Echocardiographic Evaluation of Left Atrial Function

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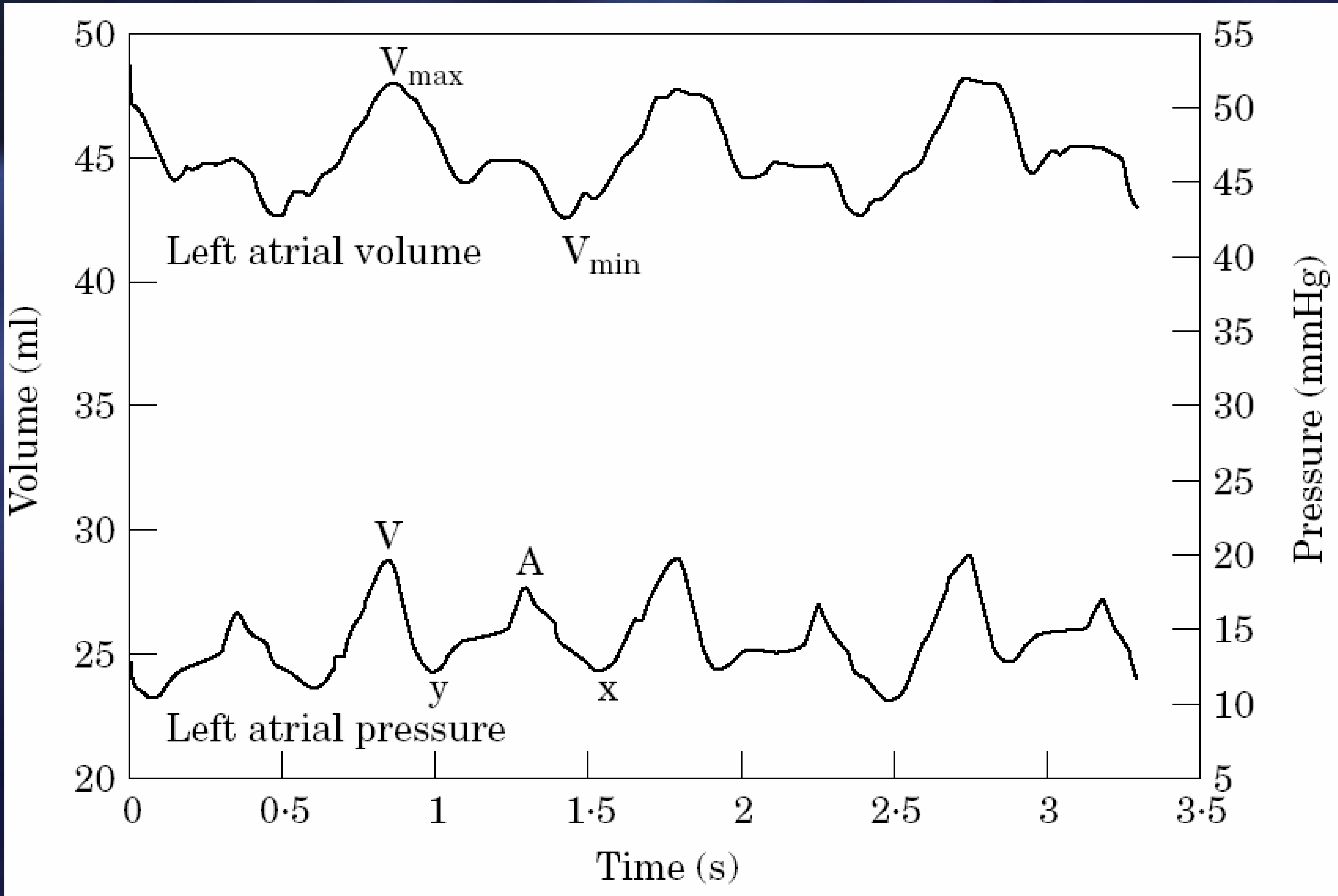
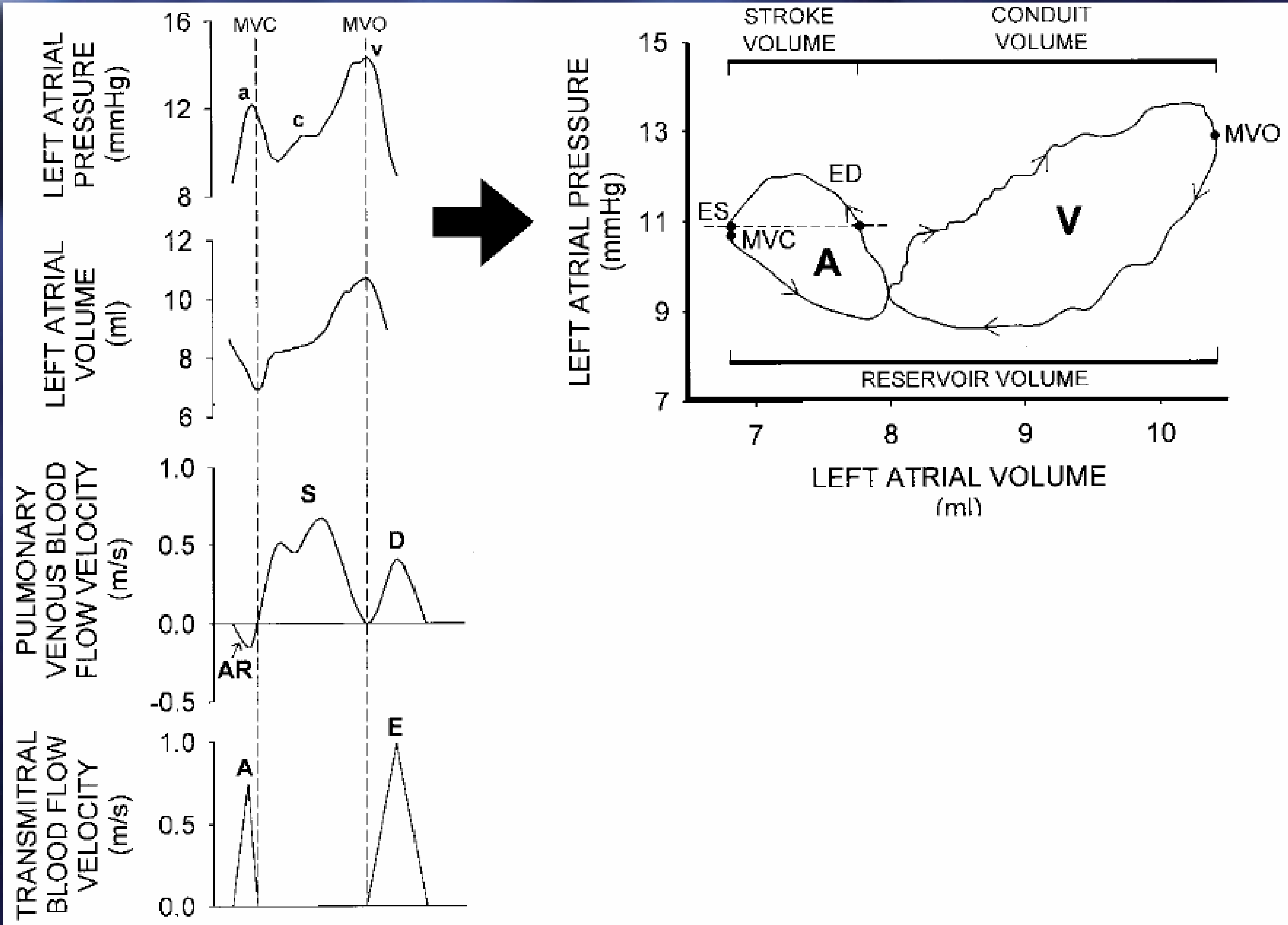
박 승 우

Three Components

- Reservoir during systole
- Conduit during diastole
- Active contraction during late diastole



50
45
40
35
30
25
20
Volume (ml)
55
50
45
40
35
30
25
20
15
10
5
Pressure (mmHg)
Vmax
Vmin
Left atrial volume
V
A
y
x
Left atrial pressure
0
0·5
1
1·5
2
2·5
3
3·5
Time (s)


LEFT ATRIAL PRESSURE (mmHg)
16
12
8
MVC
MVO
a
c
v
LEFT ATRIAL VOLUME (ml)
12
10
8
6
PULMONARY VENOUS BLOOD FLOW VELOCITY (m/s)
1.0
0.5
0.0
-0.5
S
D
AR
TRANSMITRAL BLOOD FLOW VELOCITY (m/s)
1.0
0.5
0.0
A
E
STROKE VOLUME
CONDUIT VOLUME
15
13
11
9
7
LEFT ATRIAL PRESSURE (mmHg)
ED
ES
MVC
MVO
A
V
RESERVOIR VOLUME
7
8
9
10
LEFT ATRIAL VOLUME (ml)

Echocardiographic Variables

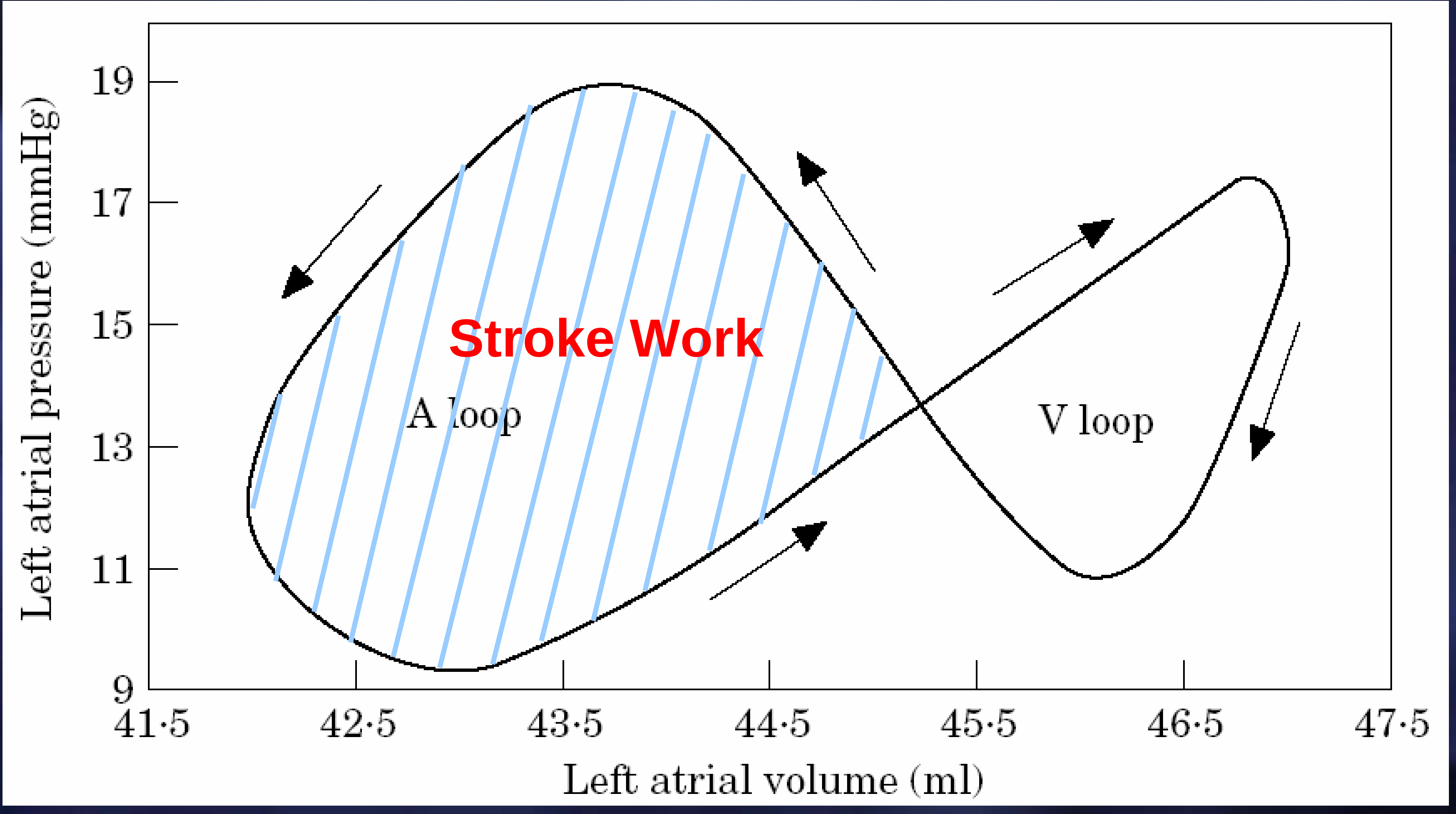
- **Indirectly derived LA variables**
  - **LA ejection force**
  - **LA kinetic energy**
  - **Estimated LA dP/dt_{max}**
- **Pulsed wave Doppler**
  - **Transmitral velocities at atrial contraction**
  - **Atrial reversal velocities at pulmonic vein**
- **Tissue Doppler**
  - **Mitral annular velocity at atrial contraction**
  - **LAA wall velocity**

Echocardiographic Variables

- LA size quantitation
  - LA volume
    - Maximal LA volume
    - Total volume of LA emptying
    - Volume of LA emptying during active atrial contraction
  - LA area
    - + phasic LA area change by AQ technique
  - LA dimension

Volumes According to Phasic Changes

1. Maximum LA volume; volume just before MV opening
2. Minimum LA volume; volume at MV closure
3. Total LA emptying volume (Reservoir volume)
   maximum LA volume - minimum LA volume
4. LA passive emptying volume
   maximal LA volume - pre-atrial contraction LA volume
   (at the onset of the P-wave on ECG)
5. LA active emptying (contractile) volume = LA stroke volume
   pre-atrial contraction LA volume - minimum LA volume
6. LA (passive) conduit volume
   LV stroke volume - the total LA emptying volume
7. LAEF = 5 / pre-atrial contraction LA volume



Stroke Work
A loop
V loop
Left atrial pressure (mmHg)
19
17
15
13
11
9
41·5
42·5
43·5
44·5
45·5
46·5
47·5
Left atrial volume (ml)

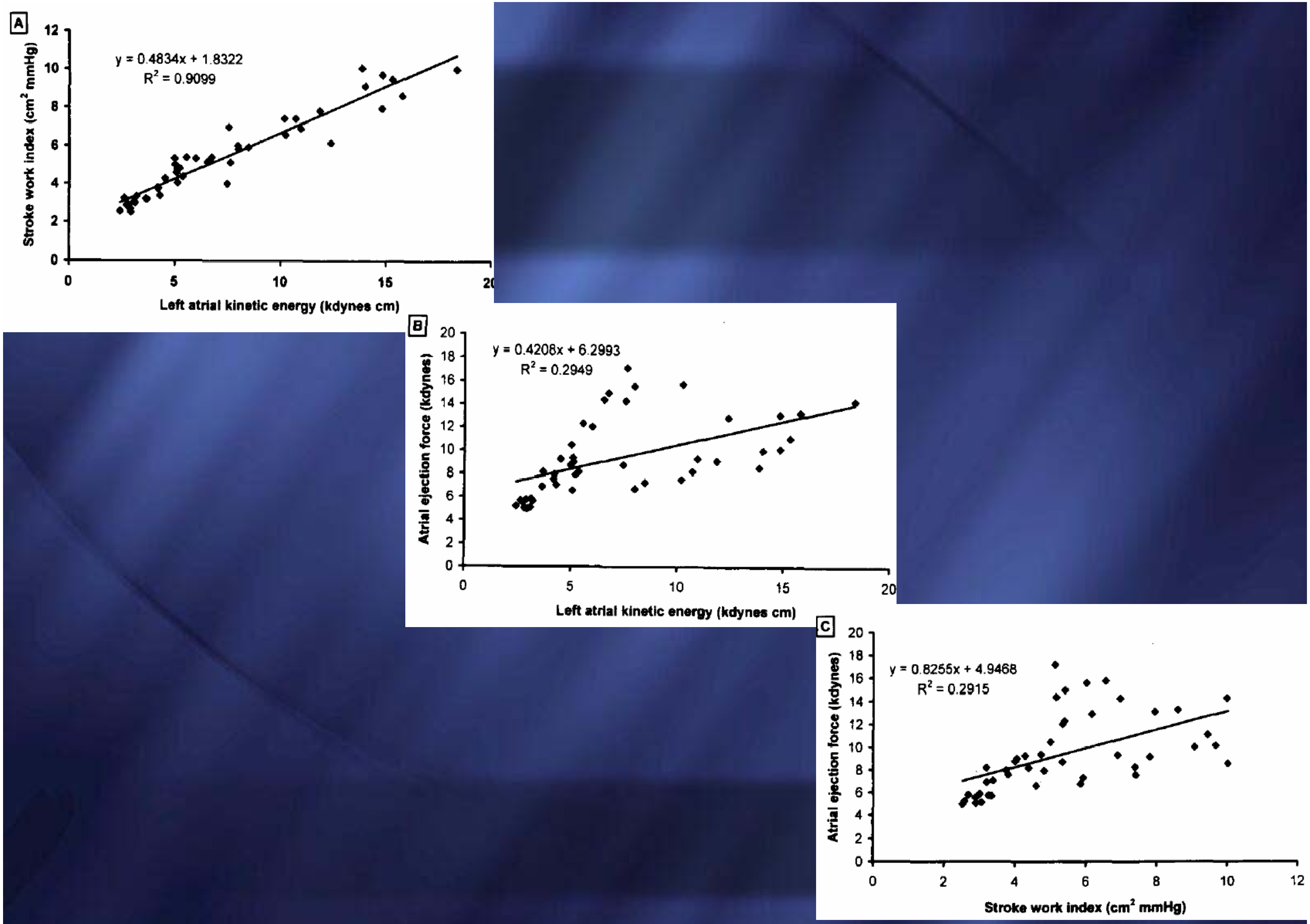
- **LA ejection force (kdyne)**

  = 0.5 x 1.06 x mitral annulus area x (peak A velocity^2)

