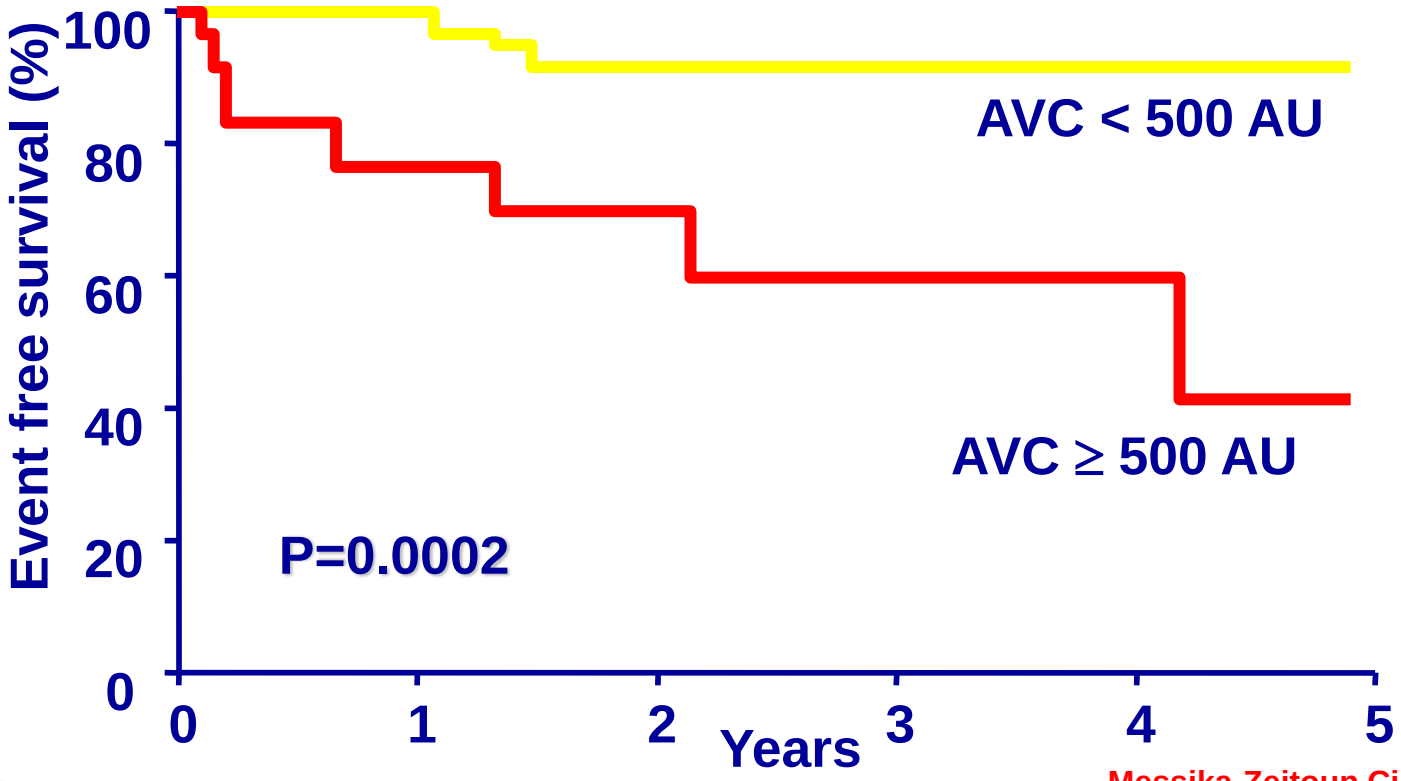
Prognostic value of AVC
Echocardiographic assessment



Rosenhek NEJM 2000

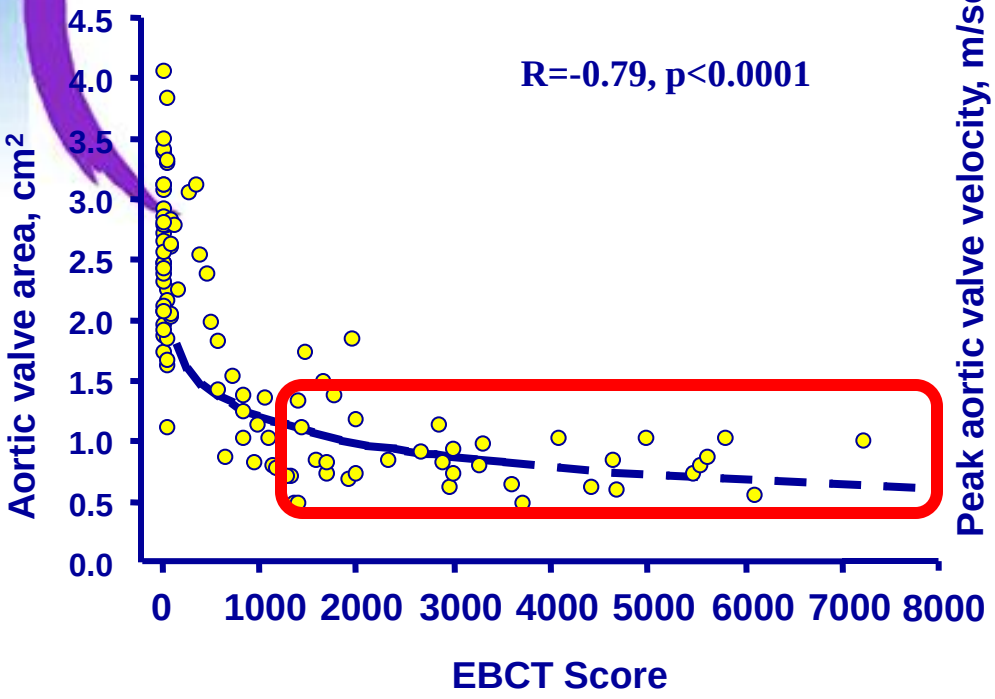
Prognostic value of AVC
EBCT assessment

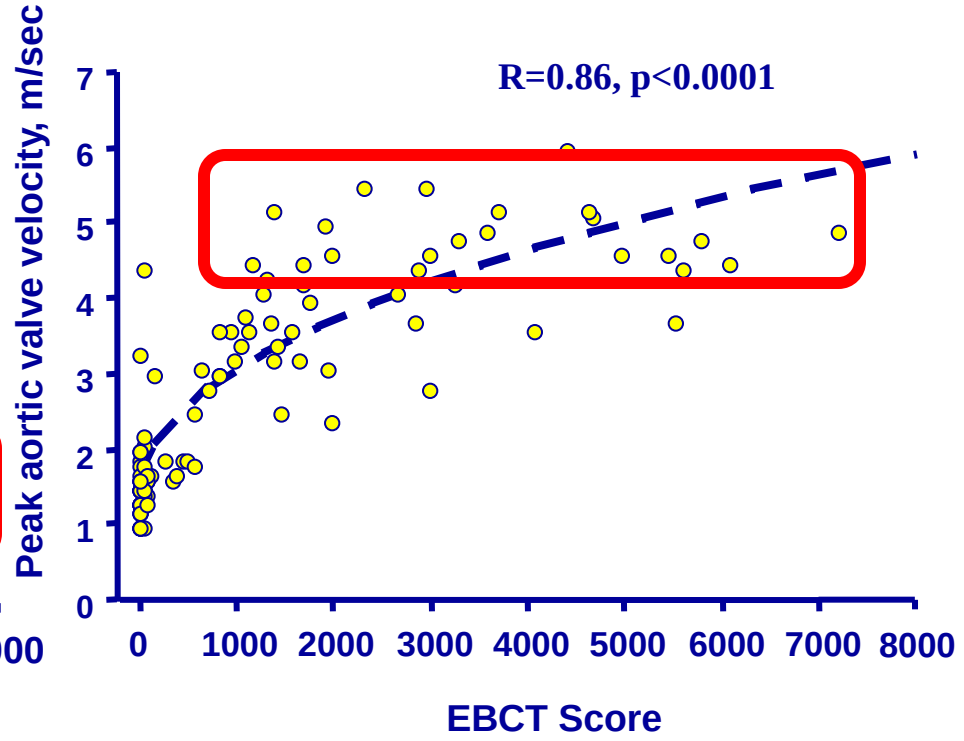
AVC and hemodynamic severity provide complementary prognostic information