- **LA kinetic energy (kerg)**

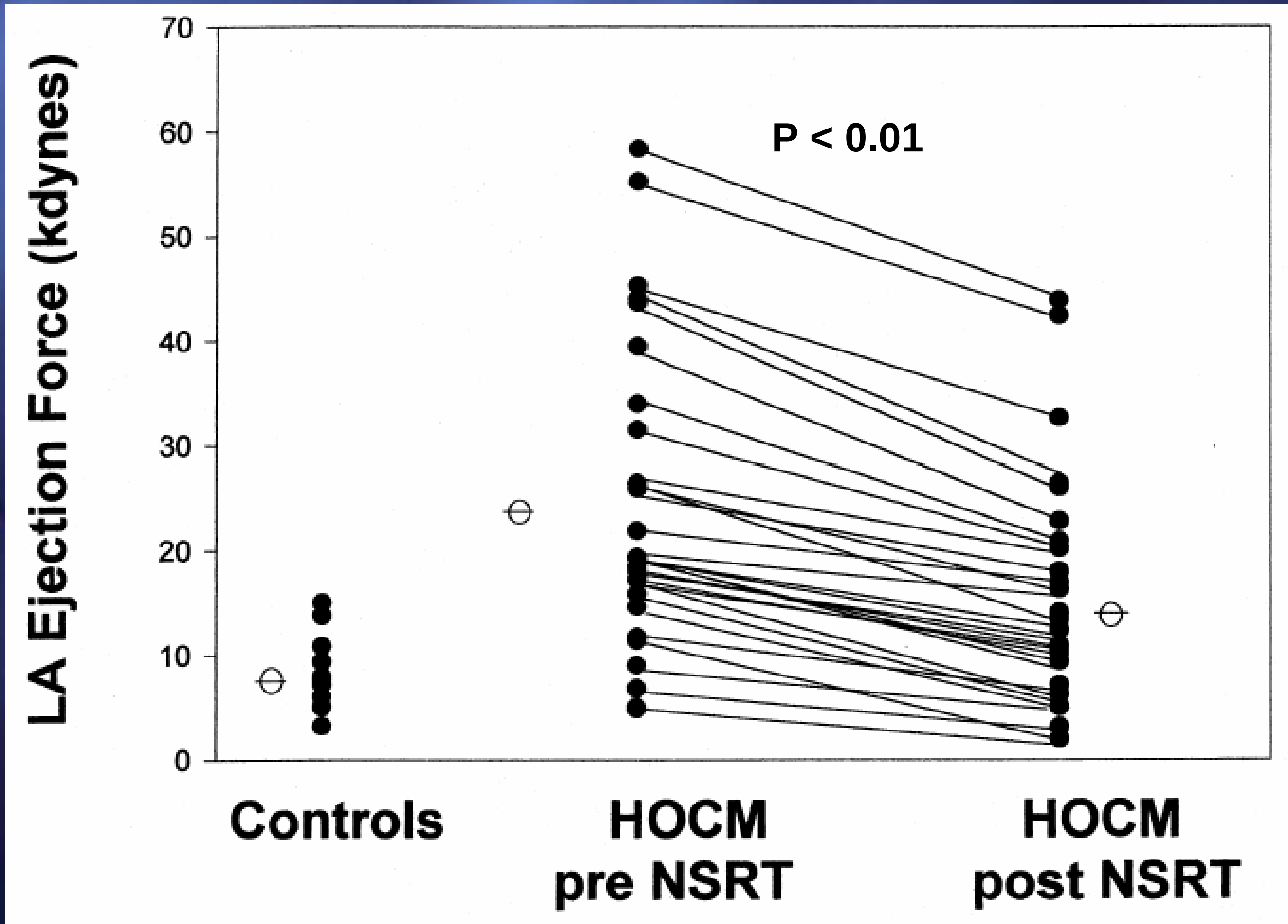
  = 0.5 x 1.06 x LA stroke volume x (peak A velocity^2)

JACC 1993, 22:221, AJC 1998, 82:1220



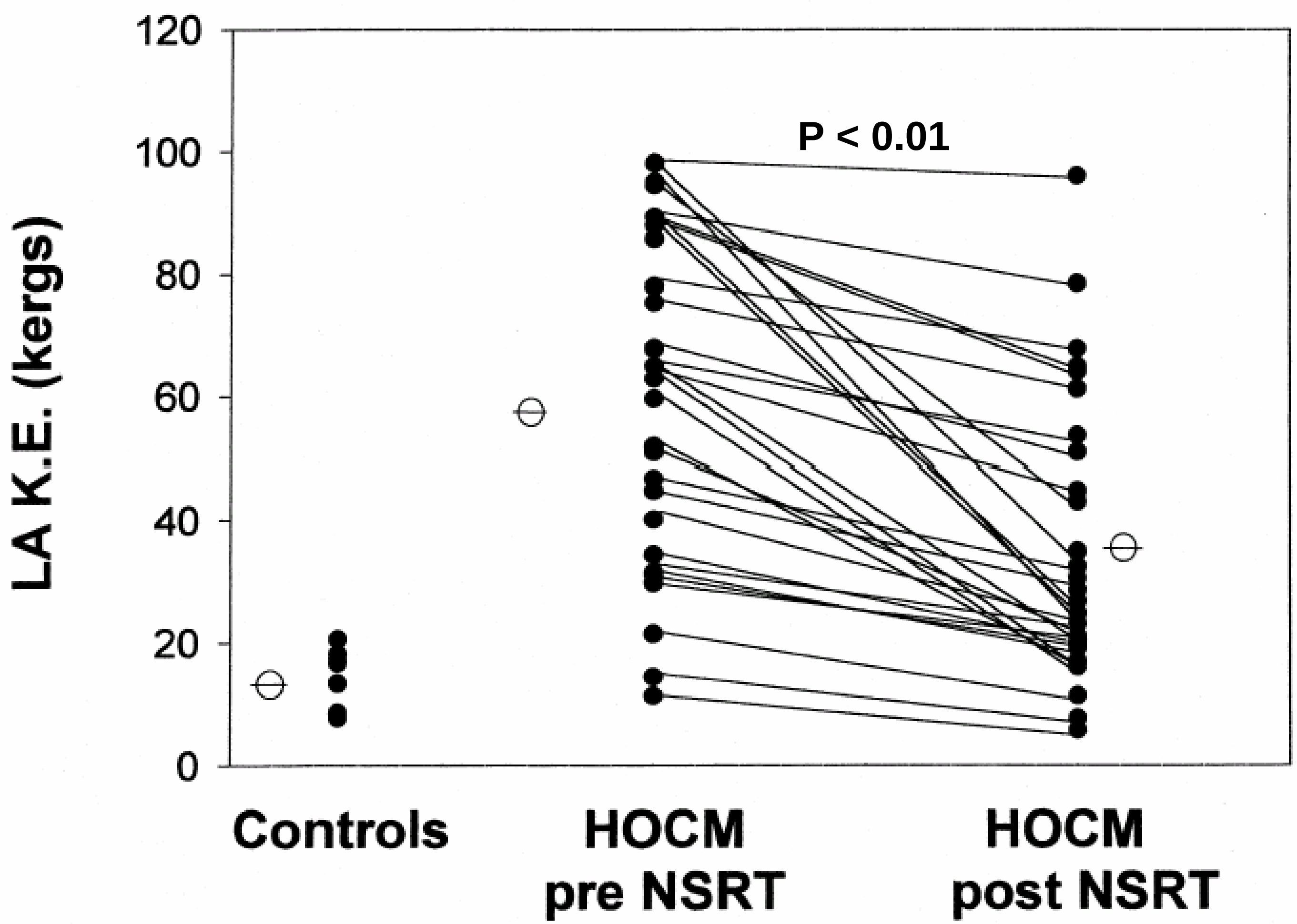
JACC 1993, 22:221, AJC 1998, 82:1220

Change of LA Function After Septal Ablation in HCM



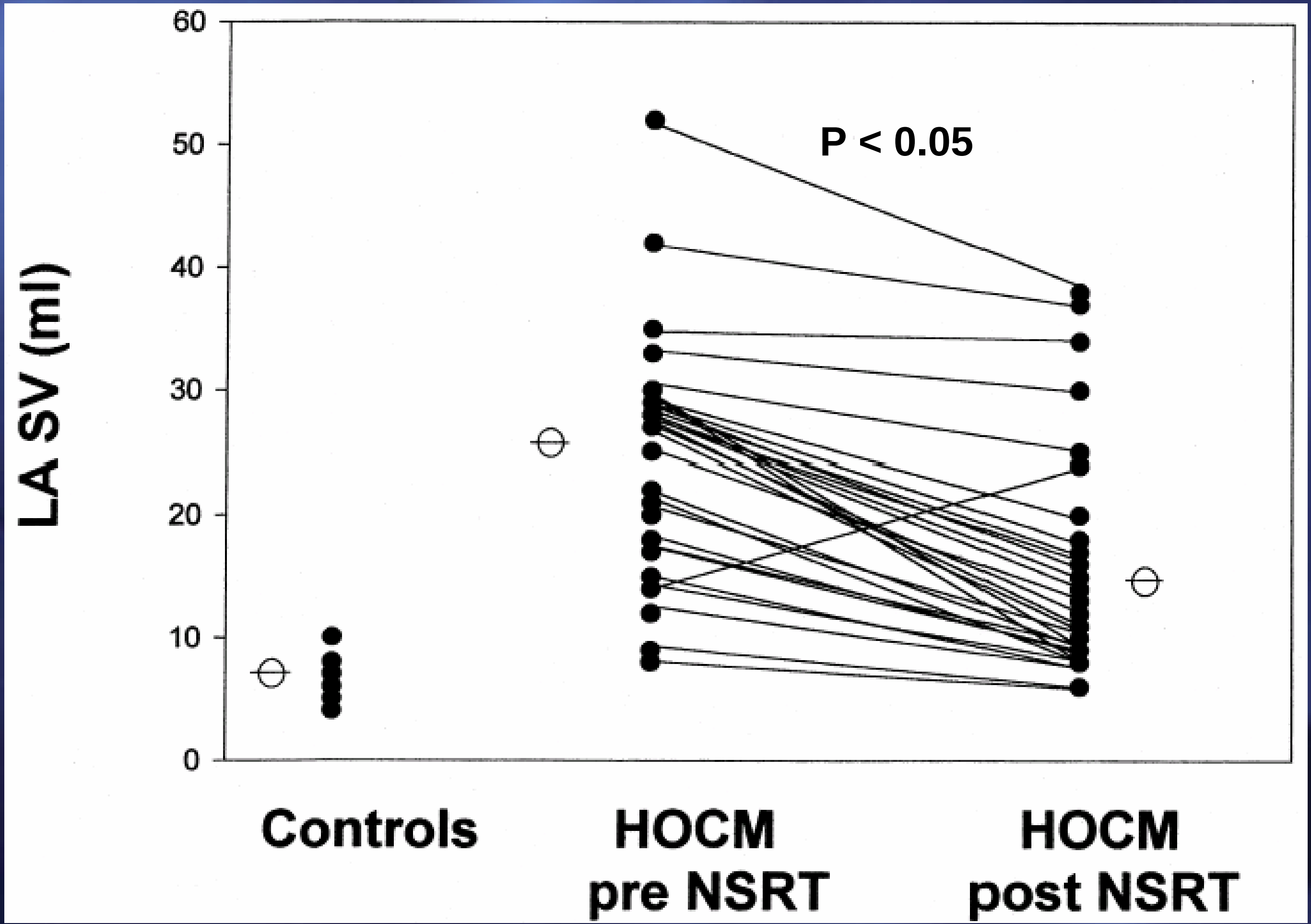
JACC 1999, 34:1123

Change of LA Function After Septal Ablation in HCM



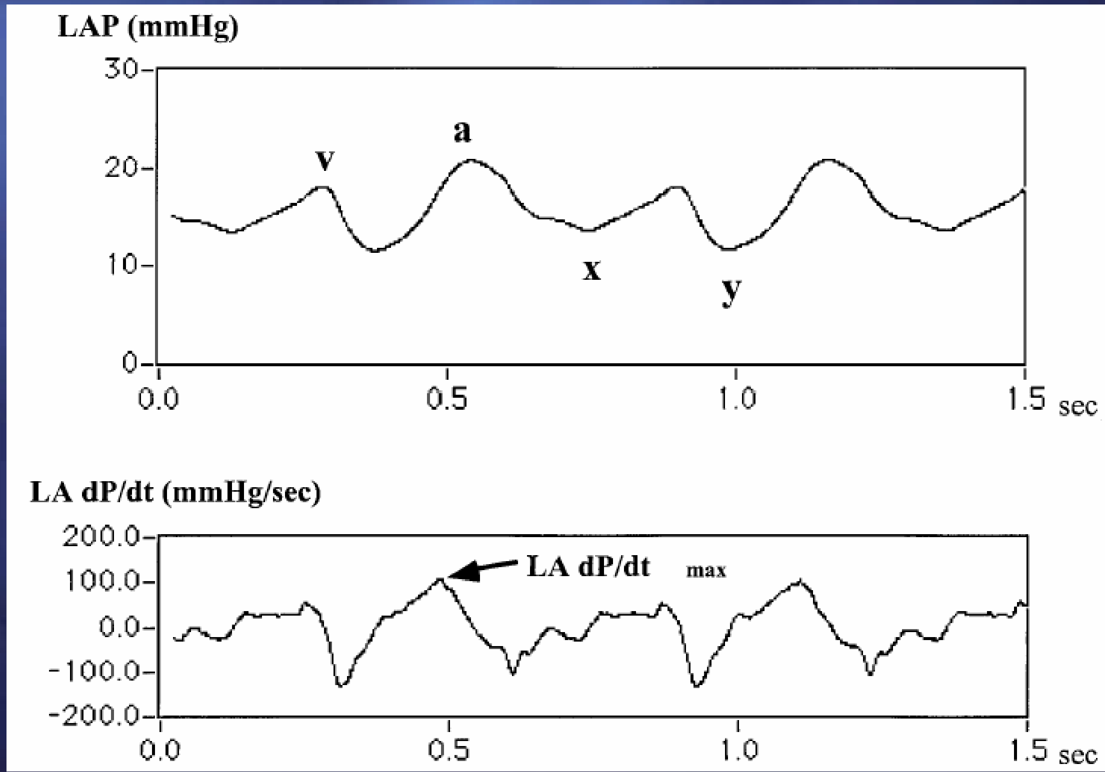
JACC 1999, 34:1123

Change of LA Function After Septal Ablation in HCM



JACC 1999, 34:1123

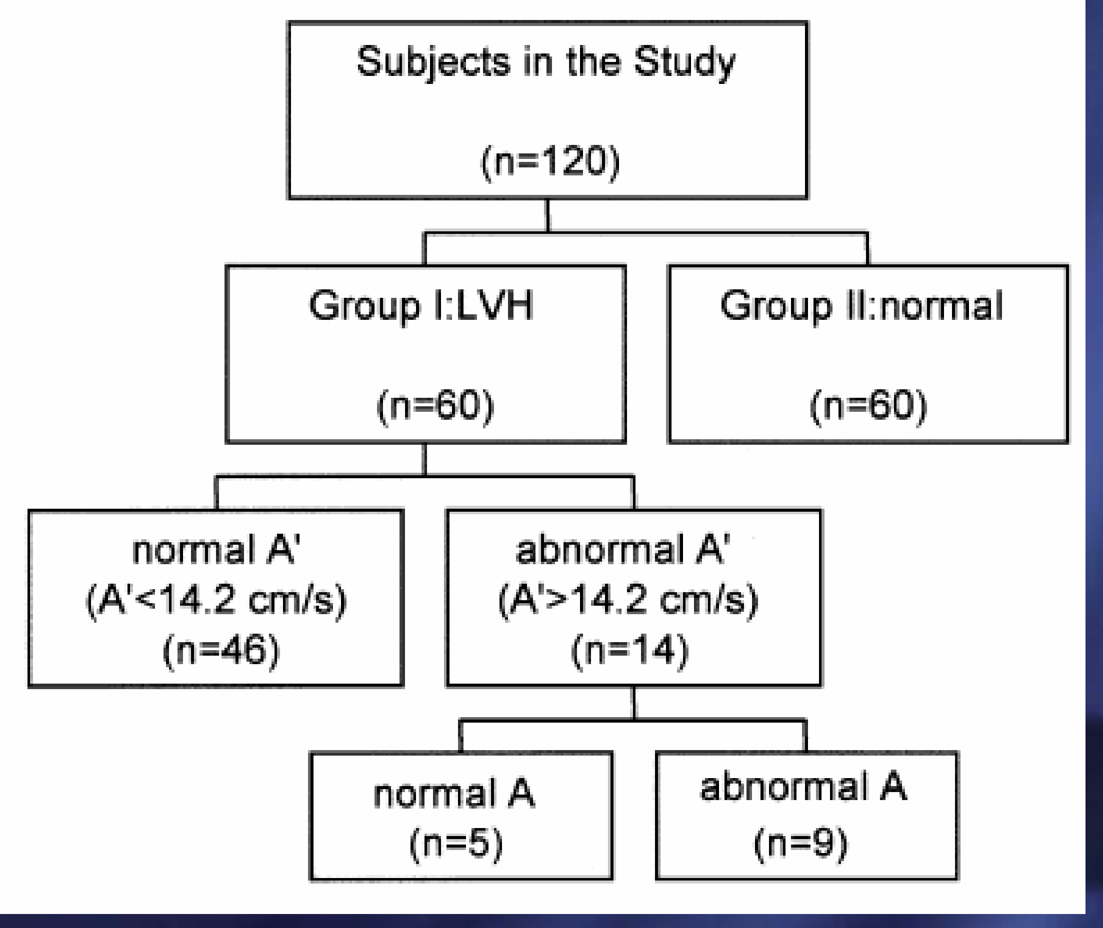
Estimation of LA dP/dt_{max} by Mitral Inflow and PV Flow



LA dP/dt_{max} = 0.1 M-AC (cm/s^2) + 1.8 PV (cm/s) - 4.1

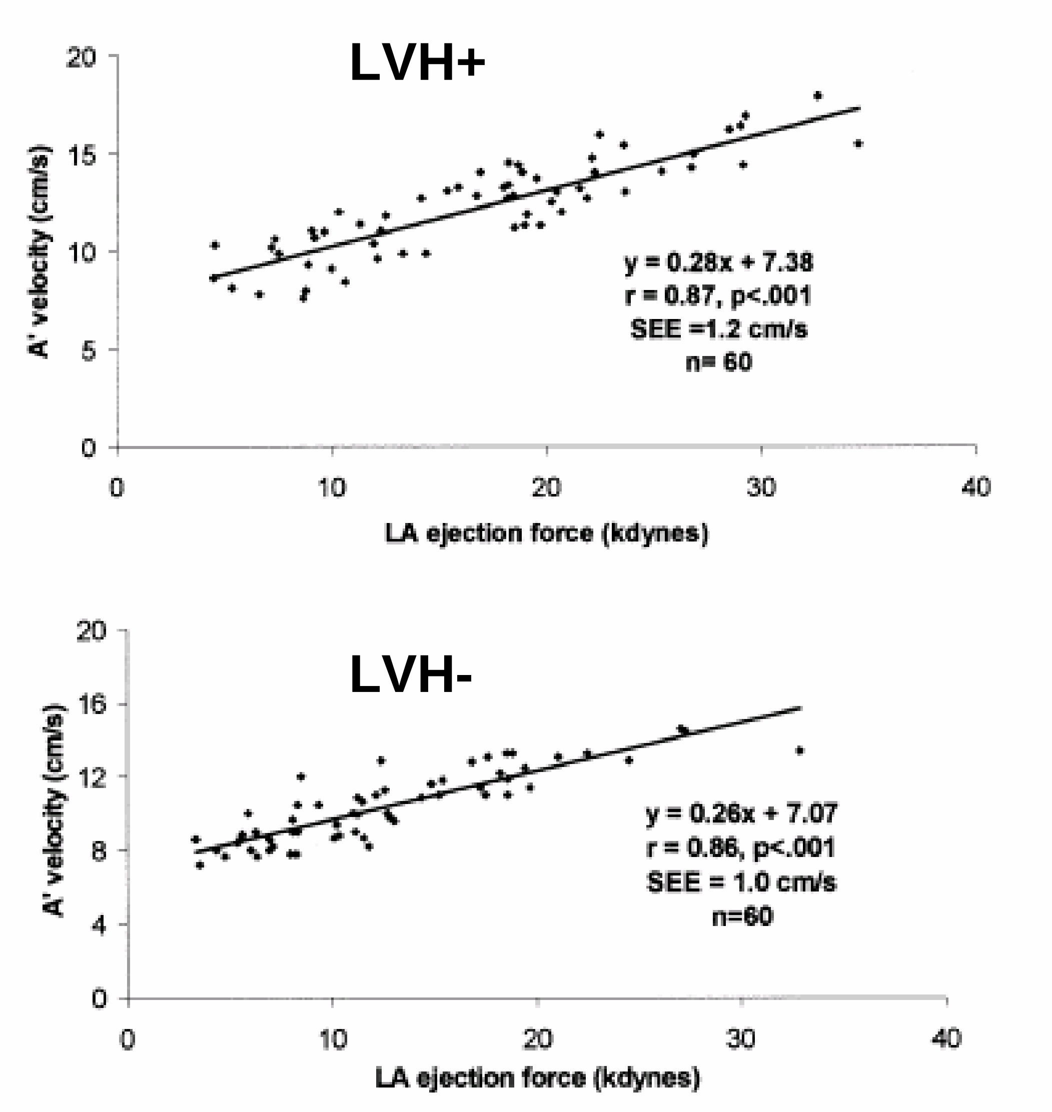
JACC 1999, 34:795

LA Systolic Function Evaluation by A' at Mitral Annulus



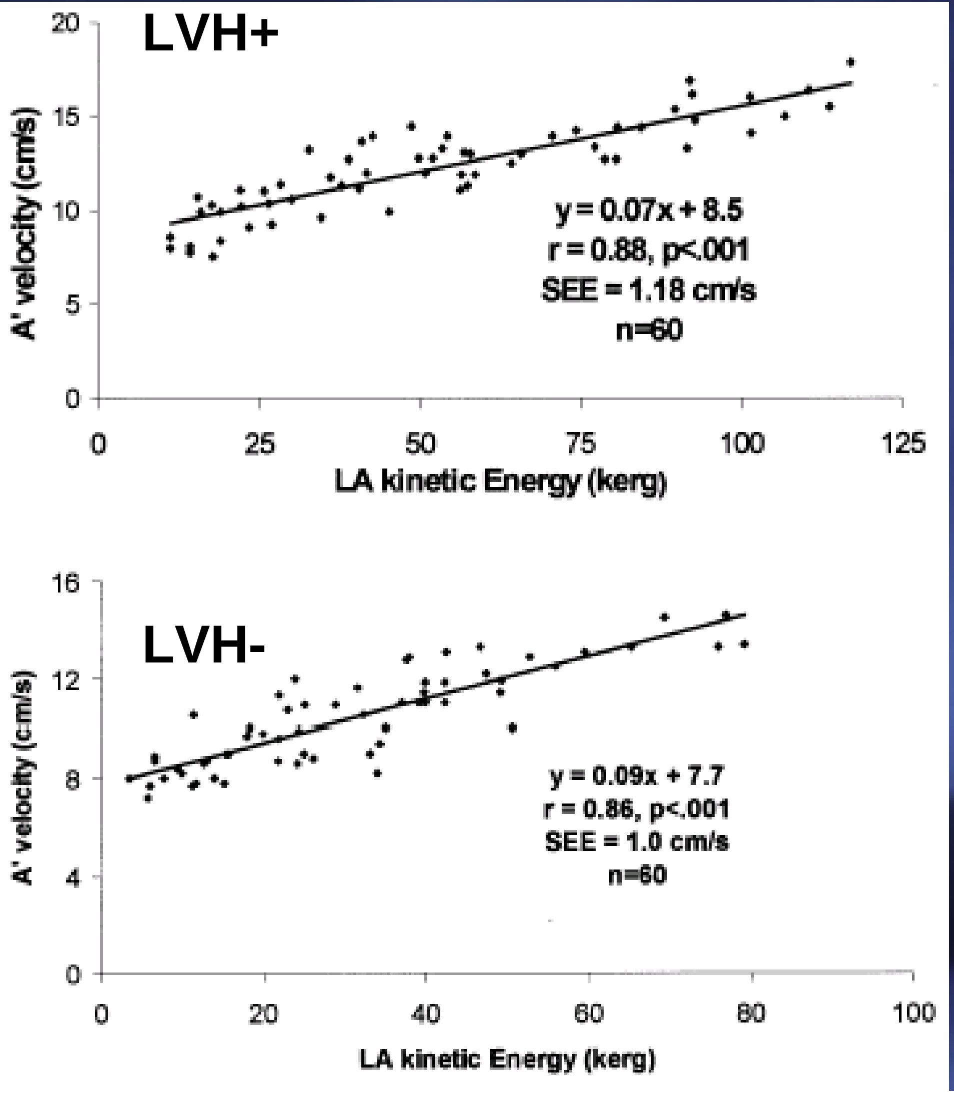
JASE 2004, 17: 353

LA Systolic Function Evaluation by A' at Mitral Annulus



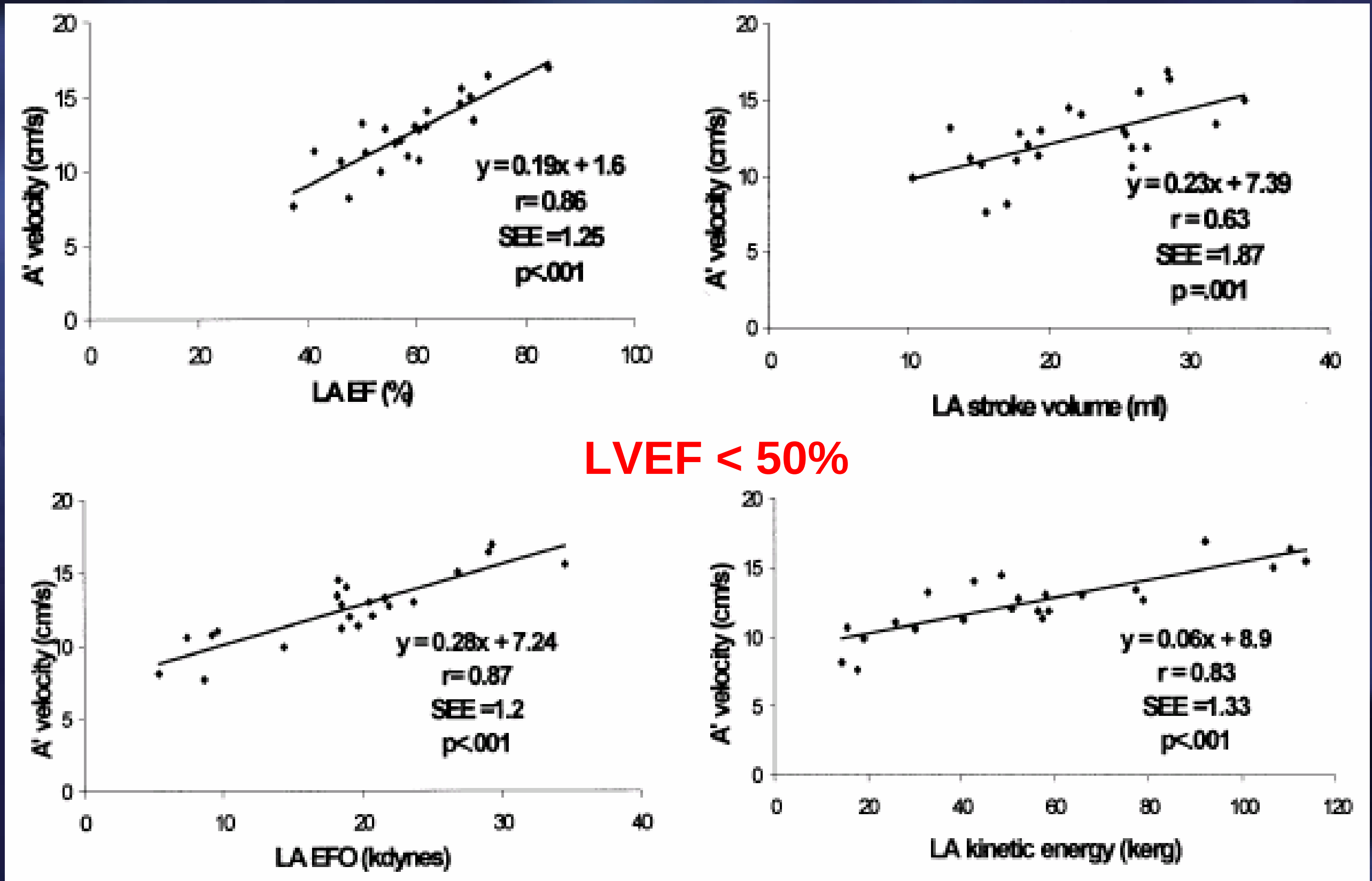
JASE 2004, 17: 353

LA Systolic Function Evaluation by A' at Mitral Annulus



JASE 2004, 17: 353

LA Systolic Function Evaluation by A' at Mitral Annulus



JASE 2004, 17: 353

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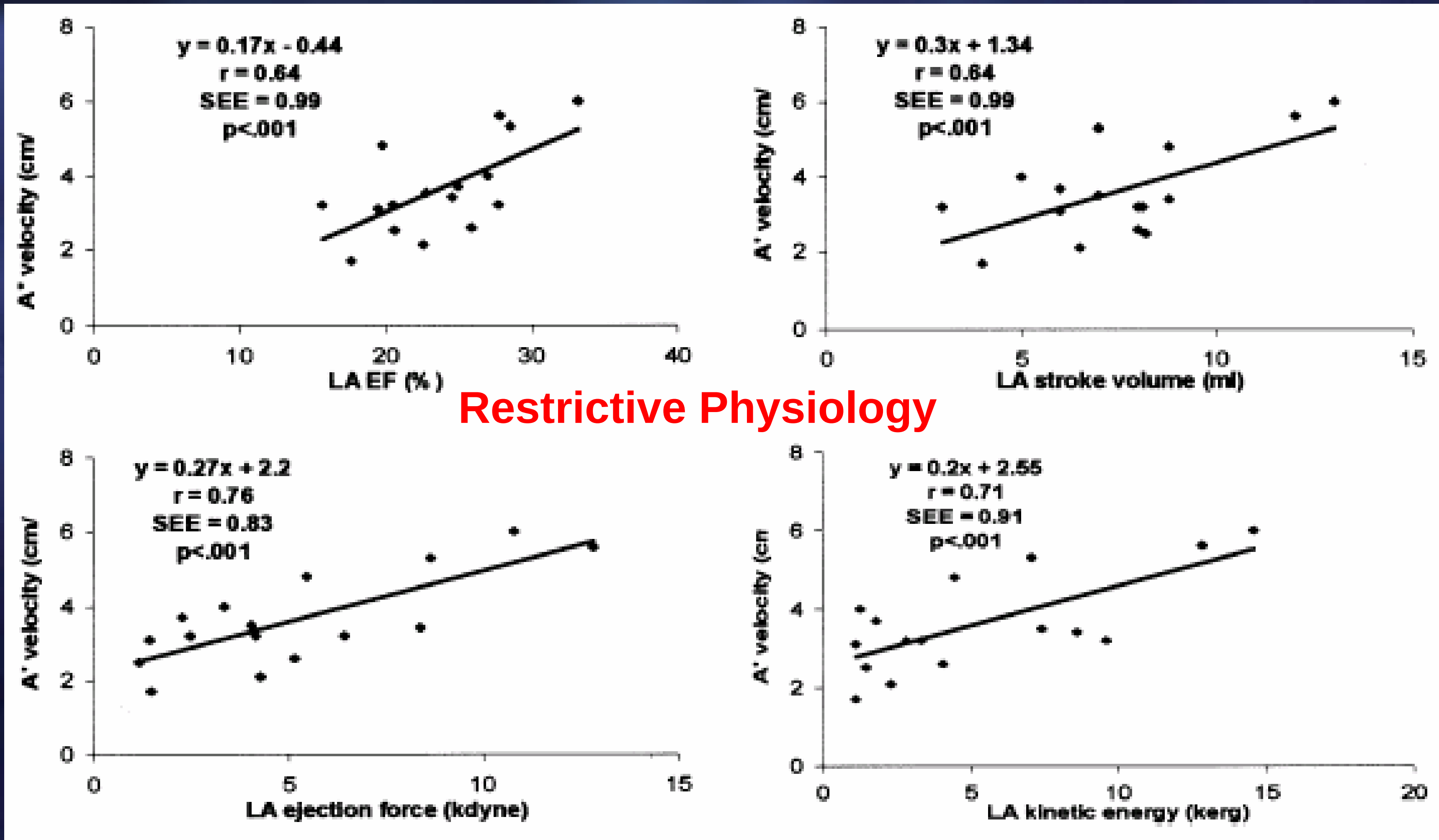
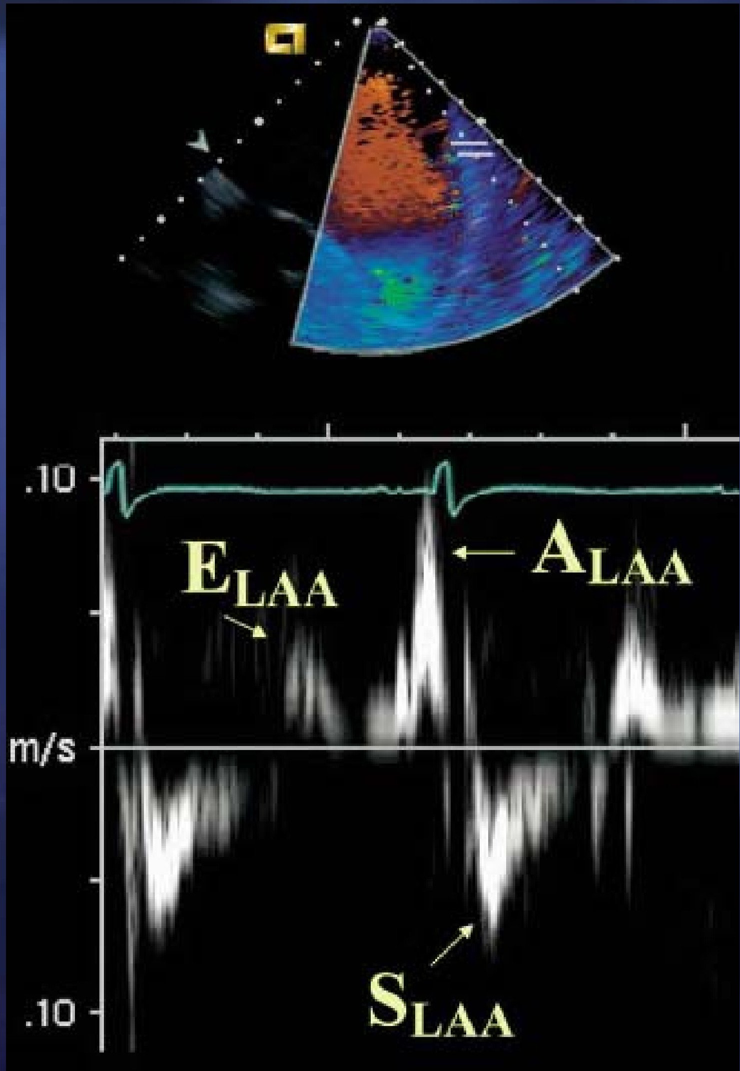