Messika-Zeitoun Circulation 2004

AVC and Hemodynamic Severity are Not Equivalent

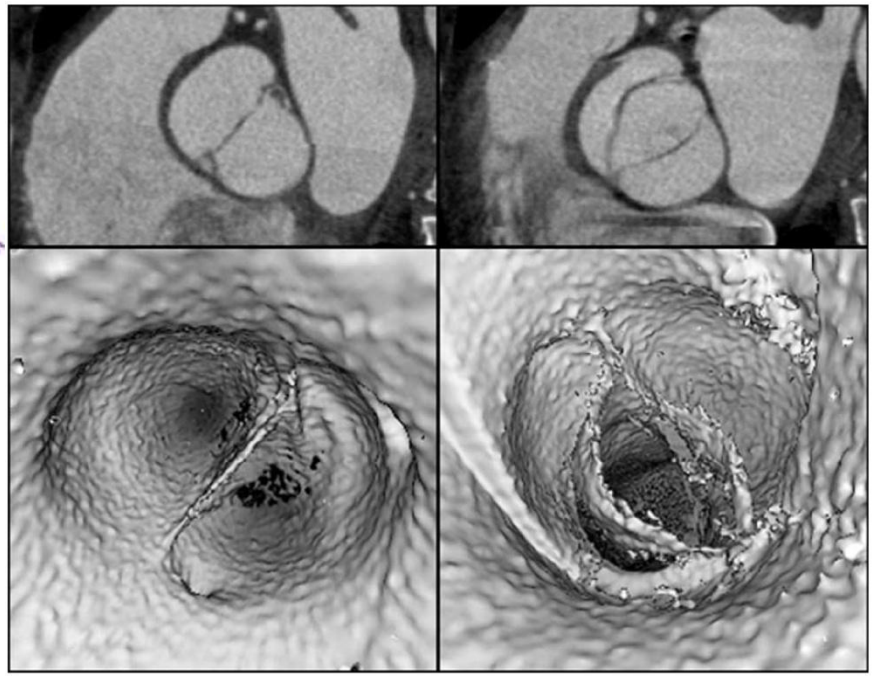




Messika-Zeitoun Circulation 2004

Valve Anatomy

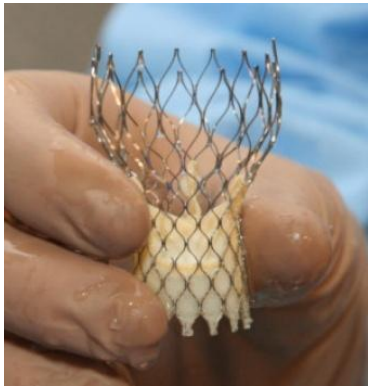
Scanner
Bicuspid vs. Tricuspid



Bouvier, EHJ 2006

Alkhadi, Radiology 2006

Transcatheter Aortic Valve Implantation (TAVI)



Vascular Access

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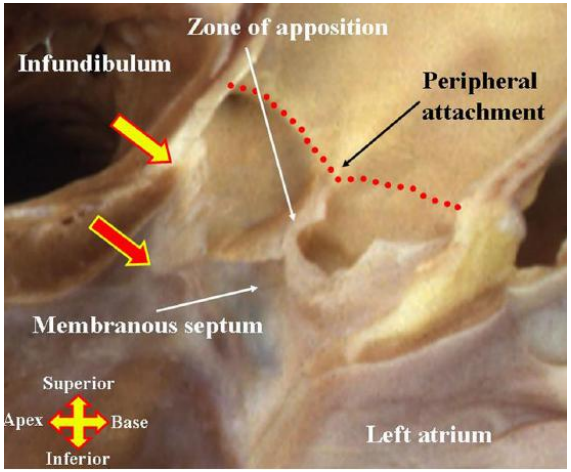
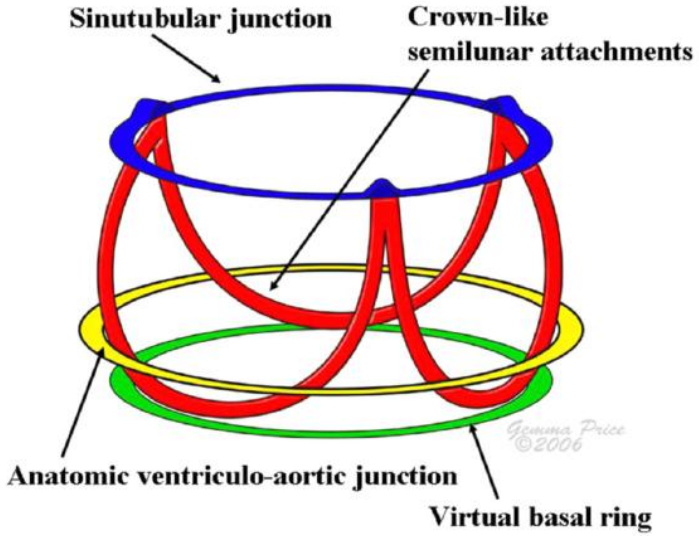
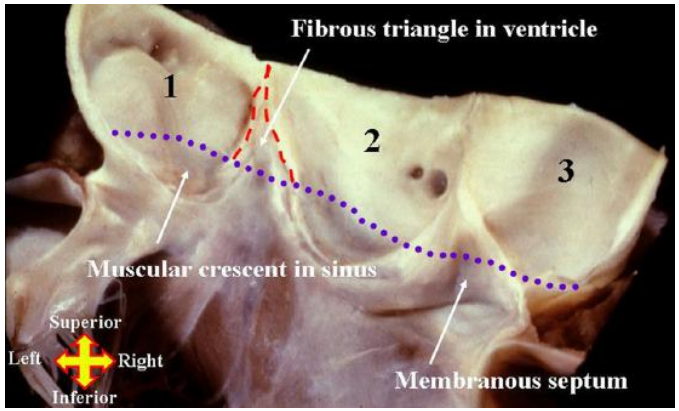
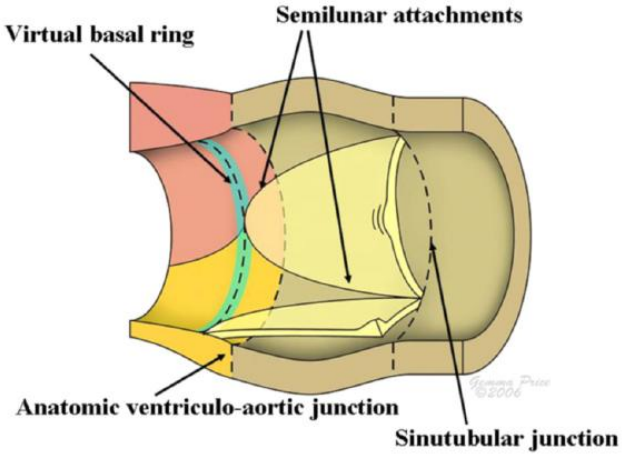
Safety Issue