JASE 2004, 17: 353

Effect of Afterload Reduction on LAA function



JASE 2005, 18:934

Effect of Afterload Reduction on LAA function

Mitral Inflow

LAA flow

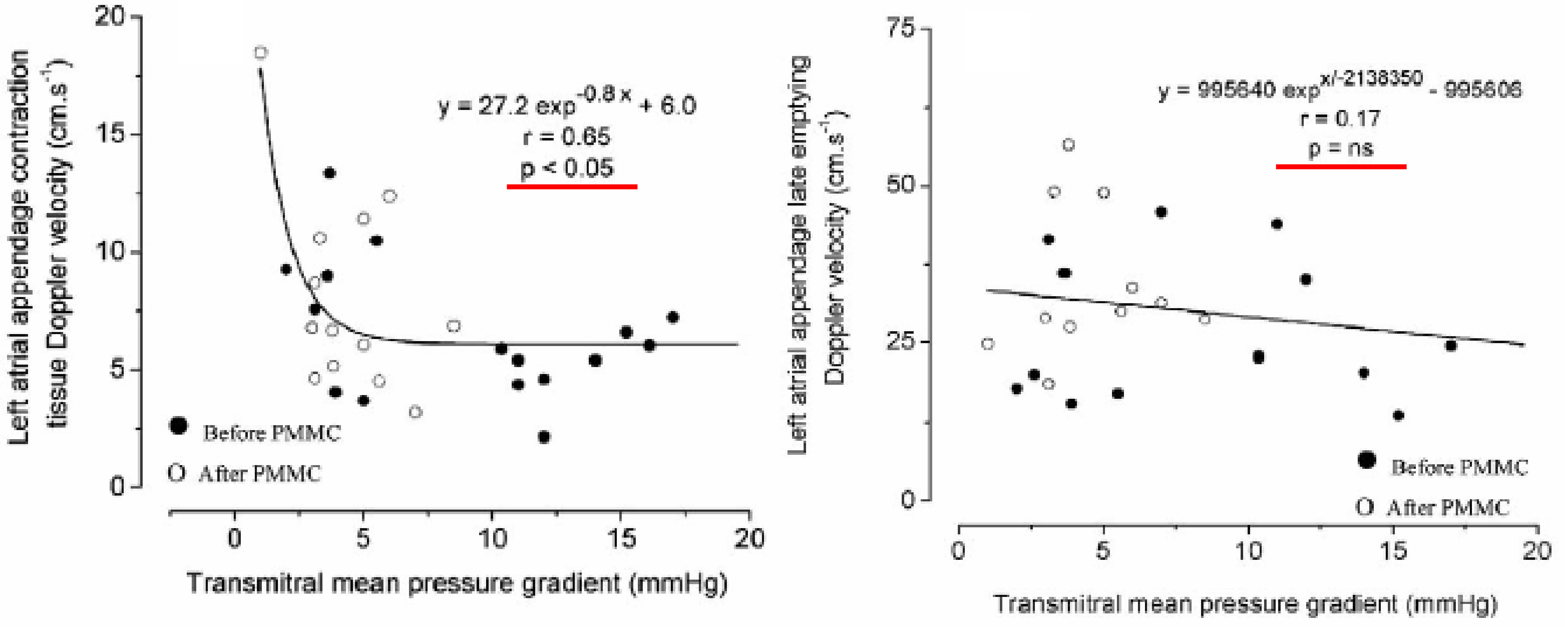
LAA Tissue Velocity

Pre PMV

Post PMV

JASE 2005, 18:934

Effect of Afterload Reduction on LAA function



JASE 2005, 18:934

Atrial Index

LAEF by TEE

= (LA max area – LA min area)/LA max area X 100

Atrial Index

= Transmitral VTI x LAEF / LA max area

AHJ 2002, 143:181

Predictors of post CABG AF

Univariate Analysis

Variables	OR (95% CI%)	P value
Age	1.07 (1.01-1.25)	.013
Atrial index	0.38 (0.14-1.04)	.059
LA dimension	2.10 (1.29-3.40)	.003
Body surface area	57 (3.97-827)	.003
Aortic cross-clamp time	1.03 (1.00-1.05)	.029
Postoperative myocardial infarction	3.28 (0.99-10.86)	.052

Multivariate Analysis

Variables	OR (95% CI)	P value
Age	1.11 (1.04-1.19)	.002
LA dimension	1.74 (1.03-2.96)	.038
BSA	114 (4.65-2810)	.004

AHJ 2002, 143:181

LV Remodeling
and Dysfunction

↓

↑ diastolic P or MR

↓

LA remodeling

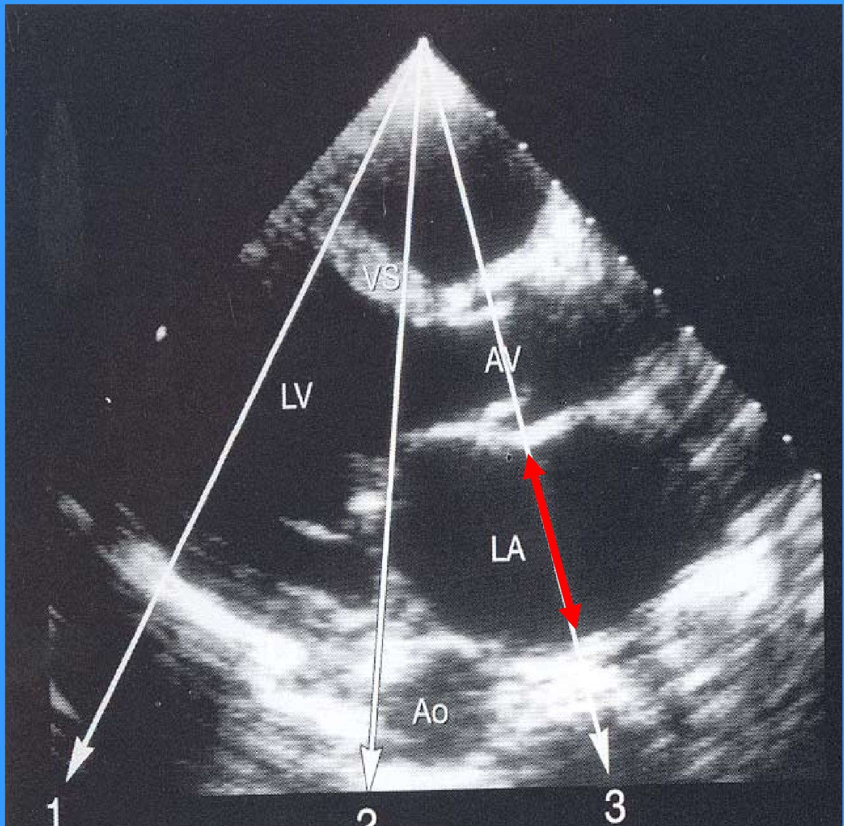
↓

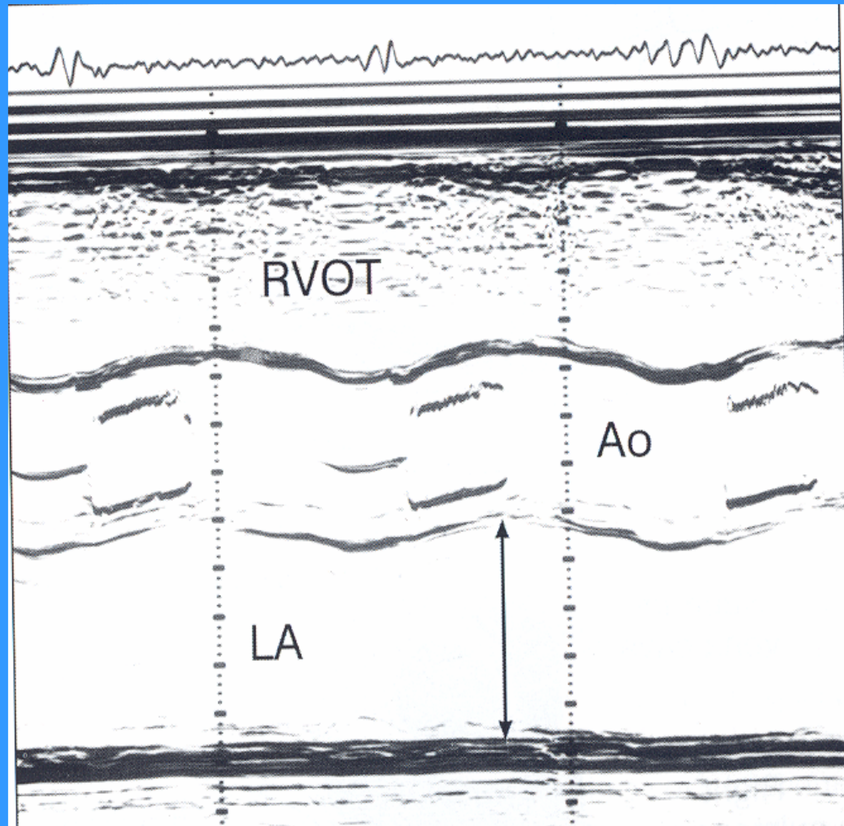
Atrial Fibrillation

↓

Stroke/Death

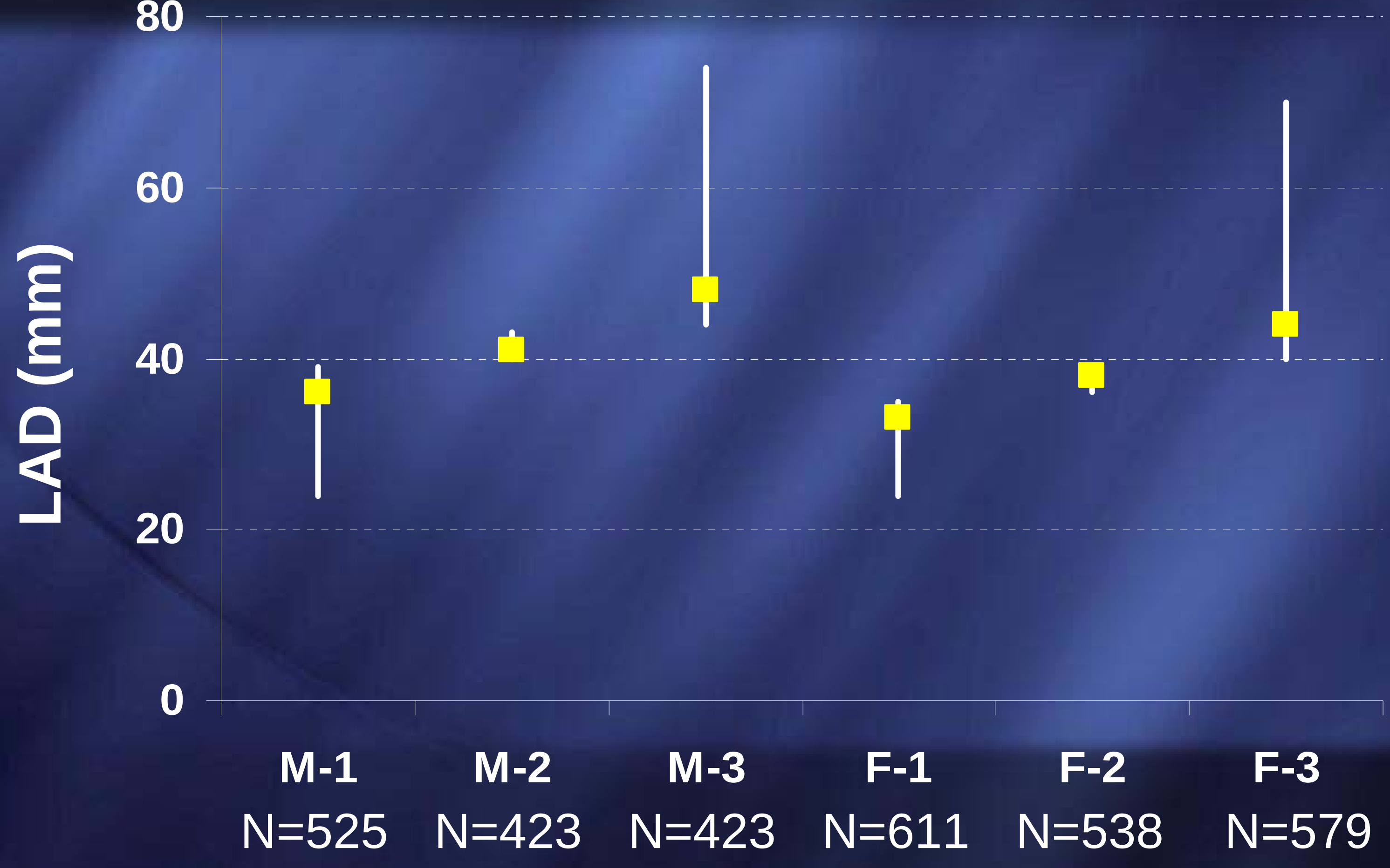
LA Dimension





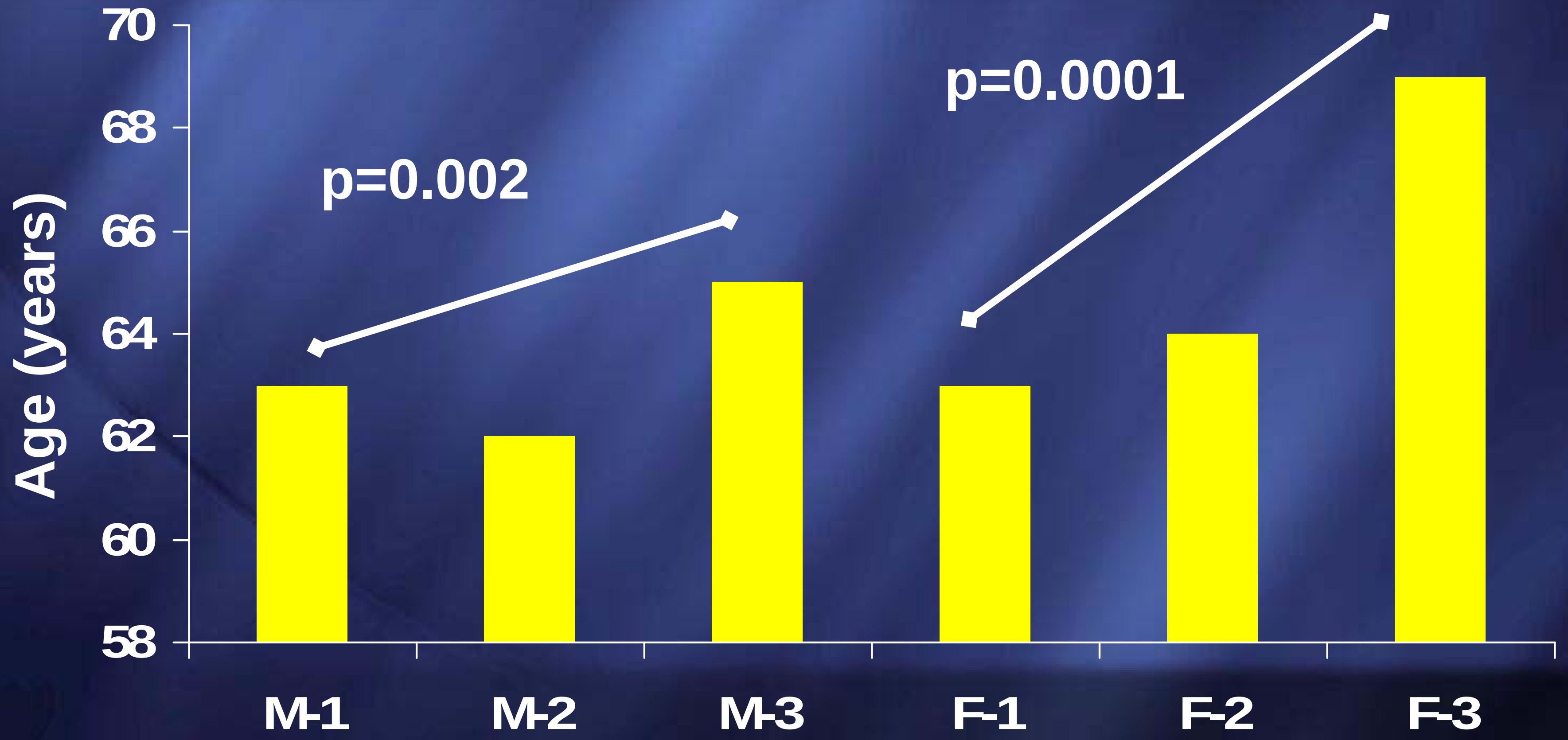
The Echo Manual. Oh, Seward, Tajik. 1999