The Aortic Annulus is not a Ring …

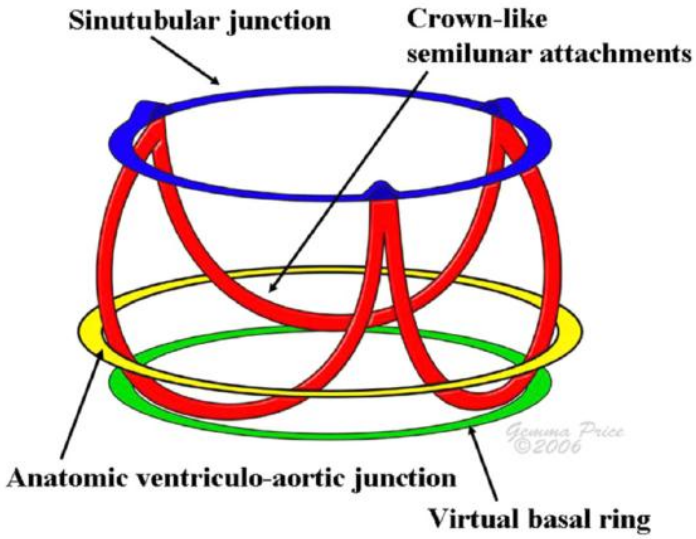




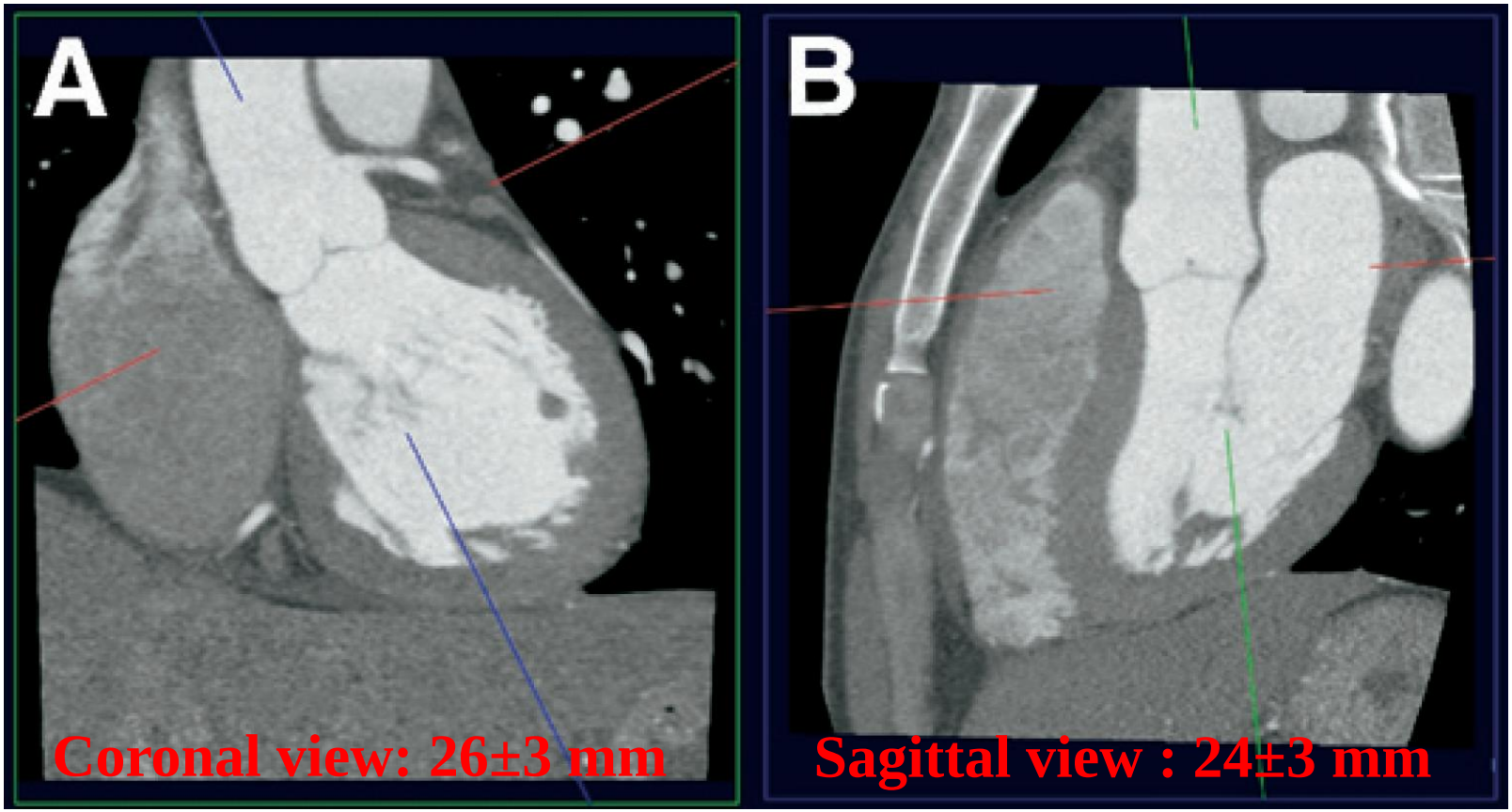


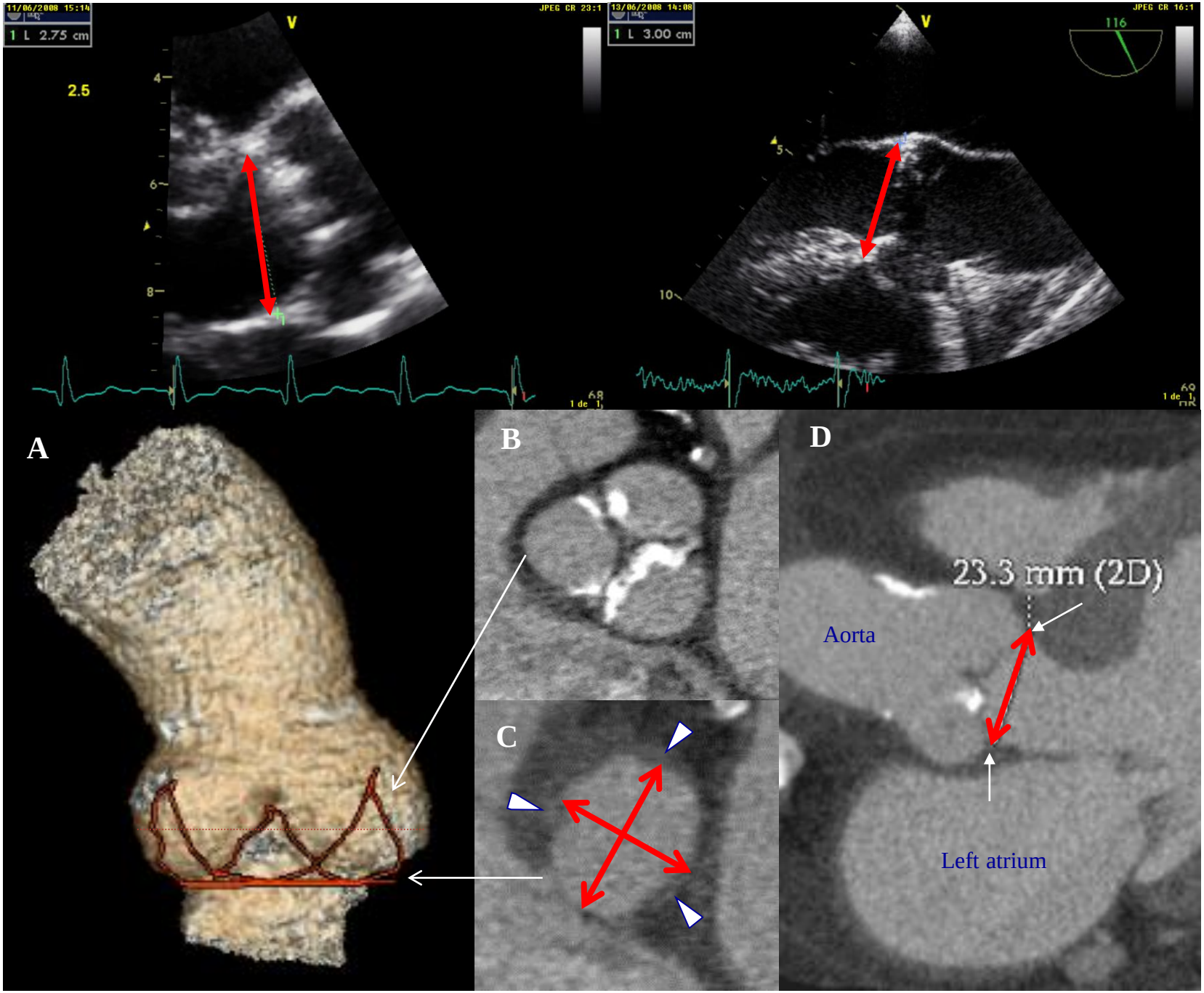


Anderson Multimedia Manual of Cardiothoracic Surgery 2006


Sinutubular junction
Crown-like
semilunar attachments
Anatomic ventriculo-aortic junction
Virtual basal ring
Gemma Price
©2006

Ovale Shape




A
B
C
D
23.3 mm (2D)
Aorta
Left atrium

	Annulus Diameter	vs. TTE		vs. TEE	
		P	R	P	R
ECHOCARDIOGRAPHY					
TTE	23.9±2.1	-	-	0.13	0.89
TEE	24.1±2.1	0.13	0.89	-	-
CT					
PLAN BASAL					
Long axis	27.5±3.1	<0.0001	0.69	<0.0001	0.67
Short axis	21.7±2.3	<0.0001	0.73	<0.0001	0.69
Mean	24.6±2.4	0.004	0.80	0.07	0.77
3 CAVITY	23.8±2.6	0.73	0.71	0.26	0.70

Implantation Strategy

26 mm Prosthesis

23 mm Prosthesis

18 **21** **25**

Aortic annulus diameter

	Strategy of implantation			Agreement with TTE		Agreement with TEE	
	23 mm Prosthesis	26 mm Prosthesis	No implantation	%	Kappa	%	Kappa
Echography							
TTE	5	29	11	-	-	83%	0.68
TEE	6	25	14	83%	0.68	-	-
CT							
BASAL							
Long axis	0	10	35	36%	0.03	42%	0.07
Short axis	16	21	8	47%	0.13	42%	0.09
Mean	4	24	17	62%	0.32	62%	0.34
3 CAVITY	7	25	13	60%	0.28	58%	0.27

3-Dimensional Aortic Annular Assessment by Multidetector Computed Tomography Predicts Moderate or Severe Paravalvular Regurgitation After Transcatheter Aortic Valve Replacement

A Multicenter Retrospective Analysis

Alexander B. Willson, MBBS, MPH,* John G. Webb, MD,* Troy M. LaBounty, MD,† Stephan Achenbach, MD,‡ Robert Moss, MBBS,* Miriam Wheeler, MBBS,* Christopher Thompson, MD,* James K. Min, MD,† Ronen Gurvitch, MBBS,* Bjarne L. Norgaard, MD, Cameron J. Hague, MD,* Stefan Toggweiler, MD,* Ronald Binder, MD,* Melanie Freeman, MBBS,* Rohan Poulter, MBBS,* Steen Poulsen, MD,§ David A. Wood, MD,* Jonathon Leipsic, MD*

Table 4 The Relationship Between Undersizing a THV Relative to the MDCT Annular Size and Increasing Grade of PAR

Grade of PAR	THV Diameter – Mean Annular Diameter (mm)	Percentage Difference Between the THV Area and Annular Area*
None/trivial	1.5 ± 1.8	14.2 ± 18.3
Mild	0.4 ± 1.8	4.3 ± 14.2
Moderate/severe	−0.7 ± 1.4	−7.0 ± 9.5
p value	<0.01	<0.01

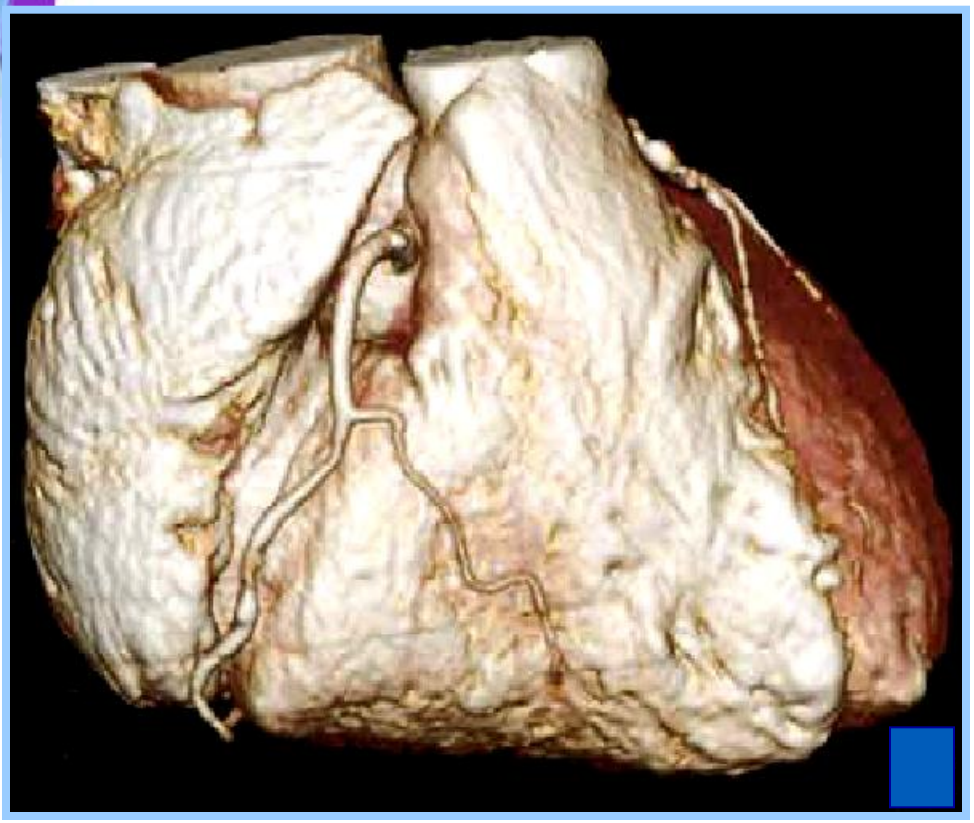
/alues are mean ± SD and measured in systole. *A positive percentage represents the amount hat the THV area is greater than the annular area. Conversely, a negative percentage represents he amount that the THV area is less than the annular area. Calculated by (THV area/annular ırea – 1) × 100.