LAD in the FHS



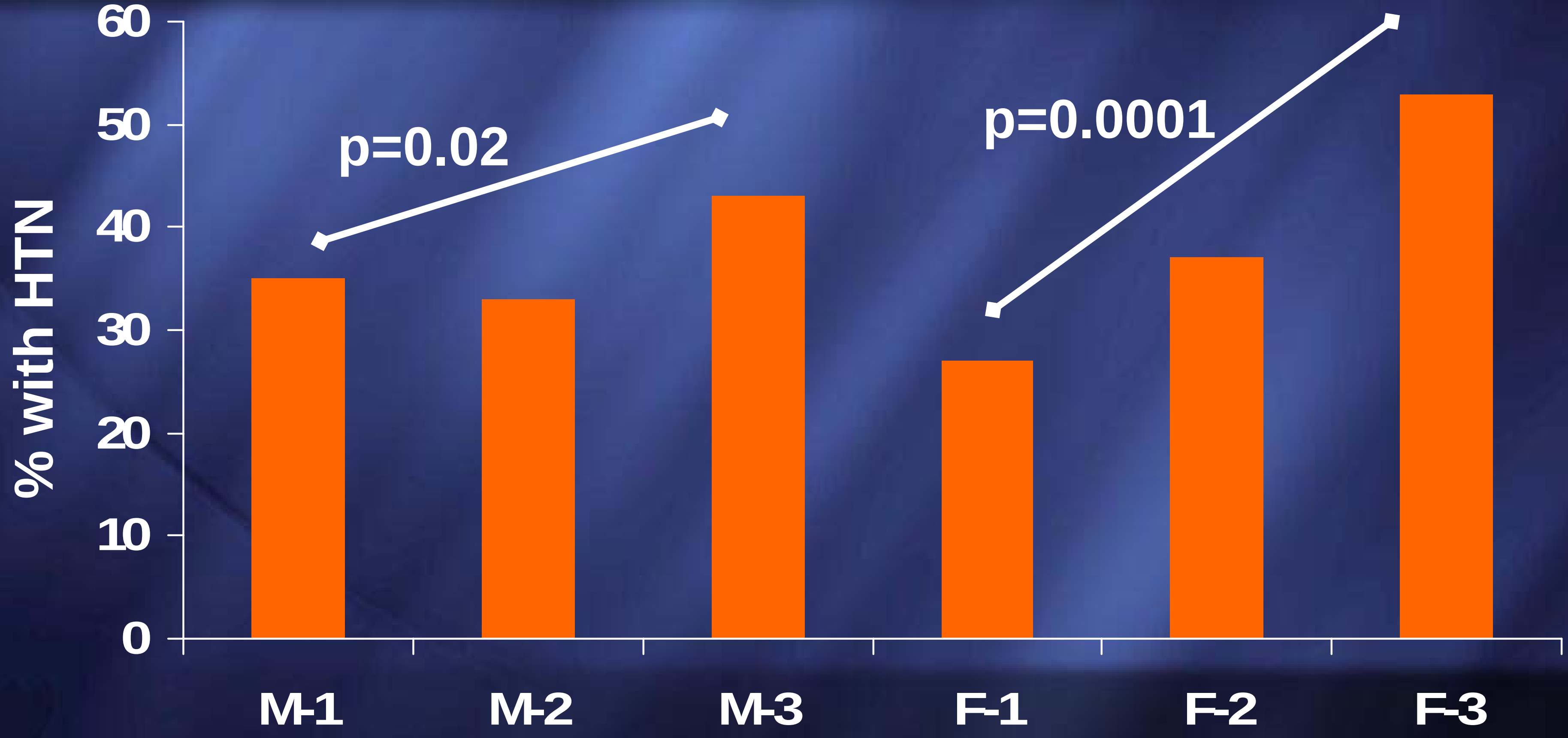
Circulation 1995, 92: 835

LAD and Age



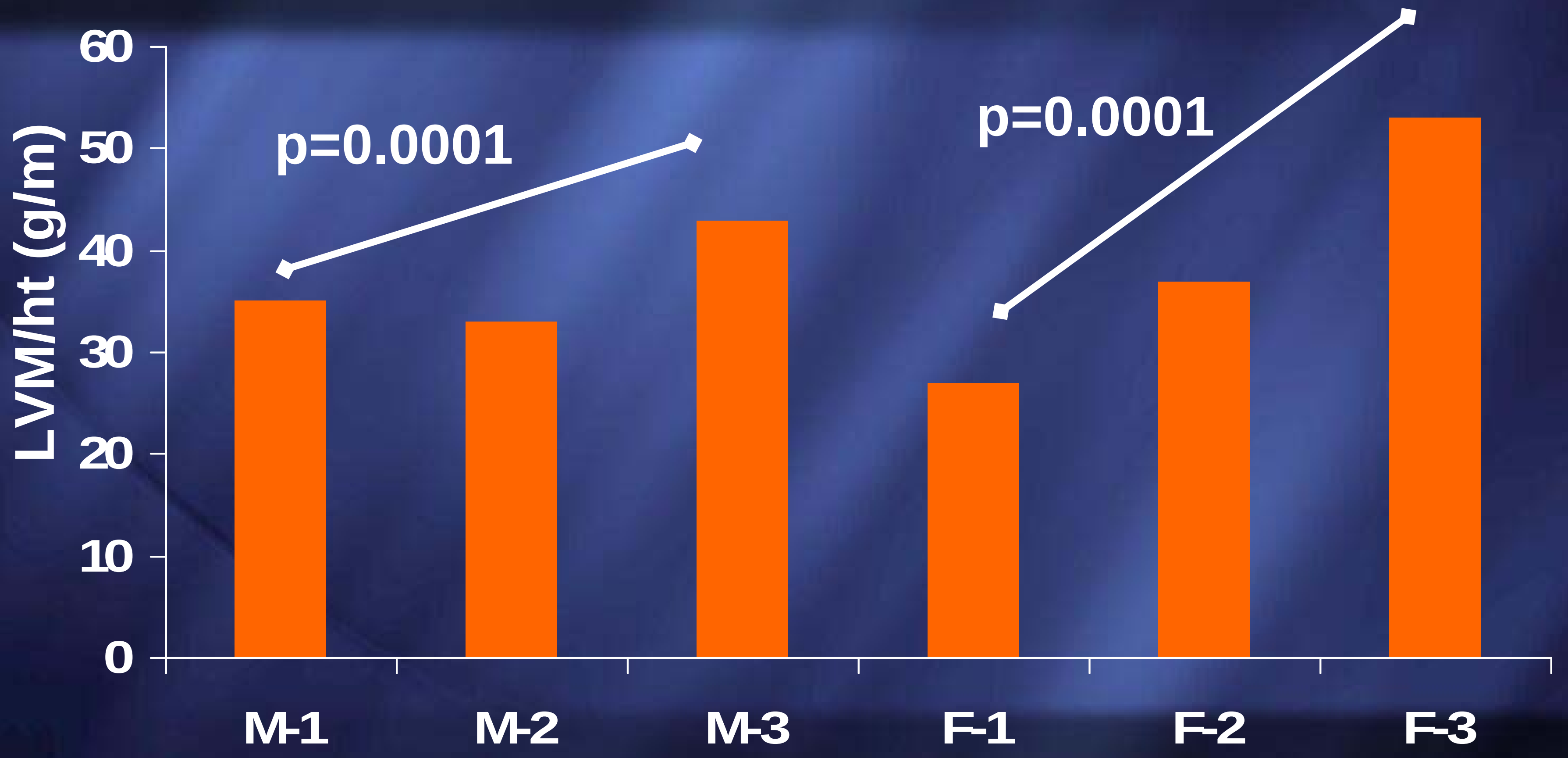
Circulation 1995, 92: 835

LAD and HTN



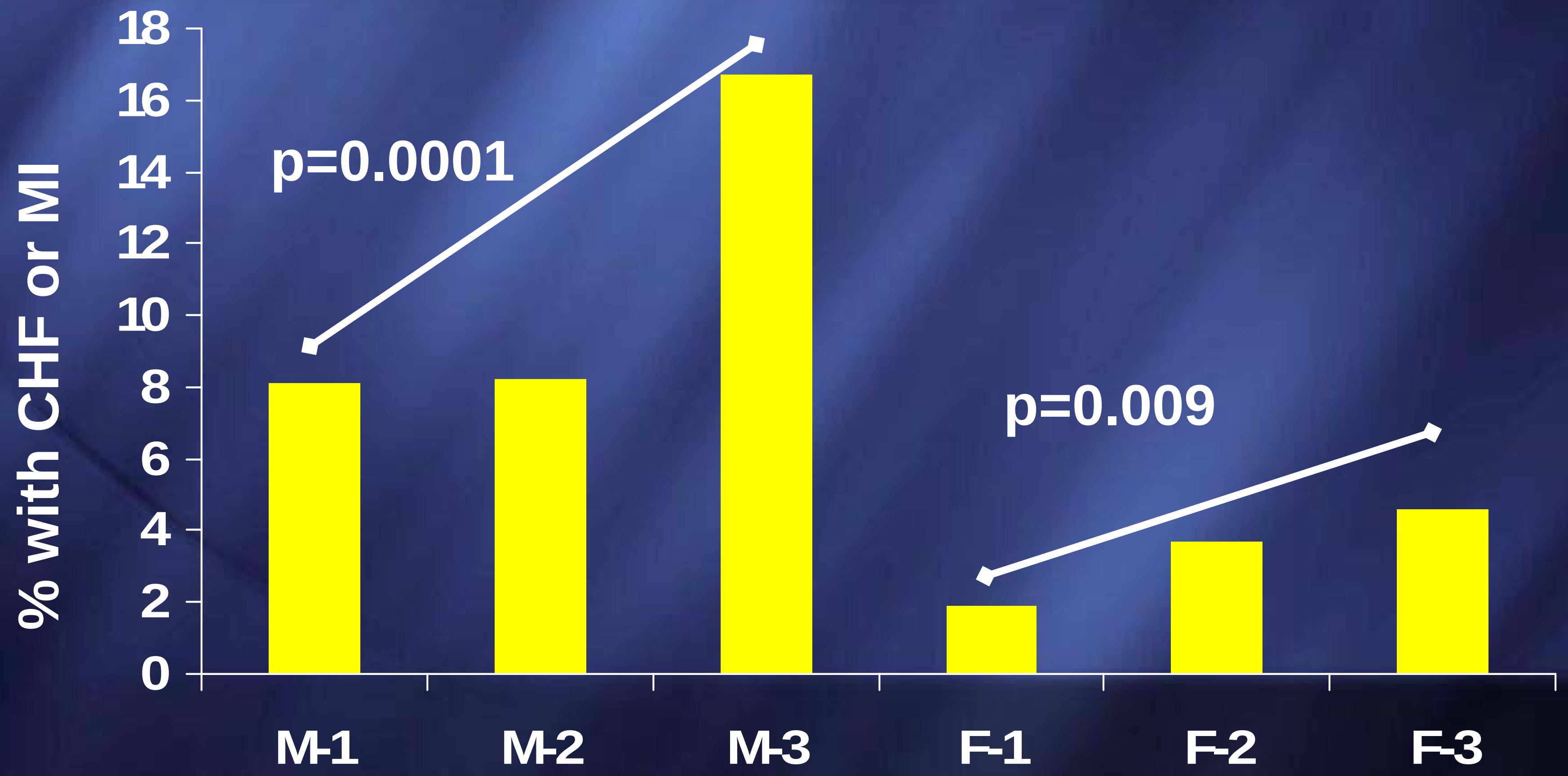
Circulation 1995, 92: 835

LAD with LV Mass



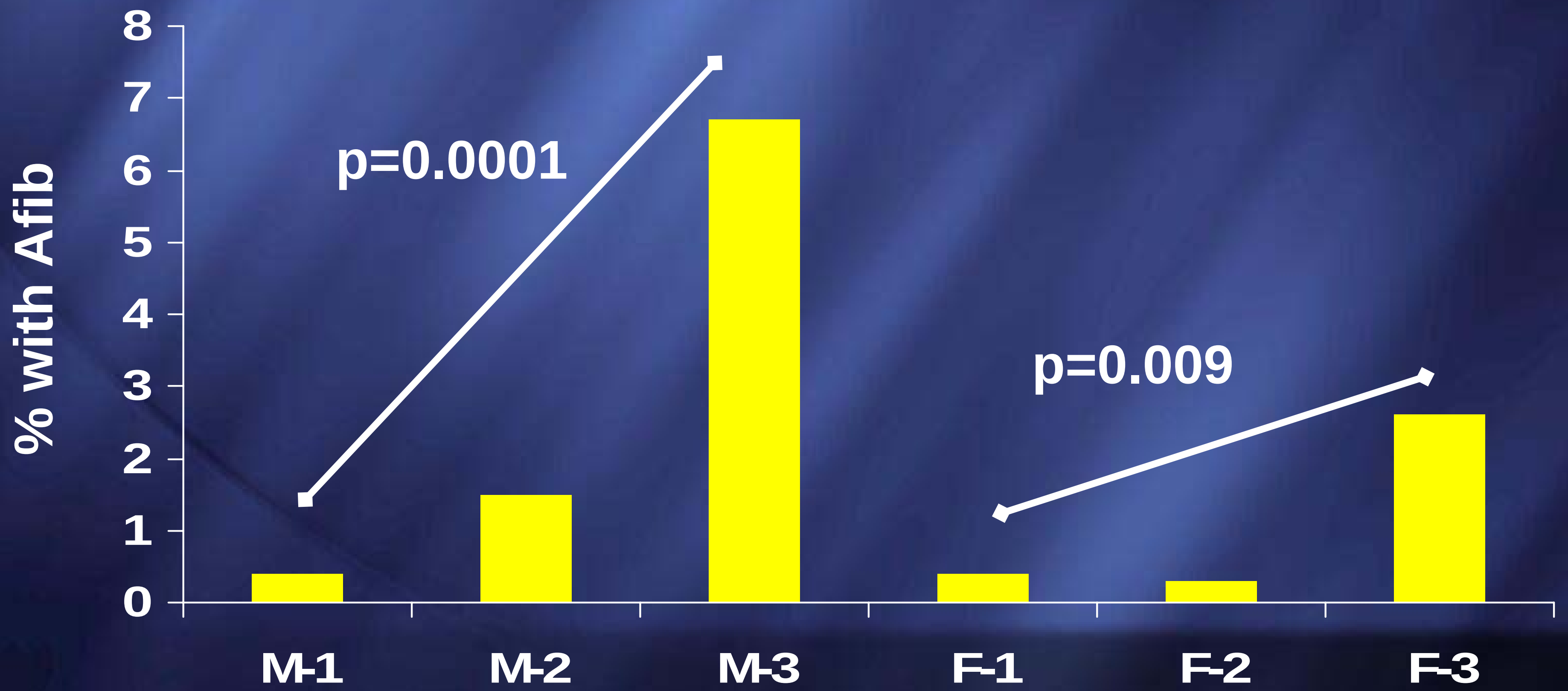
Circulation 1995, 92: 835

LAD and CV disease



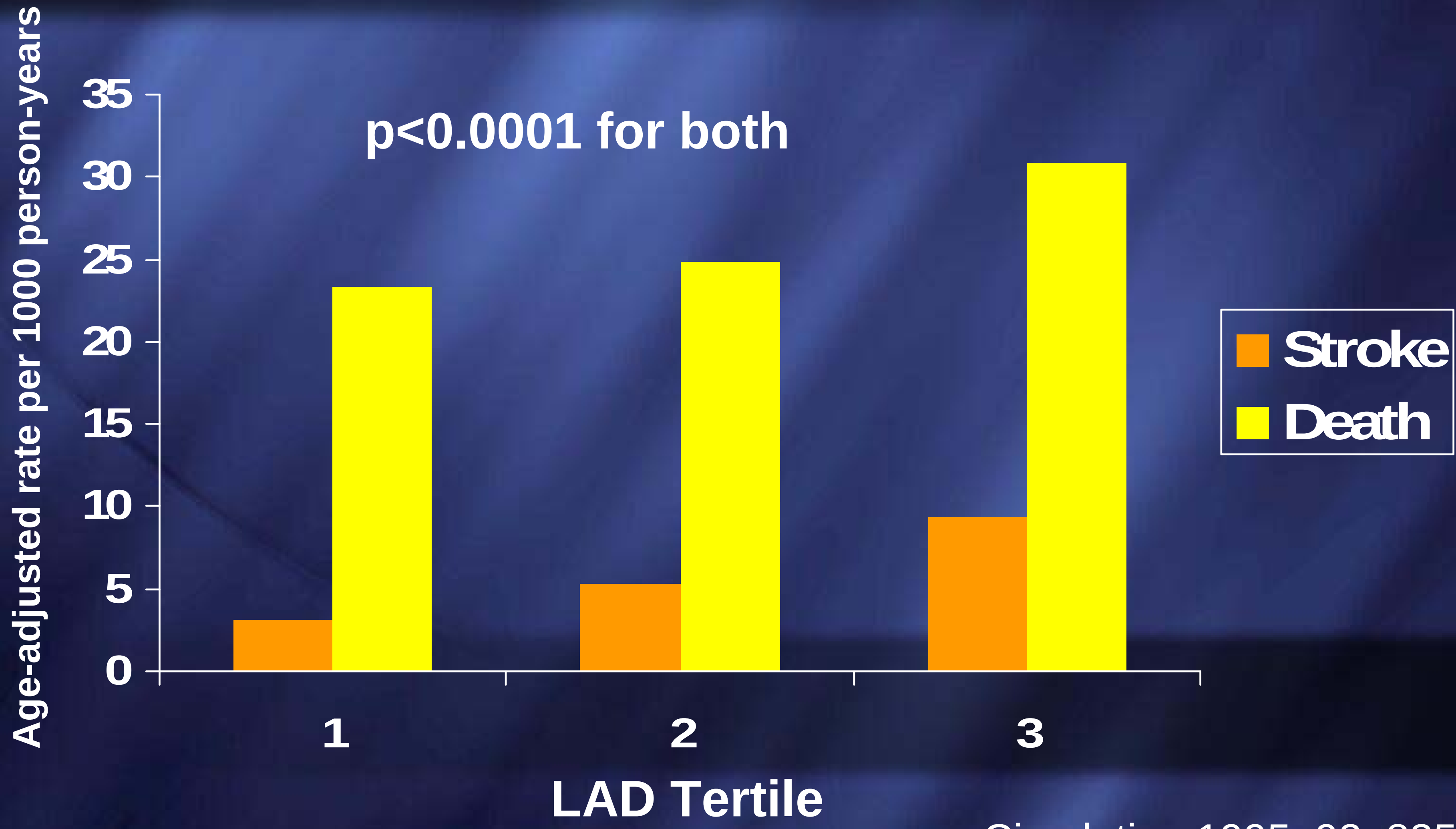
Circulation 1995, 92: 835

LAD and Afib



Circulation 1995, 92: 835

LAD and Stroke / Death



Circulation 1995, 92: 835

LA Volume Measurement

Area-Length Method

$$V = \frac{0.85 * A_1 * A_2}{L}$$

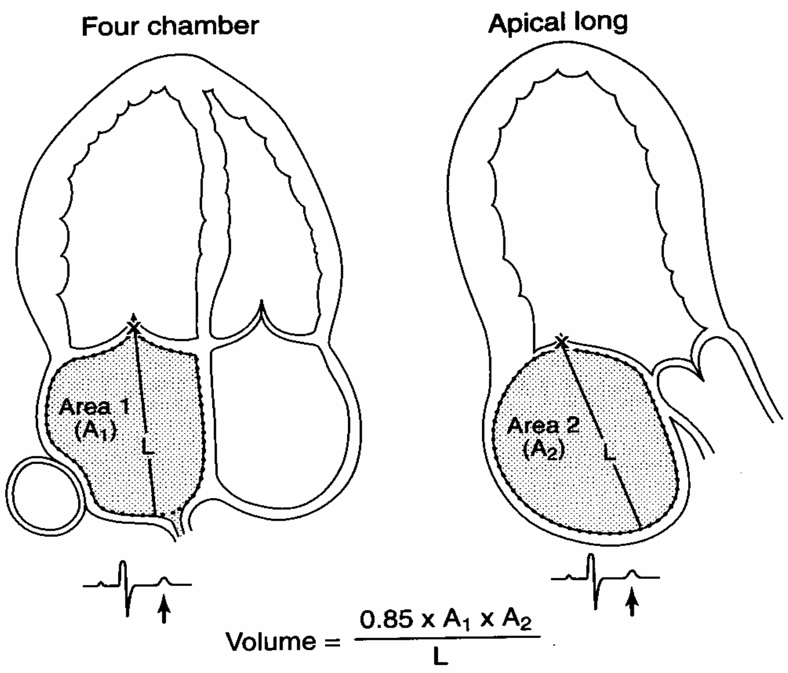
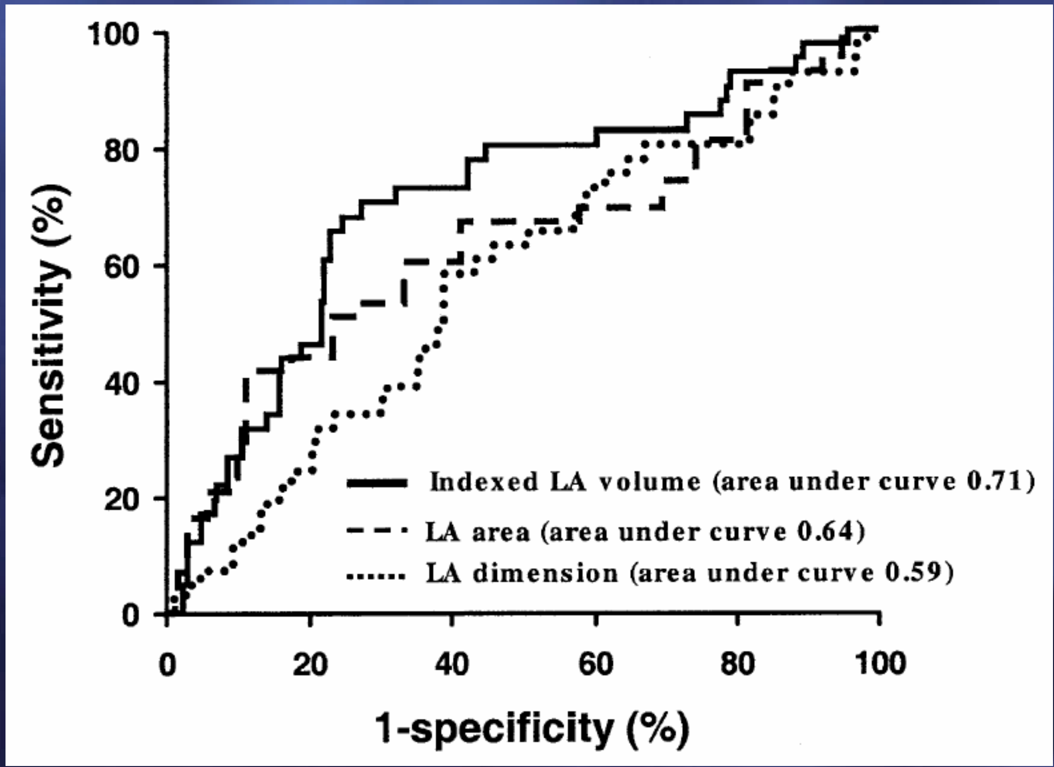


FIG. 4-3. Diagram of apical four-chamber and apical long-axis views of the left atrium (*LA*) showing how to measure LA size and volume. (Courtesy of Mary Ann Capps.)

The Echo Manual. Oh, Seward, Tajik. 1999

Volume, Area or Dimension?

- **Prediction of CV outcomes in SR**
  (AF, TIA, MI, CHF, CV death)



JACC 2006, 47:1018

Volume, Area or Dimension?

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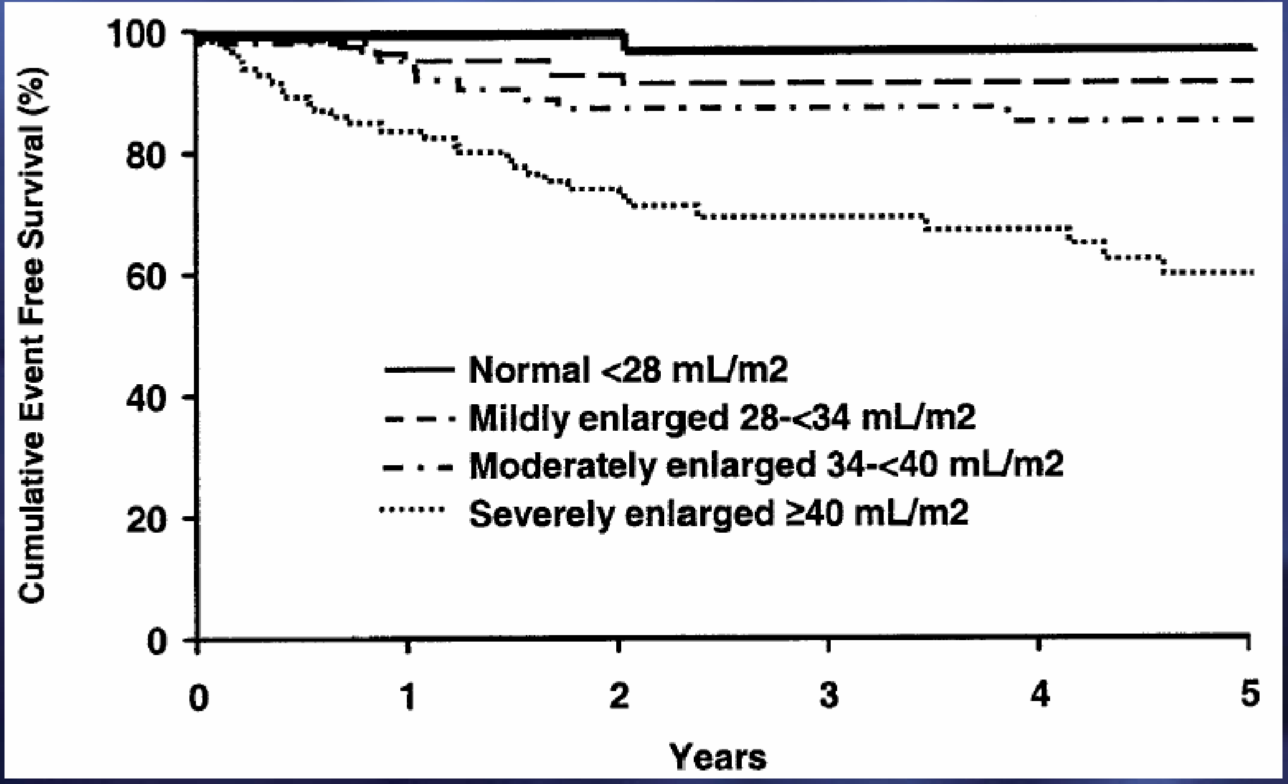


JACC 2006, 47:1018

Volume, Area or Dimension?

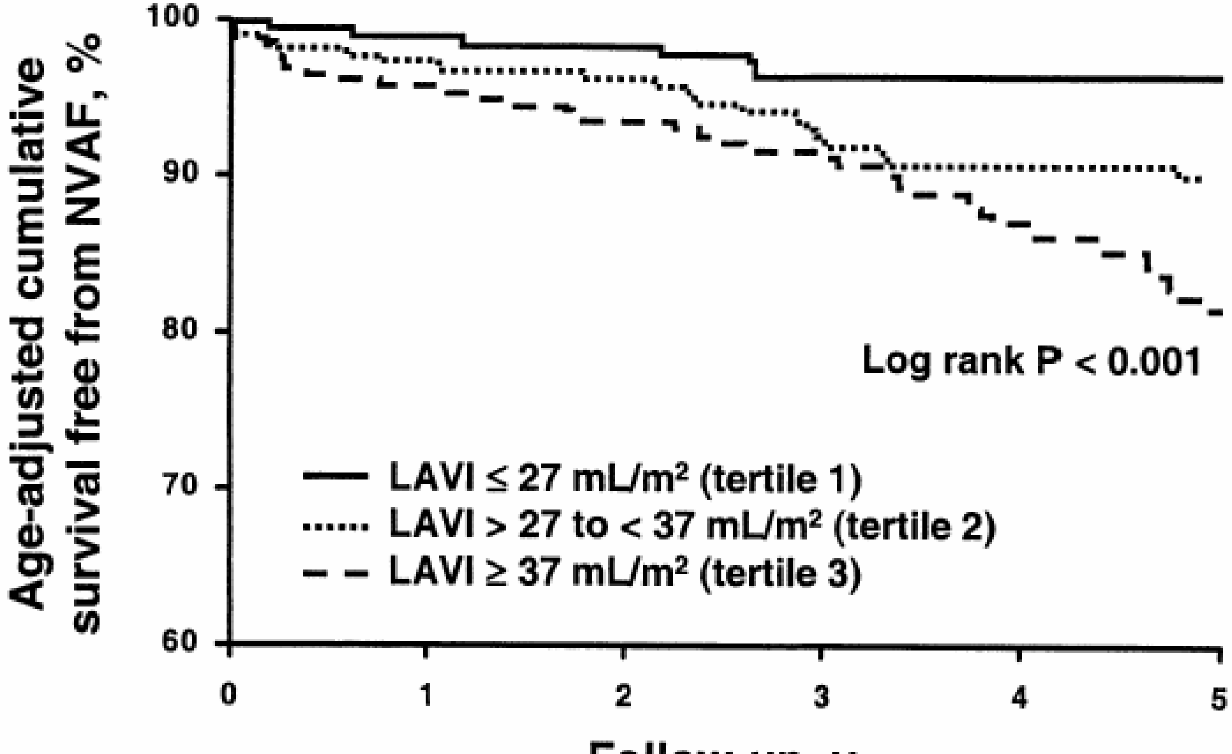
Prediction of CV outcomes in AF

(TIA, MI, CHF, CV death)

CV events ≠ LA size quantitation

JACC 2006, 47:1018

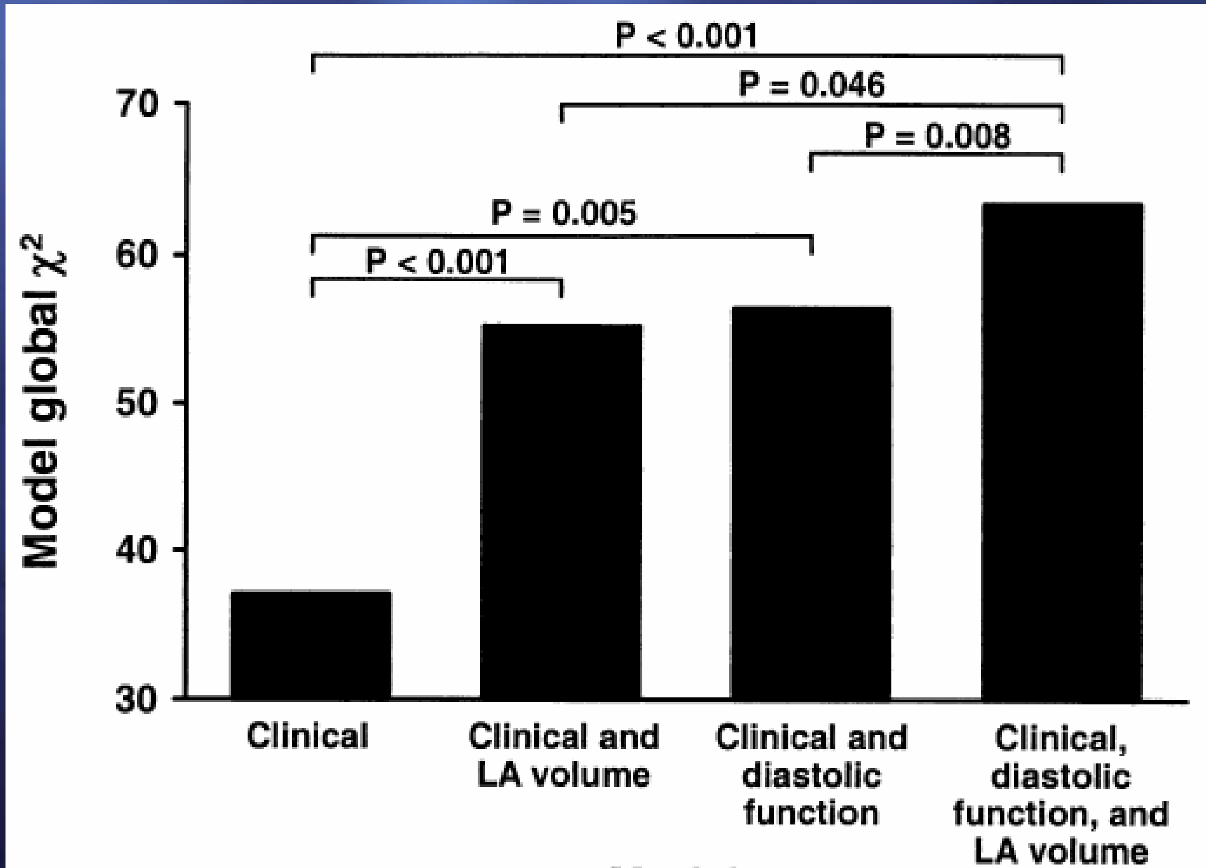
LA Volume Predicts NVAF in Elderly People



No. at risk						
Tertile 1	277	242	217	168	139	105
Tertile 2	273	233	199	154	121	93
Tertile 3	290	246	216	173	135	94

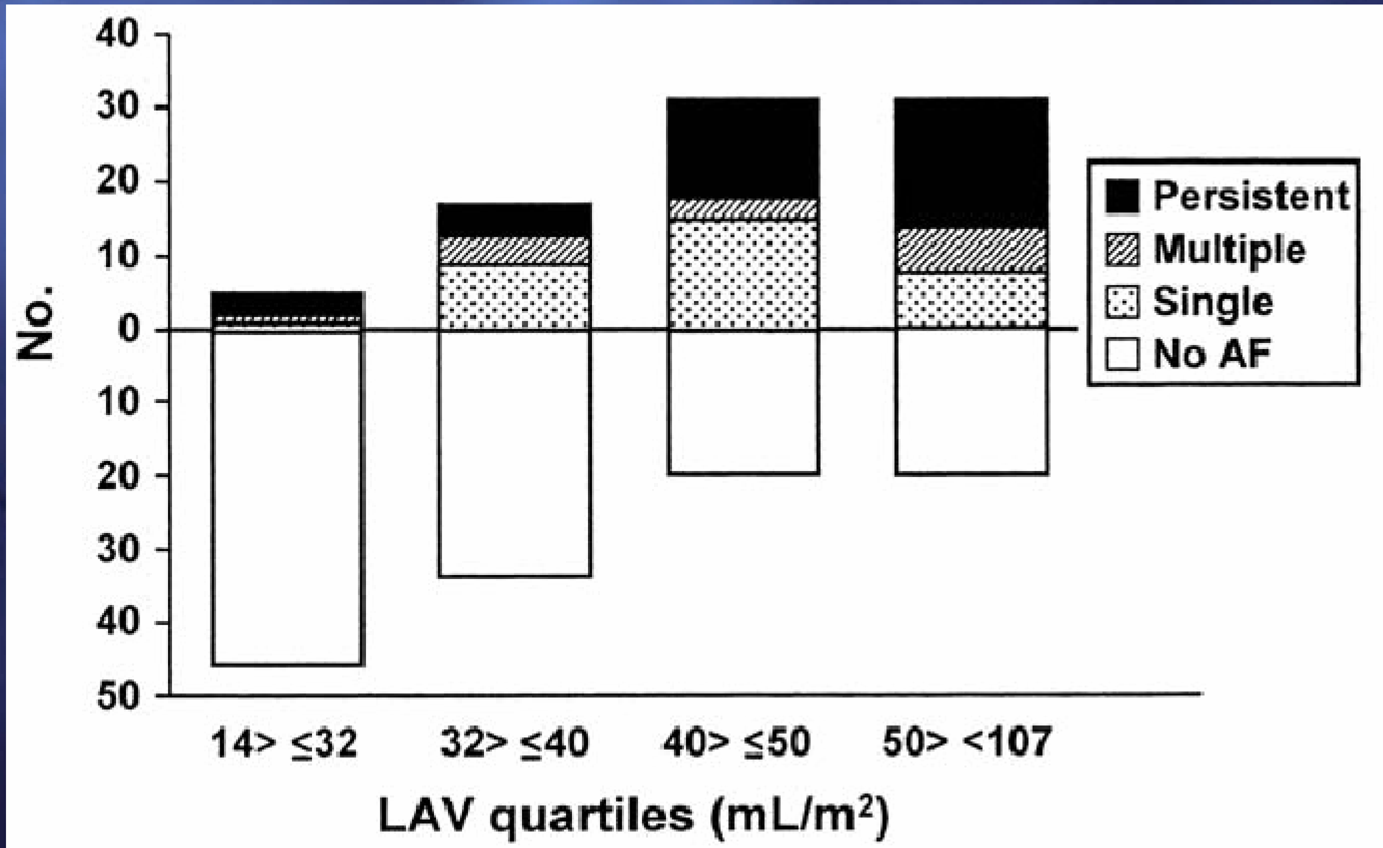
JACC 2002, 40:1636

LA Volume Predicts NVAF in Elderly People



JACC 2002, 40:1636

LA Volume Predicts Postop AF After Cardiac Surgery



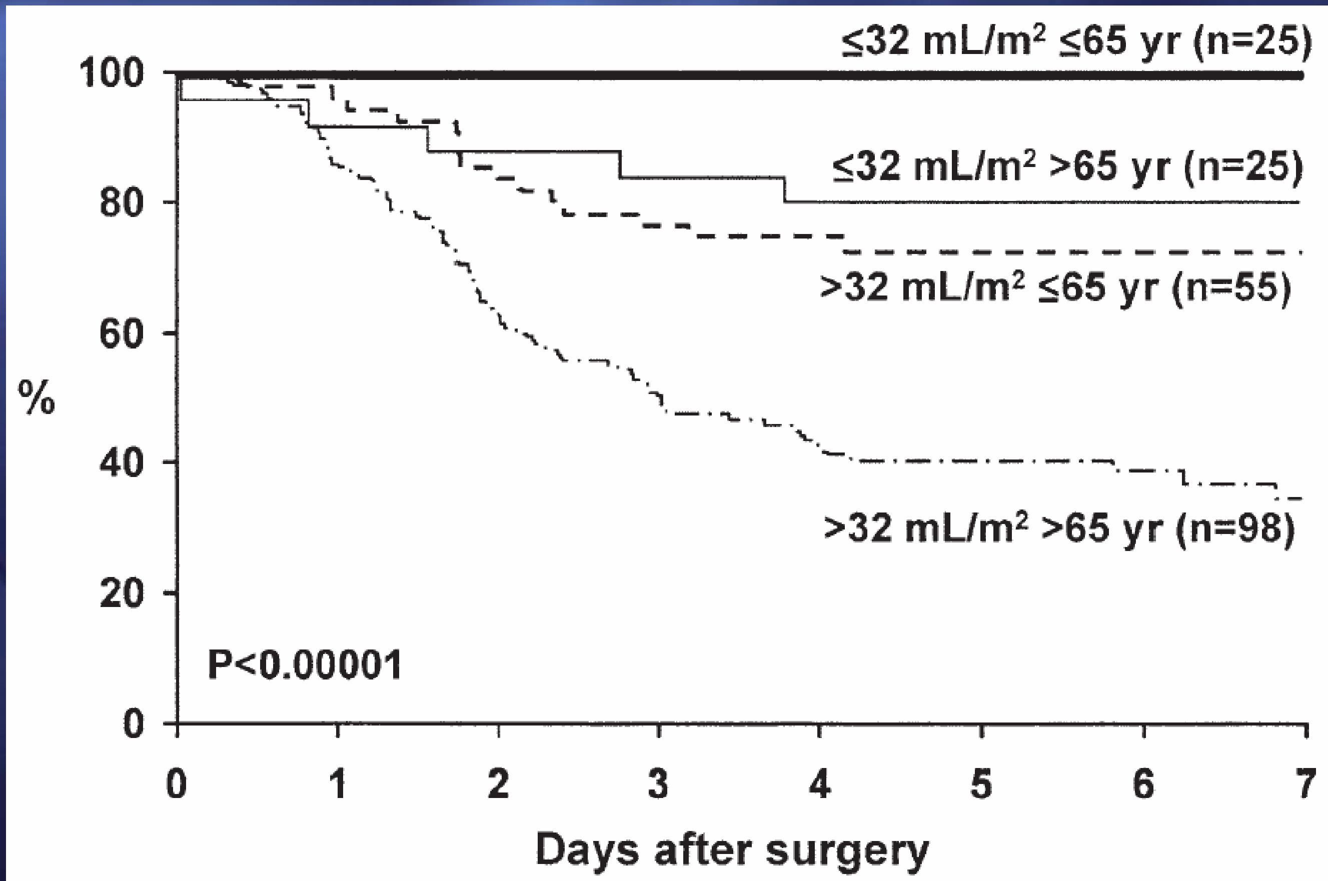
JACC 2006, 48:779

LA Volume Predicts Postop AF After Cardiac Surgery

	HR	(95% CI)	p Value
Age (yrs)	1.04	(1.02–1.06)	0.0002
LAV (ml/m²)	1.03	(1.01–1.04)	0.0001
History of CHF	1.21	(0.77–1.92)	0.41
History of AF	1.38	(0.73–2.61)	0.32
Smoking	1.50	(0.95–2.36)	0.08
CABG + AV	1.54	(0.88–2.70)	0.14
SBP (mm Hg)	1.01	(0.99–1.02)	0.42
Ejection fraction (%)	1.00	(0.99–1.02)	0.65