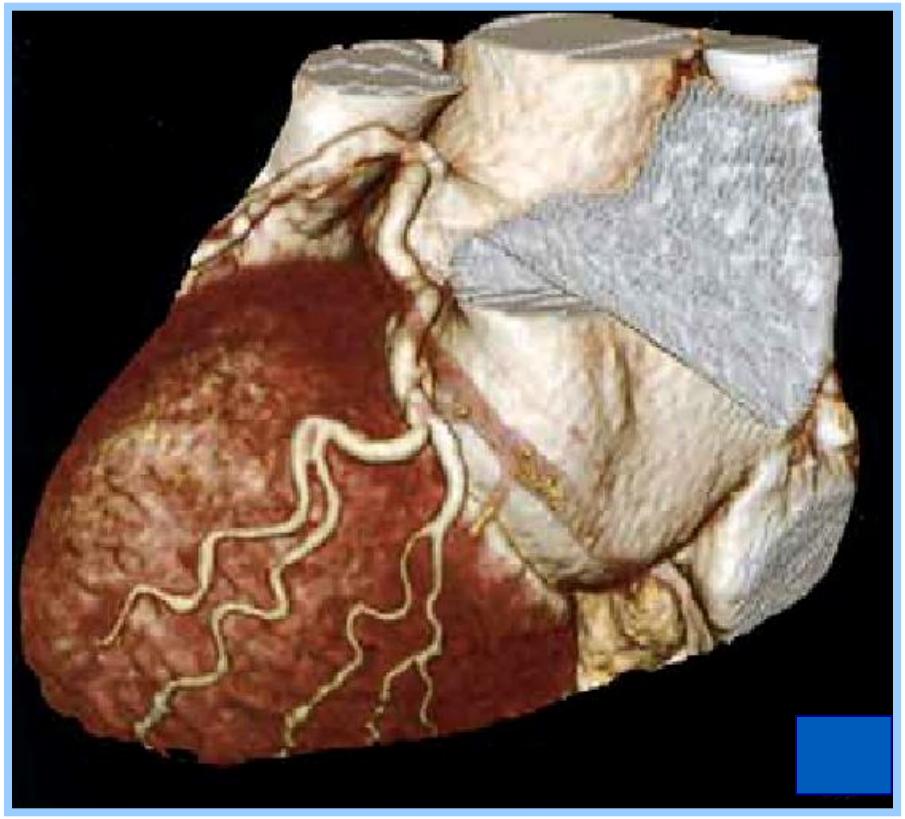
Table 5 Clinical, Procedural, and Echocardiographic Characteristics of Undersized (THV Nominal Area < MDCT Area) Versus Oversized THV (THV Nominal Area > MDCT Area)

	Undersized (n = 46)	Oversized (n = 56)	p Value
Clinical characteristics			
Age, yrs	80.1 ± 9.2	82.2 ± 7.5	0.22
Sex			0.05
Female	19 (41.3%)	32 (57.1%)	
Male	27 (58.7%)	24 (42.9%)	
STS PROM	6.9 ± 3.7	6.4 ± 3.3	0.47
GFR, ml/min	53.6 ± 22.1	58.7 ± 21.2	0.25
Height, cm	167.1 ± 22.6	166.4 ± 11.0	0.86
Weight, kg	80.7 ± 24.2	74.3 ± 18.3	0.20
Procedural characteristics			
PAR			
None/trivial	13 (28.3%)	34 (60.7%)	<0.01
Mild	24 (52.2%)	18 (32.1%)	0.02
Moderate or severe	9 (19.6%)	4 (7.1%)	0.04
Post-TAVR mean aortic valve area, cm^2	1.45 ± 0.26	1.55 ± 0.31	0.13
Post-TAVR mean aortic gradient, mm Hg	11.5 ± 4.7	10.8 ± 4.0	0.48
PAR			
None/trivial	13 (28.3%)	34 (60.7%)	<0.01
Mild	24 (52.2%)	18 (32.1%)	0.02
Moderate or severe	9 (19.6%)	4 (7.1%)	0.04

Comprehensive Evaluation of AS

CT Coronary Angiography



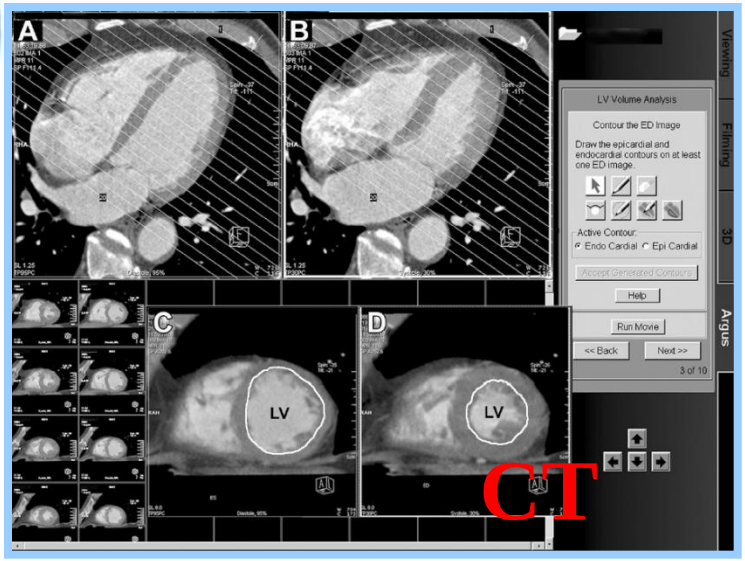


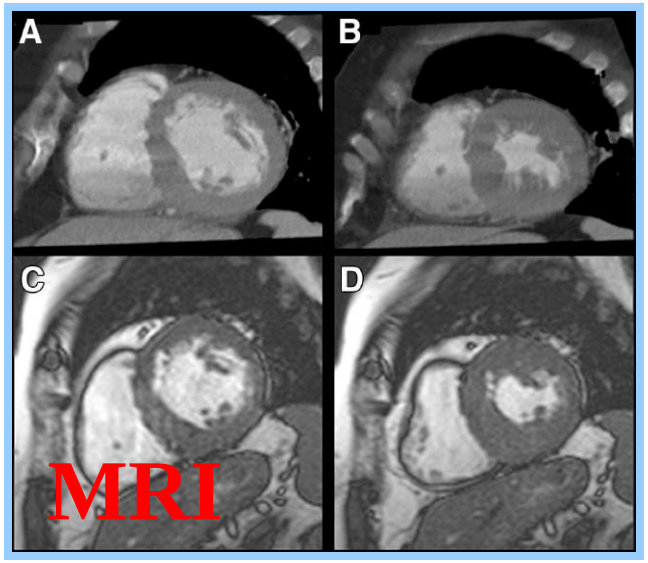
Mollet JACC 2004

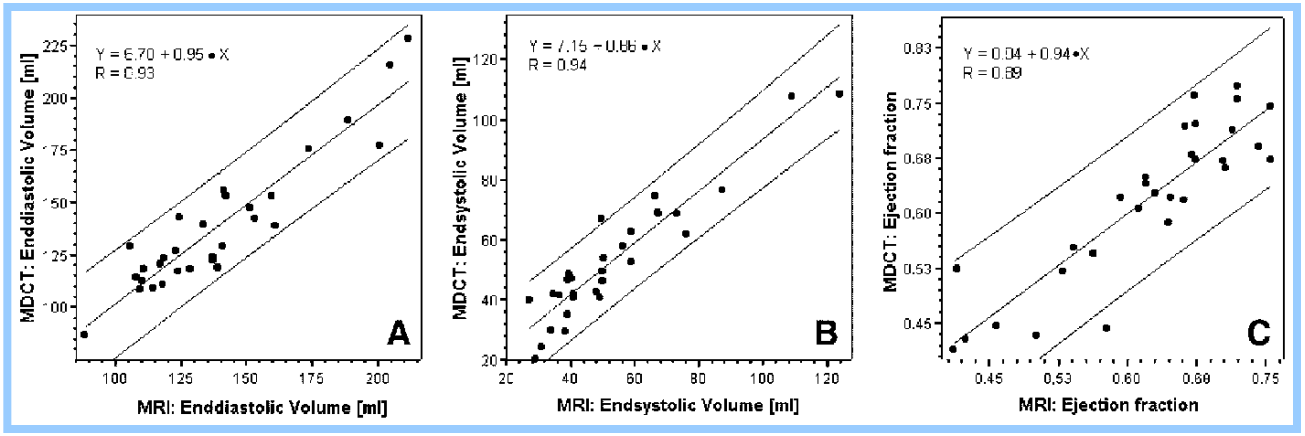
CT Coronary Angiography in AS

	Gilard	Reant	Laissy
N of patients	55	40	40
Prevalence of coronary stenosis (coronary angiogram)	20	32.5	33
Sensibility, %	100	85	85
Specificity, %	80	78	93
Positive predictive value, %	55	67	85
Negative predictive value, %	100	96	93

Left Ventricular Volumes and Ejection Fraction







Juergens Radiology 2004

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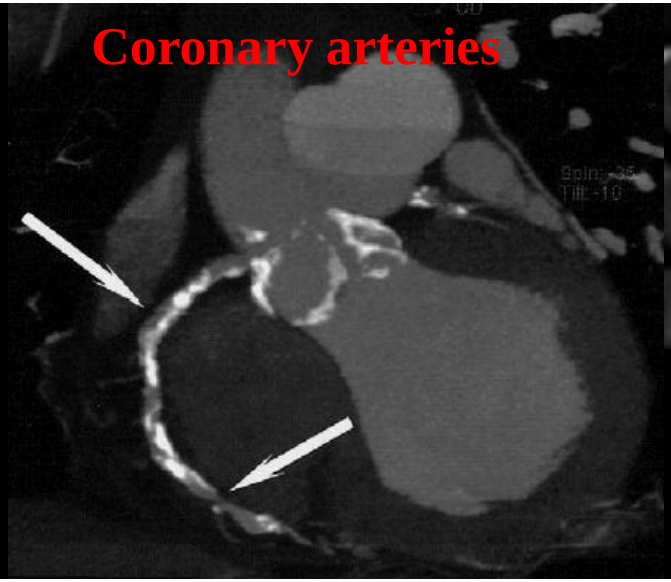
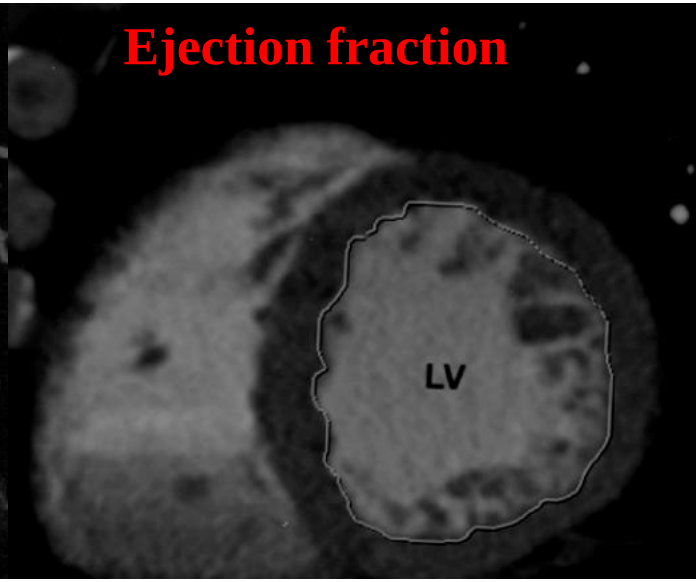
Comprehensive Evaluation

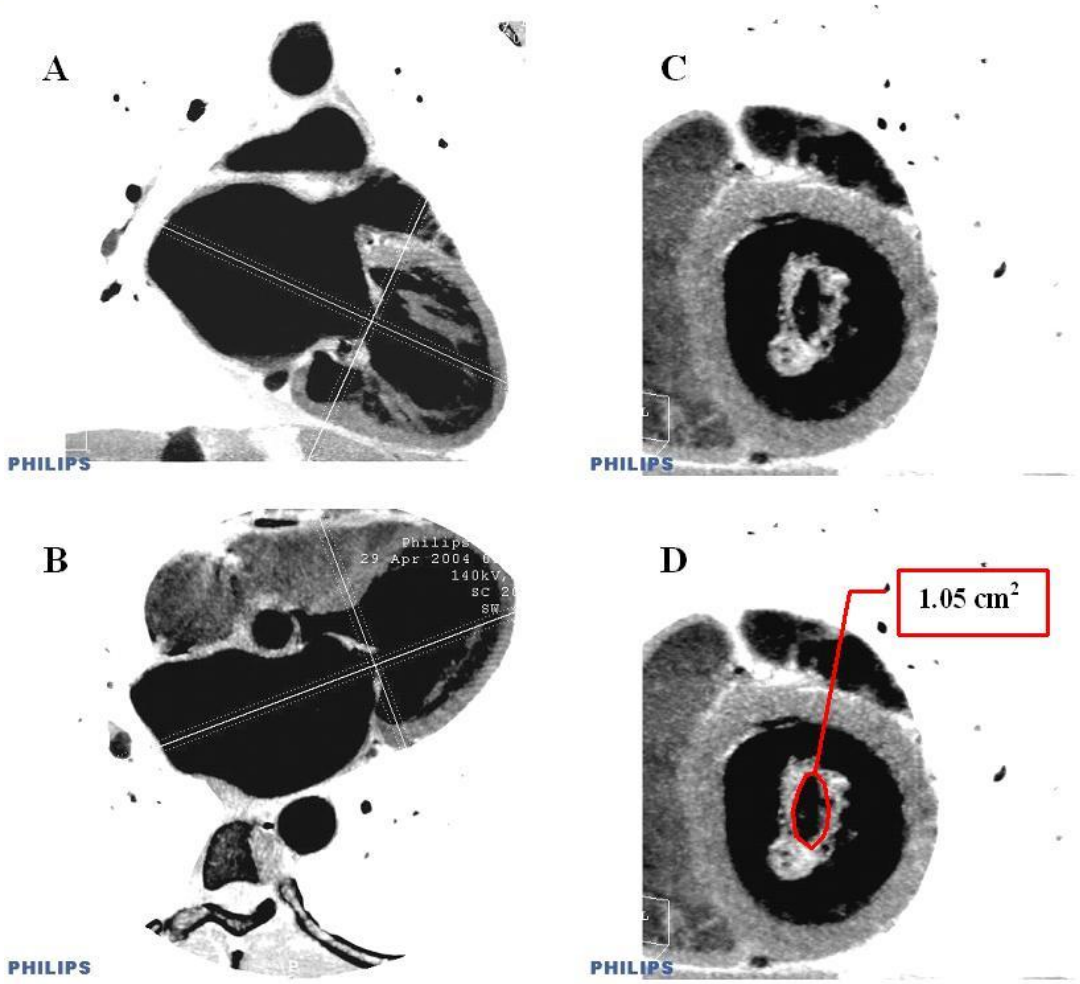




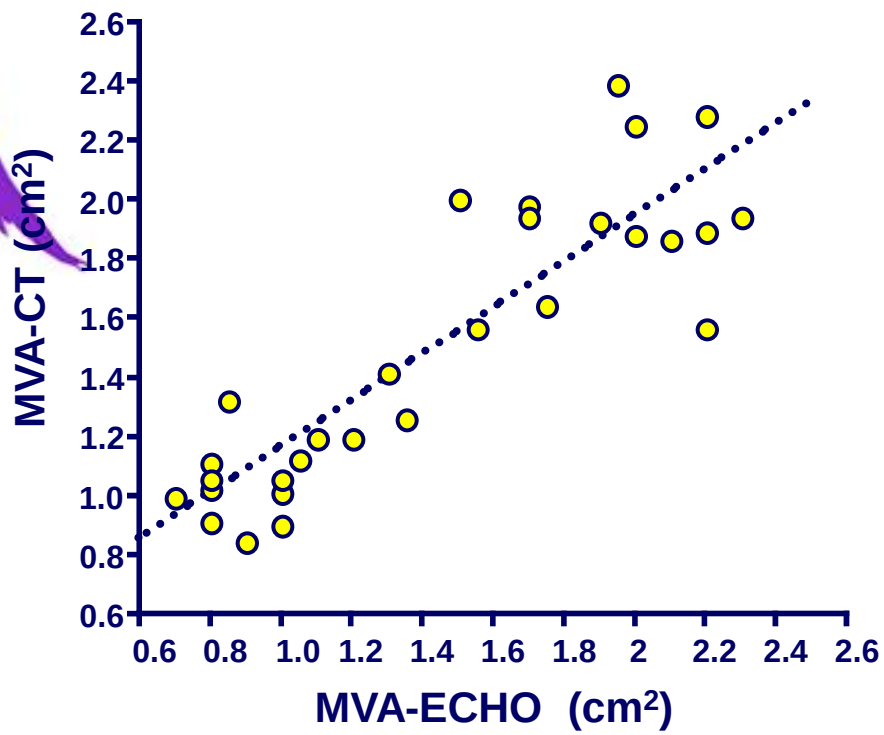
Mitral Stenosis

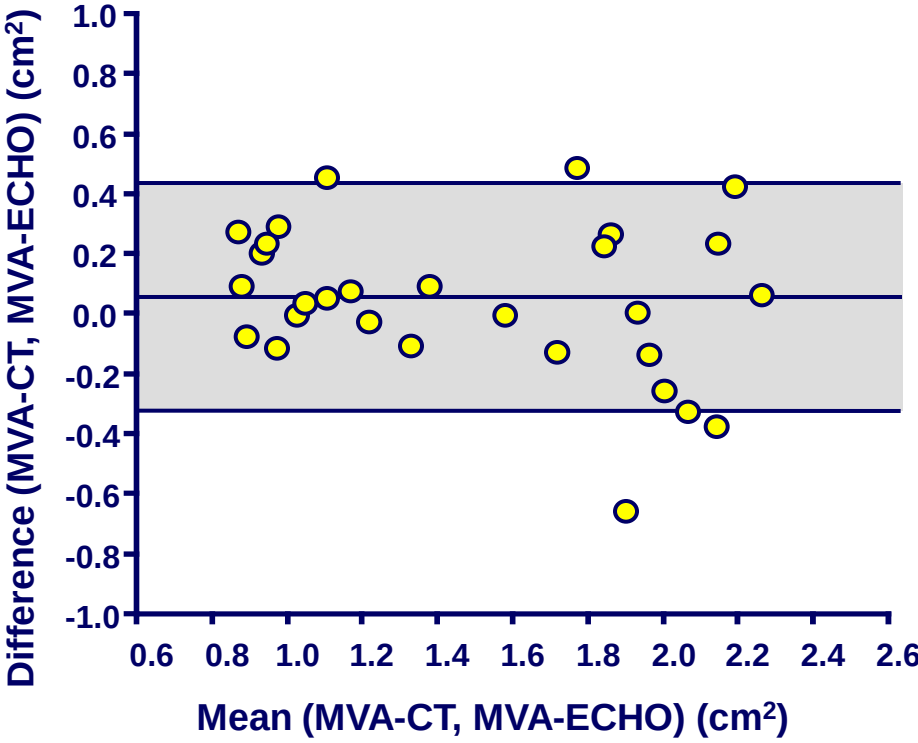
Mitral Valve Area

- 29 patients
- Sinus Rhythm
- MVA_{ECHO} : $1.44 \pm 0.53\ cm^2$ (0.7- 2.3)
- Early diastole



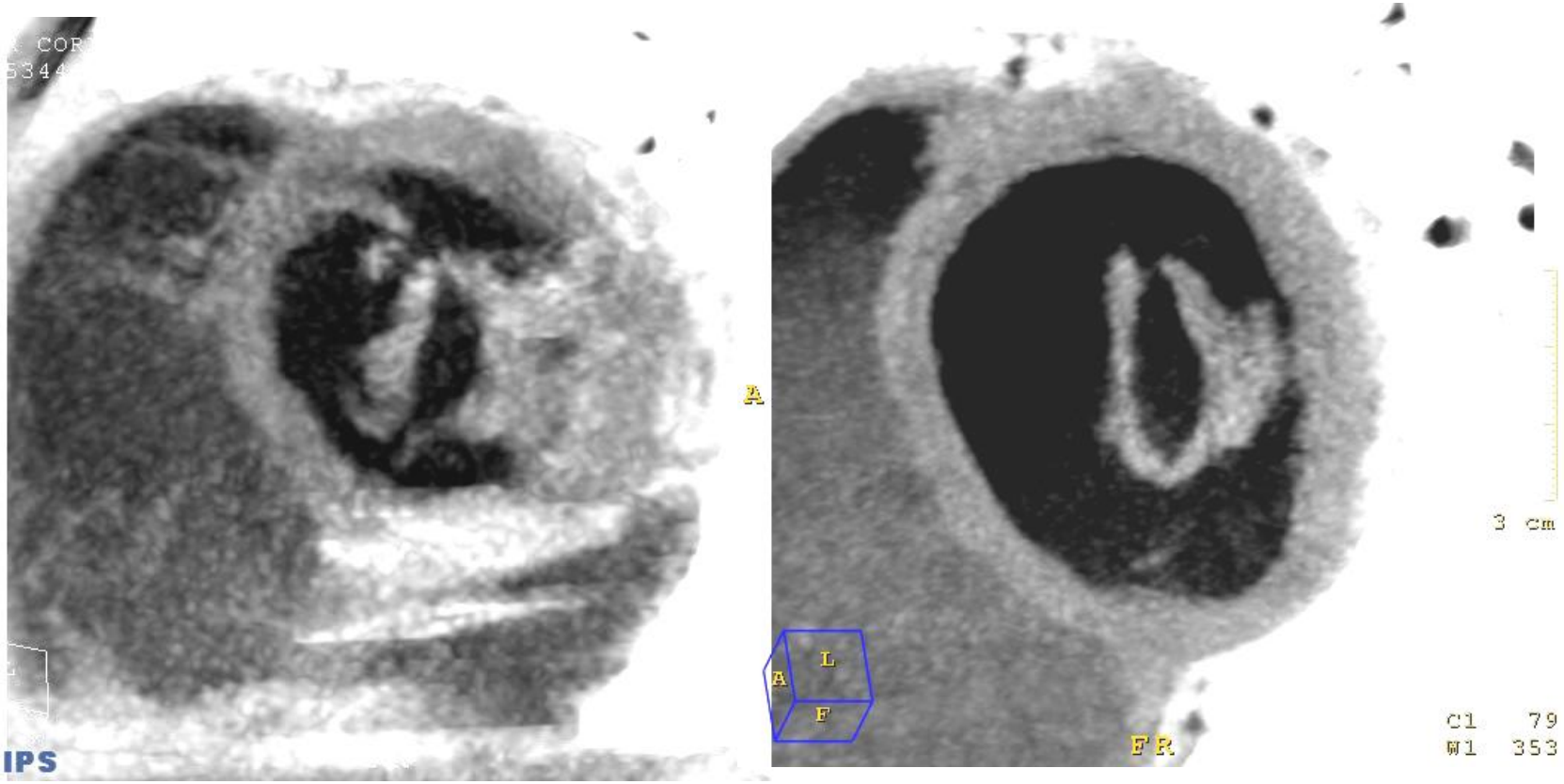
MVA – Experienced Operator



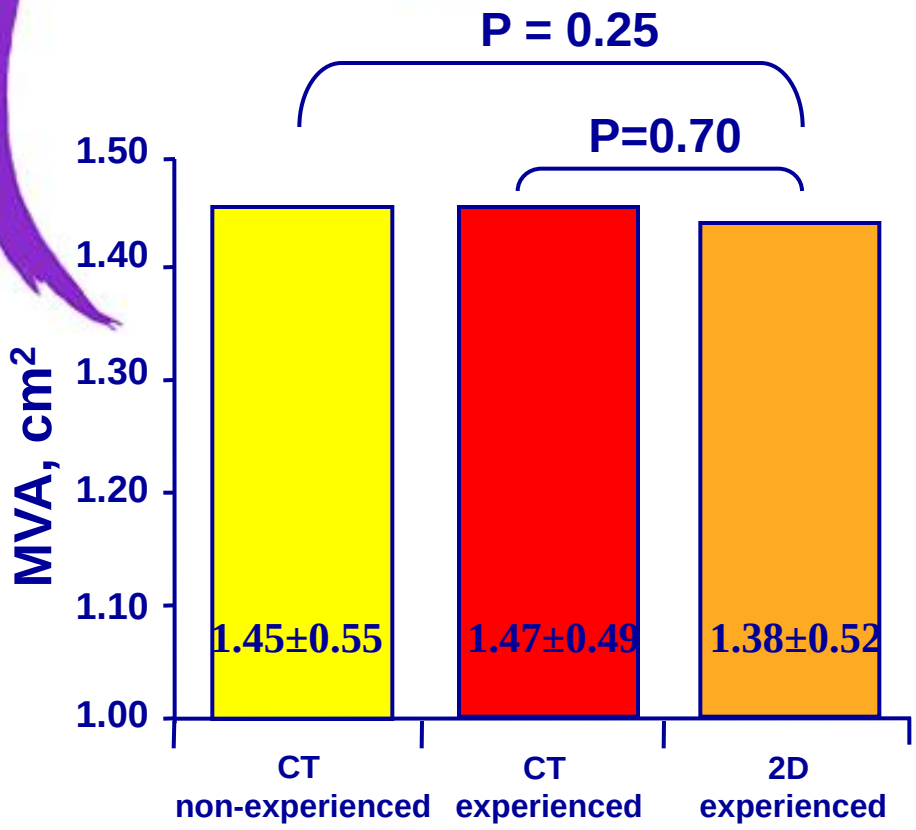


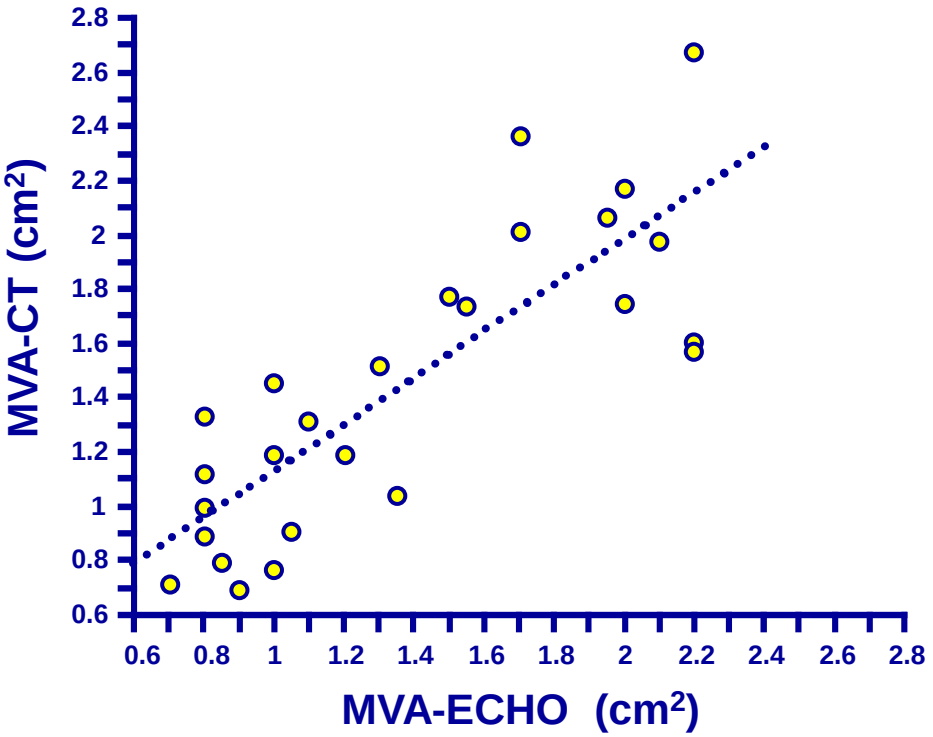
Messika-Zeitoun, JACC 2006

Examples



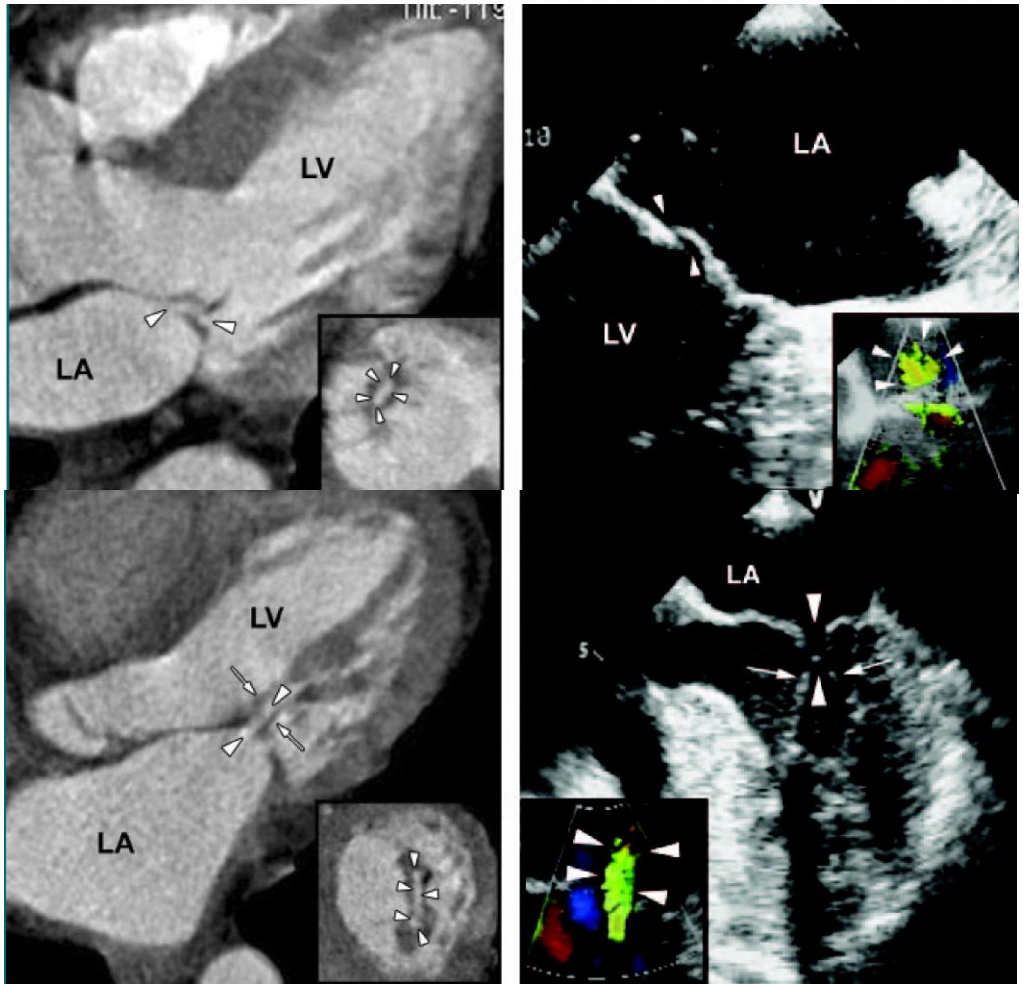
MVA – Non-experienced Operator





Work in Progress

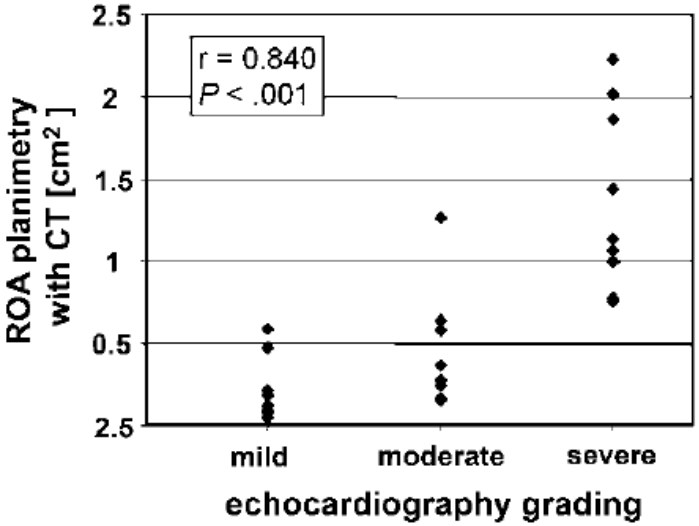
Mitral Insufficiency

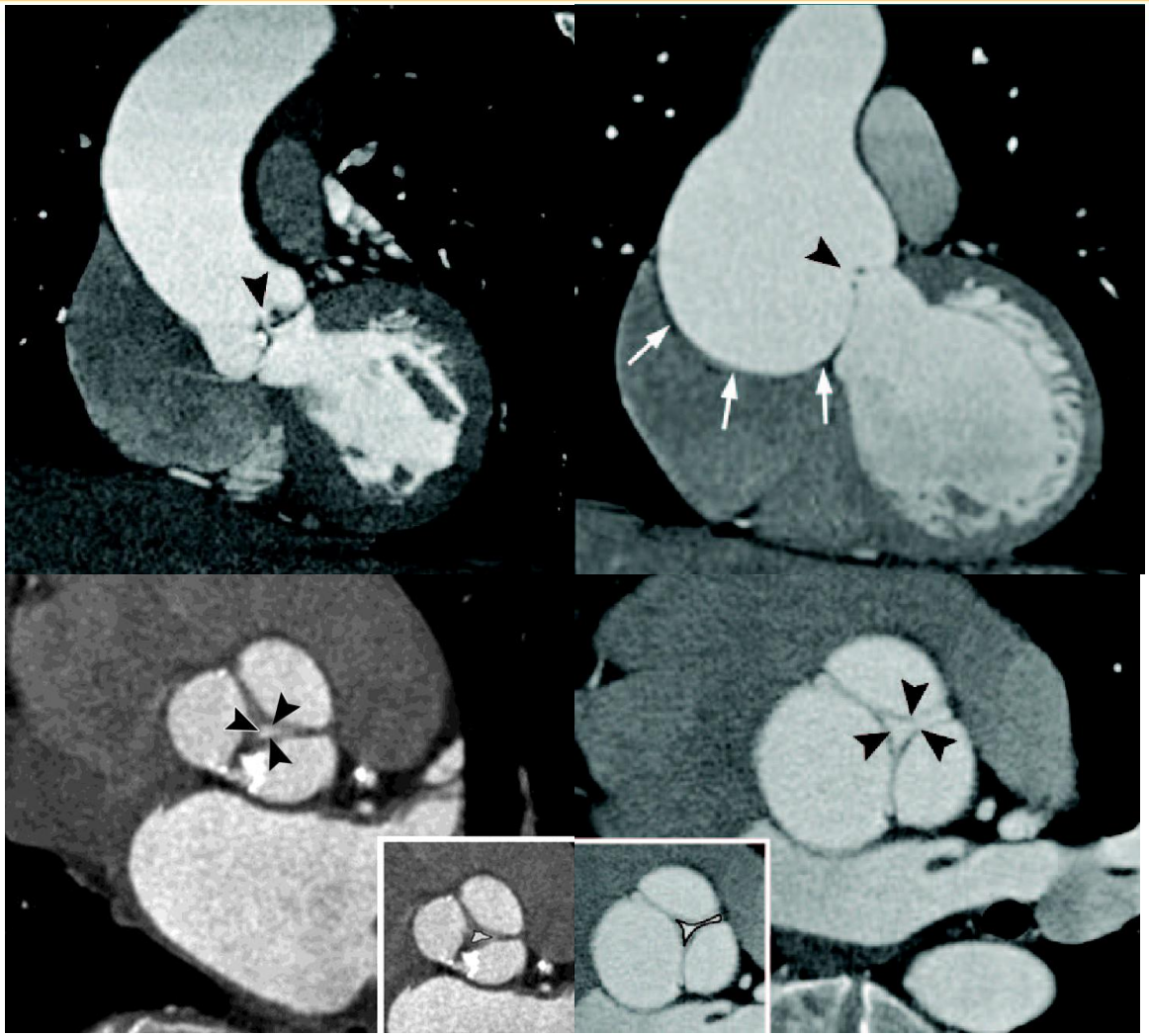


Alkhadi, Radiology 2005

Aortic Insufficiency

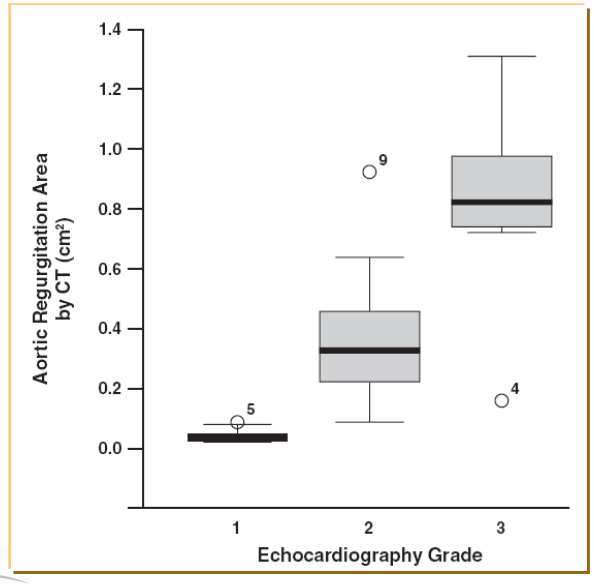
Alkhadi, Radiology 2005



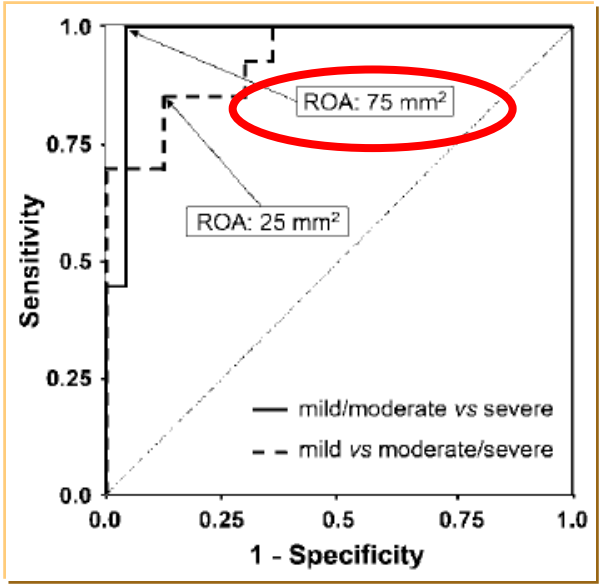


Limits

- Image Quality
- Exclusion of patients in AF
- Reference method debatable: semi-quantitative echocardiography or angiography
- Thresholds

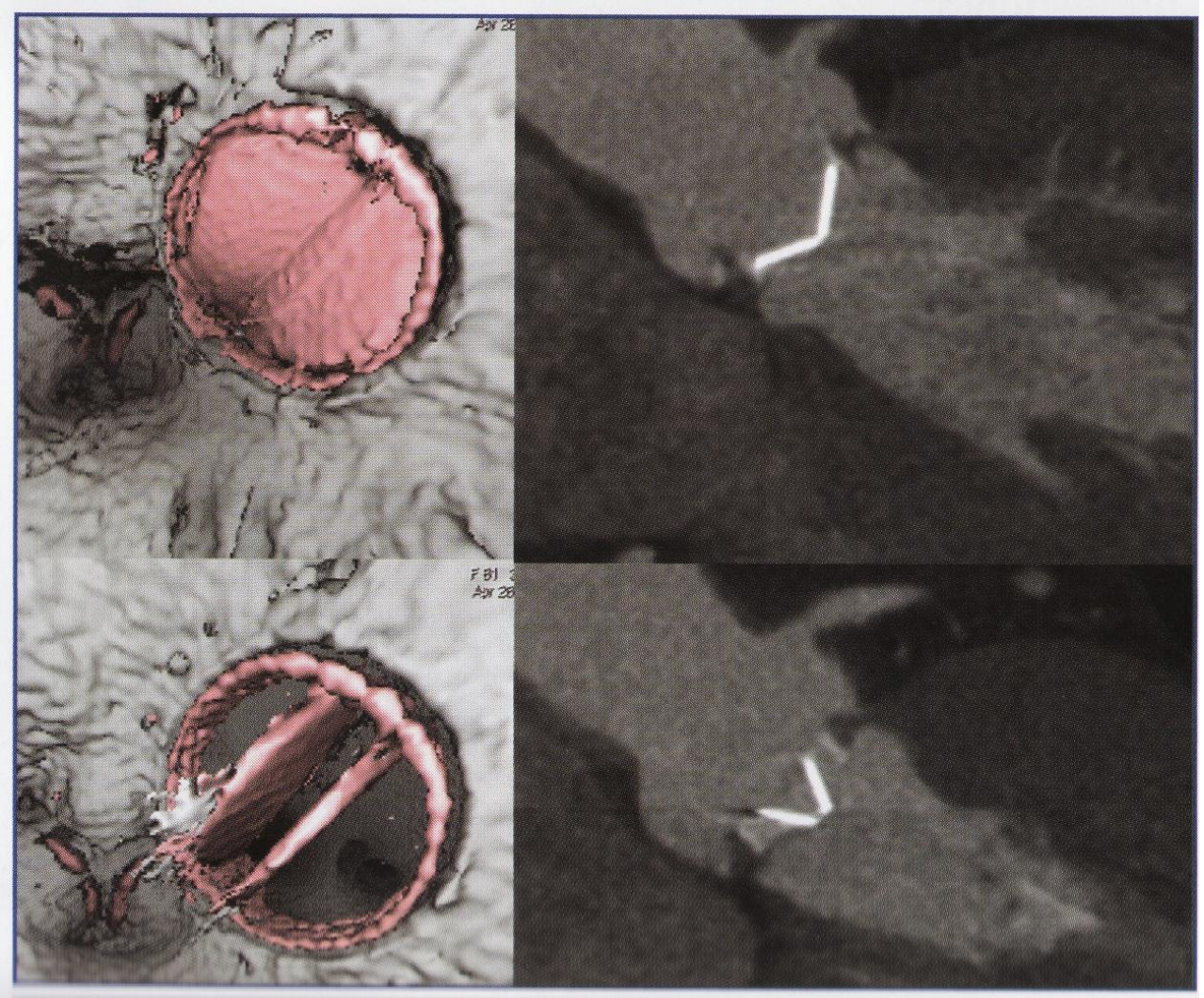


FEUCHTNER AJR 2008

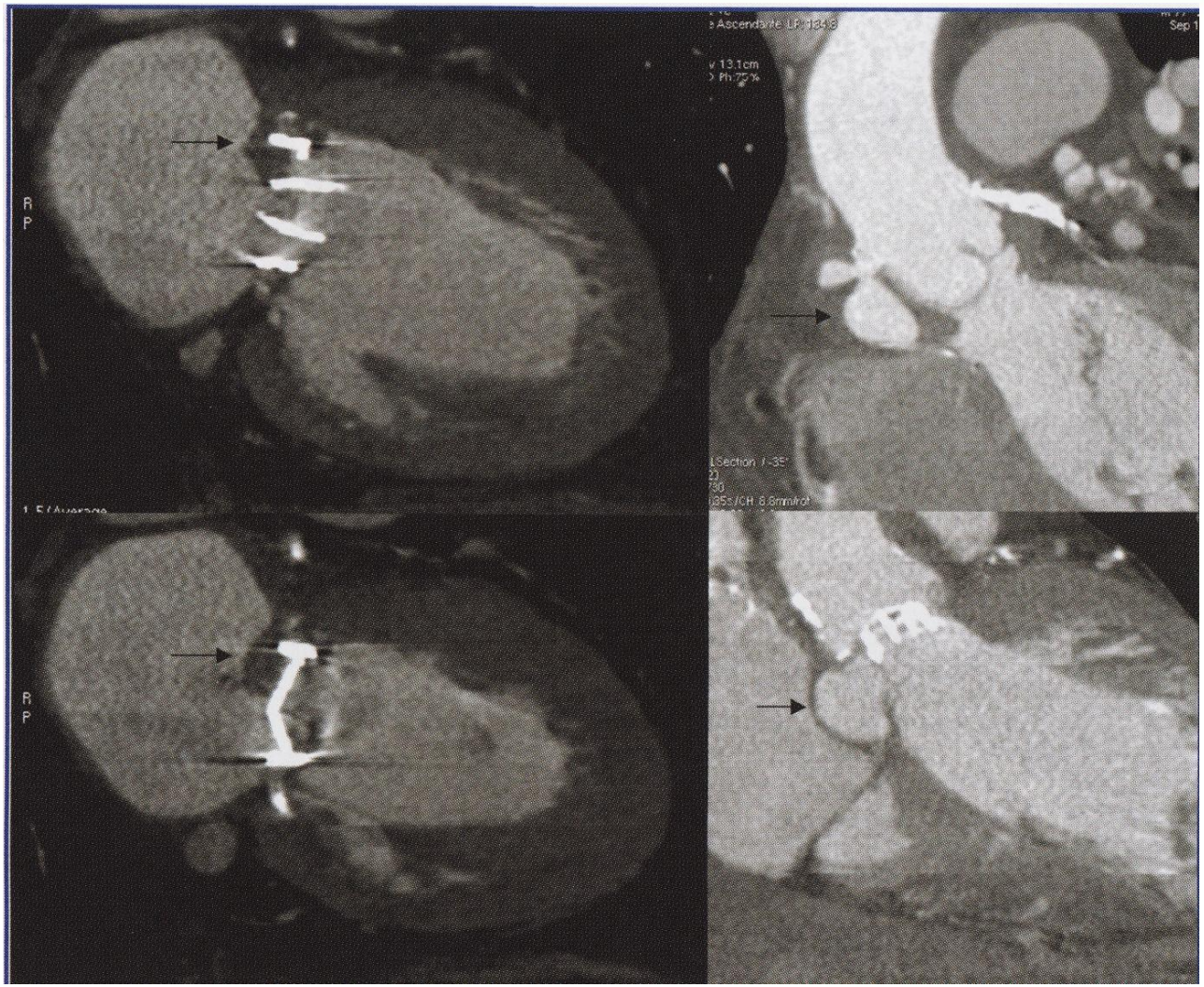


Alkhadi, Radiology 2007

Prosthetic Valves



Infective Endocarditis



Conclusion

First Line Examination

- Calcium Scoring in patients in low gradient low ejection fraction
- TAVI

Seconde Line Examination

- Aortic Valve Area
- CT coronary angiography
- Ejection fraction
- Mitral valve area
- Mitral and aortic insufficiency , Prosthesis, Infective endocarditis?


Thank You