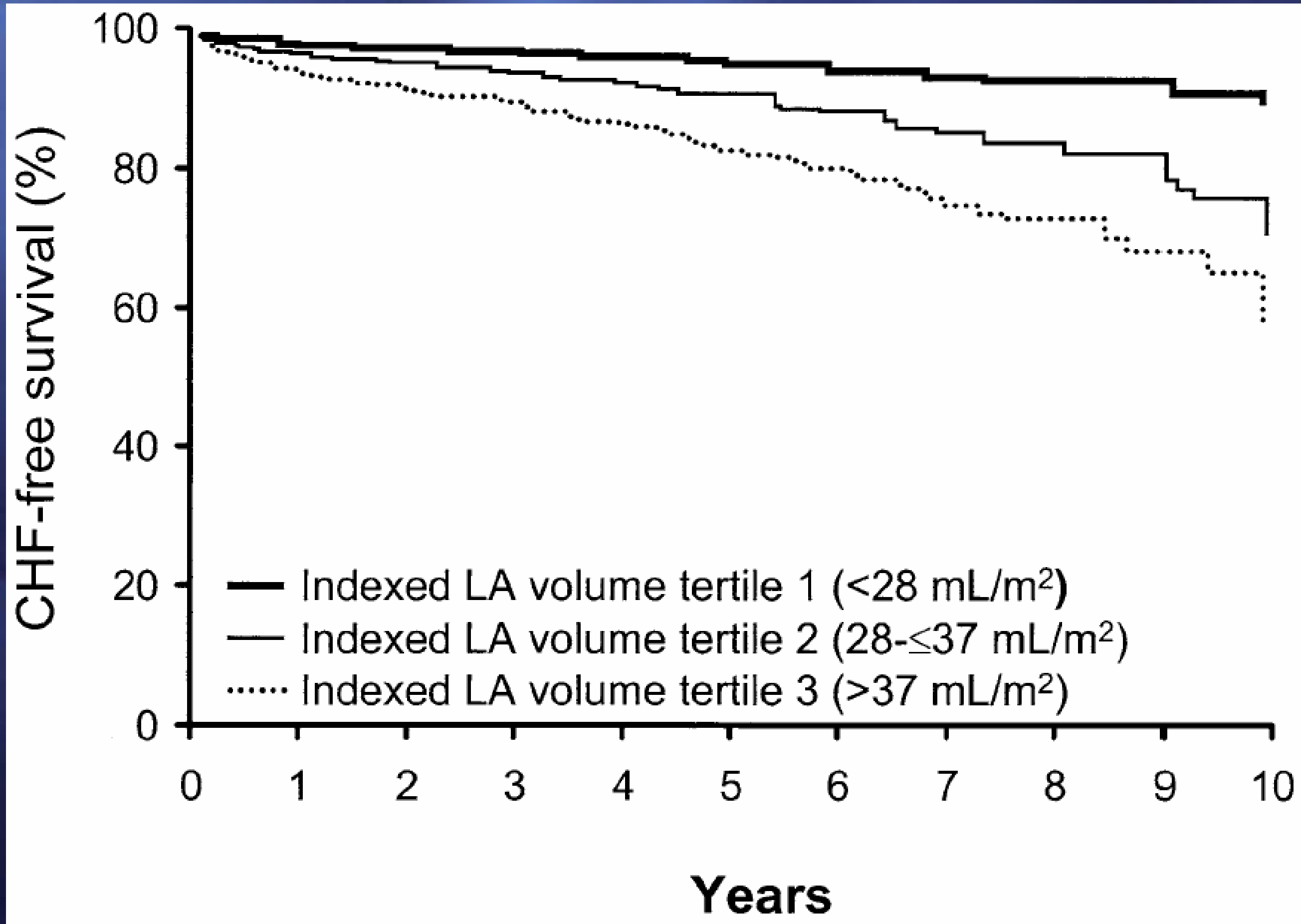
JACC 2006, 48:779

LA Volume Predicts Postop AF After Cardiac Surgery



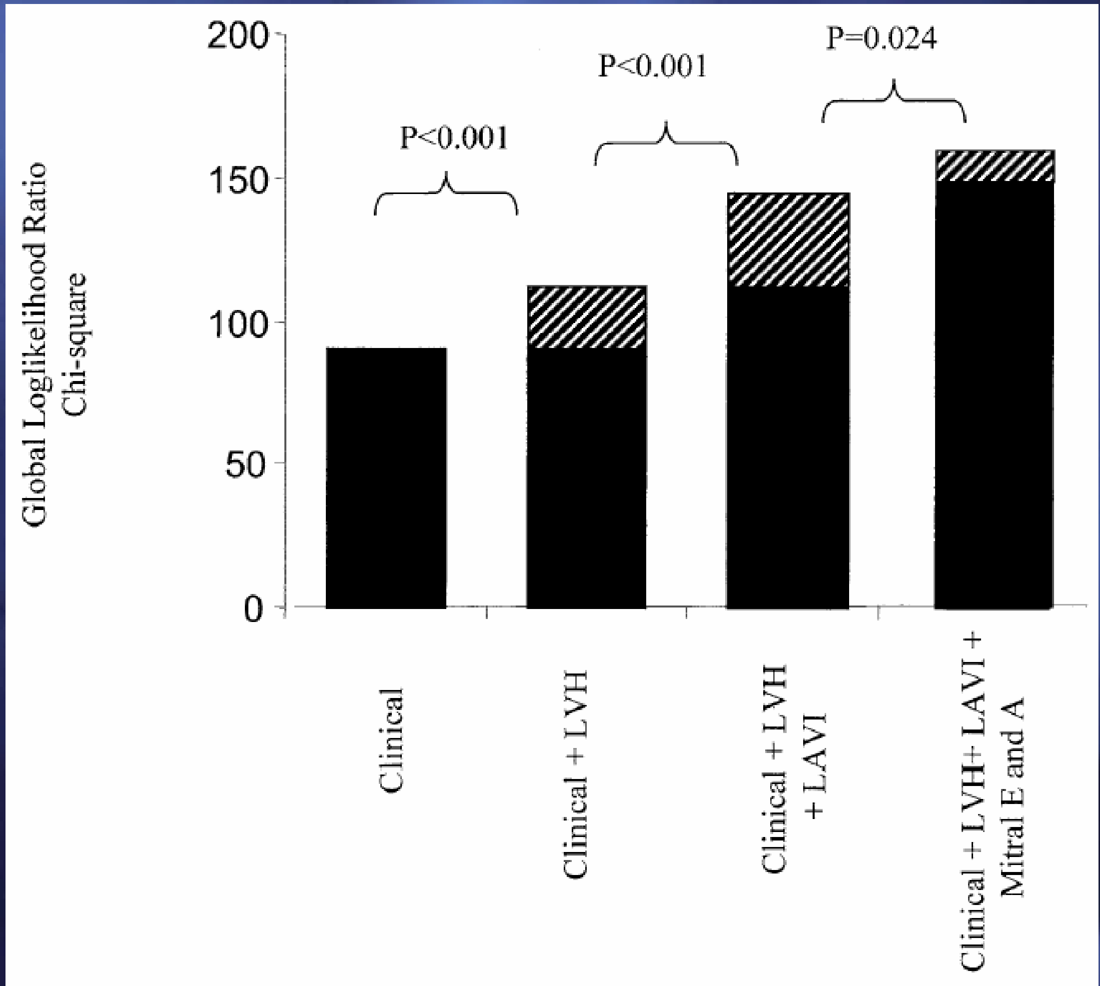
JACC 2006, 48:779

Prediction of 1st CHF in elderly patients with normal LVEF



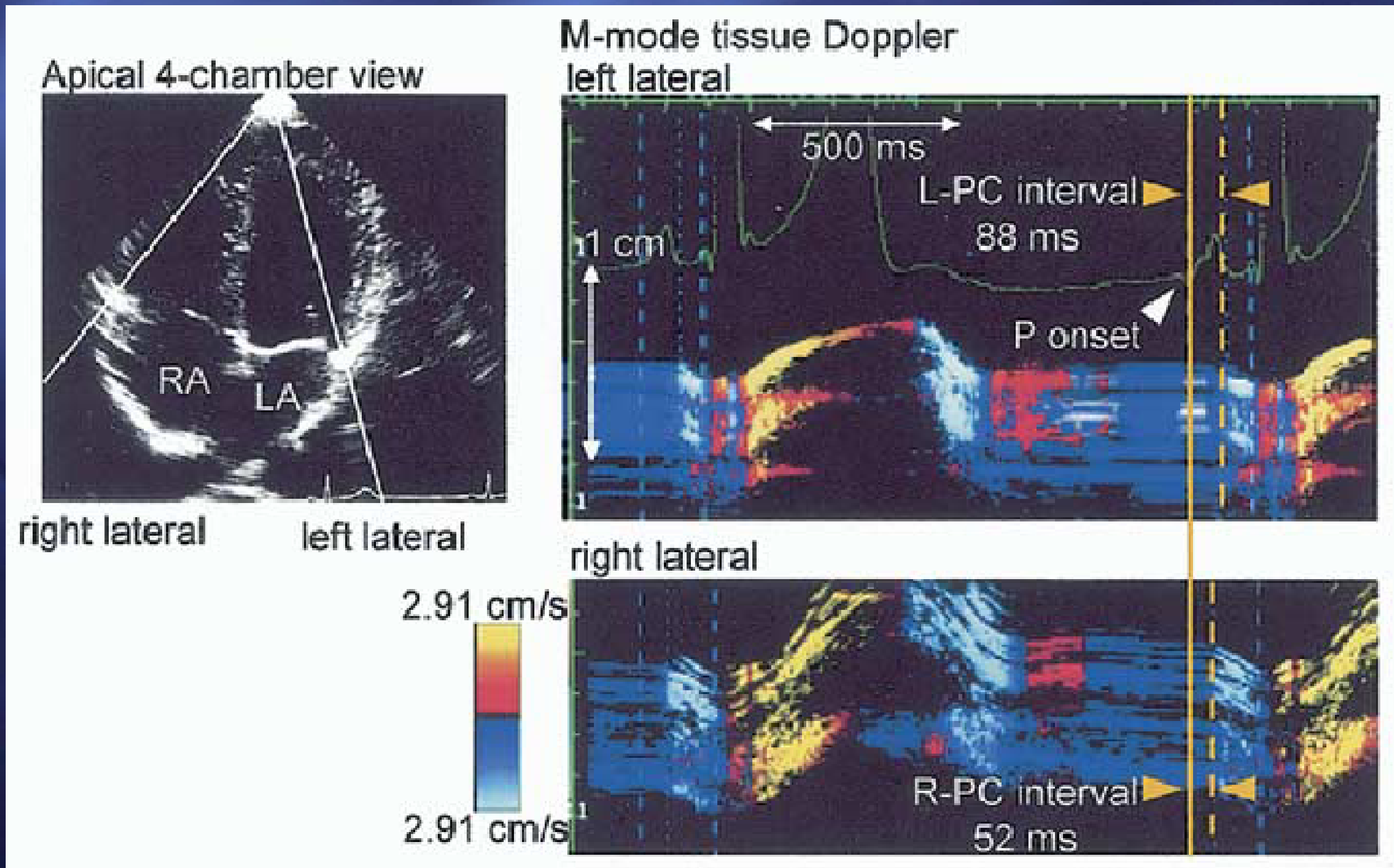
AJC 2005, 96:832

Prediction of 1st CHF in elderly patients with normal LVEF



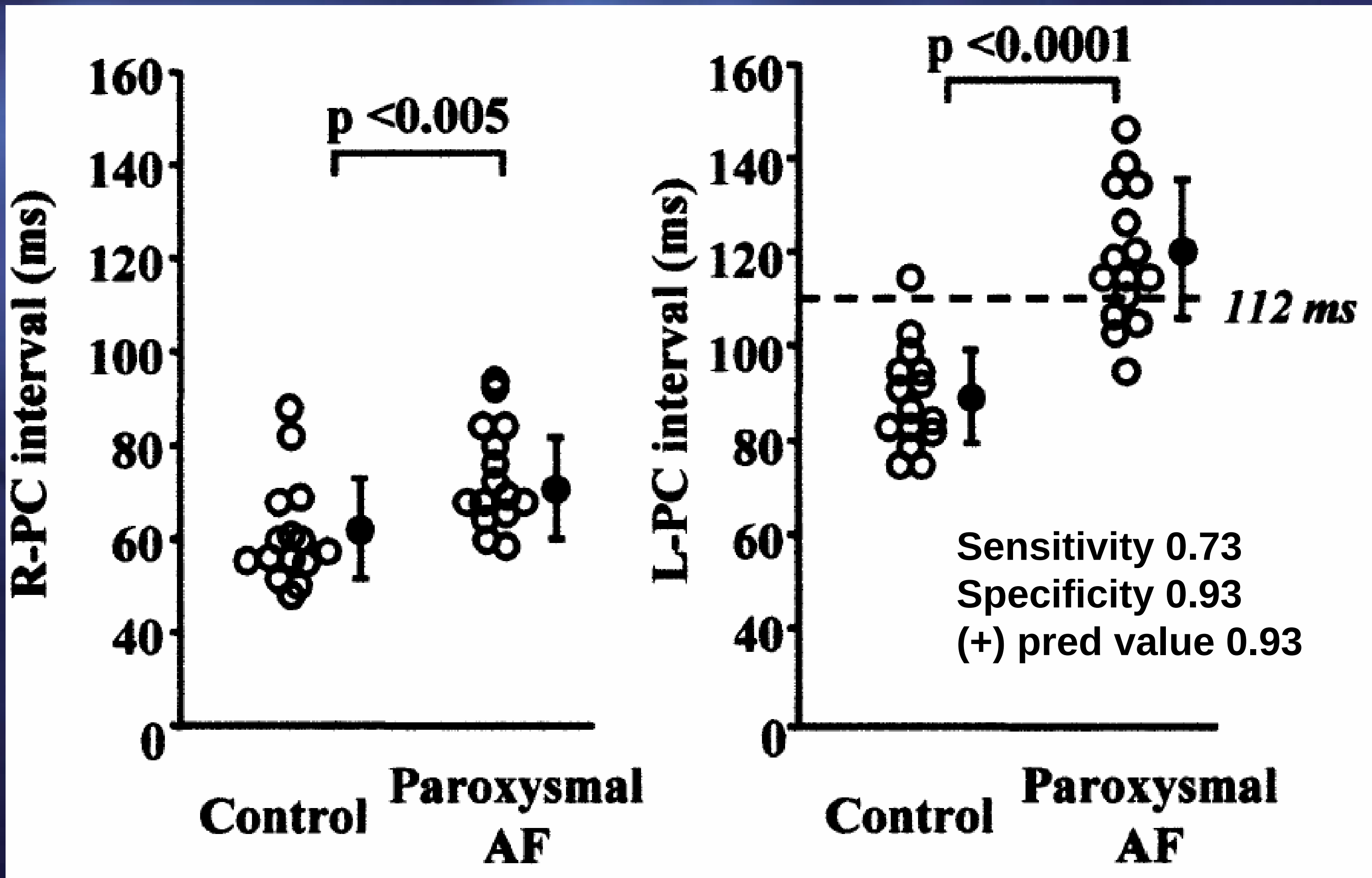
AJC 2005, 96:832

Electromechanical Coupling in Paroxysmal Atrial Fibrillation



JASE 2005, 18:39

Electromechanical Coupling in Paroxysmal Atrial Fibrillation



JASE 2005, 18:39

Regional LA Deformation Assessment

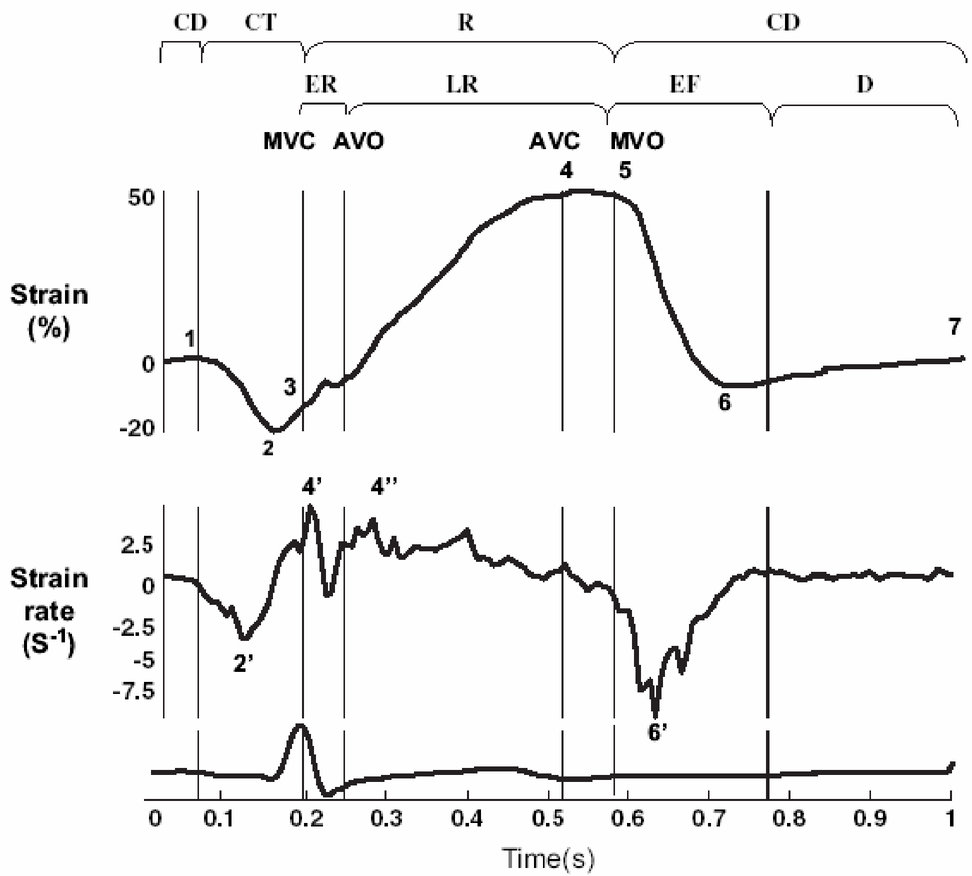
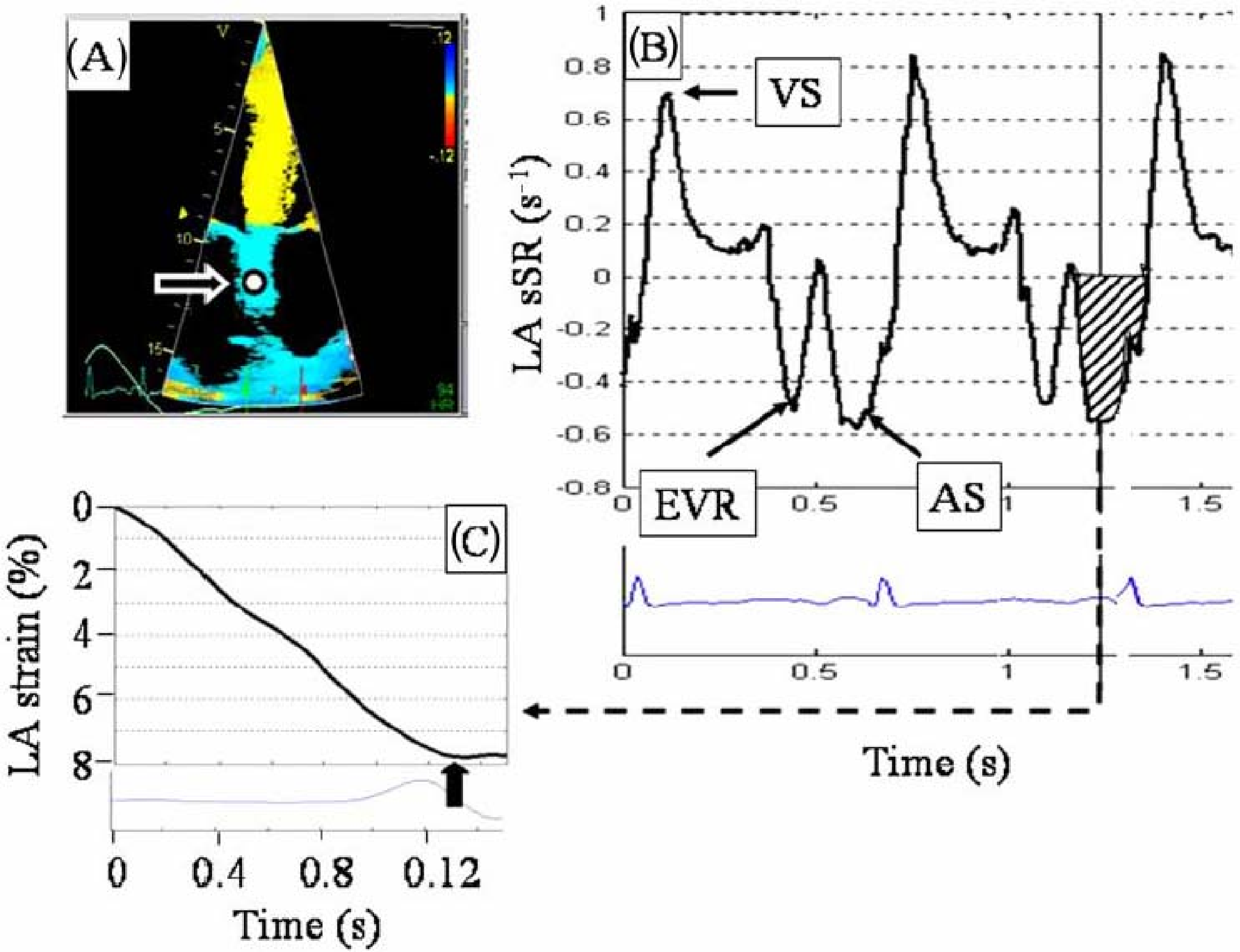


Figure 1 Extracted SR/ε profiles for LA wall longitudinal deformation. MVC, mitral valve closure; AVO, aortic valve opening; AVC, aortic valve closure; MVO, mitral valve opening; CT, contractile period (1, onset; 2, peak ε; 2′, peak SR; 3, end); R, reservoir period (3, onset; 4, peak ε; 5, end); ER, early reservoir period (4′, peak SR); LR, late reservoir period (4″, peak SR); CD, conduit period (5, onset; 6, peak ε; 6′, peak SR; 7, end of LA wall deformation during diastasis; EF, early ventricular filling; D, diastasis).

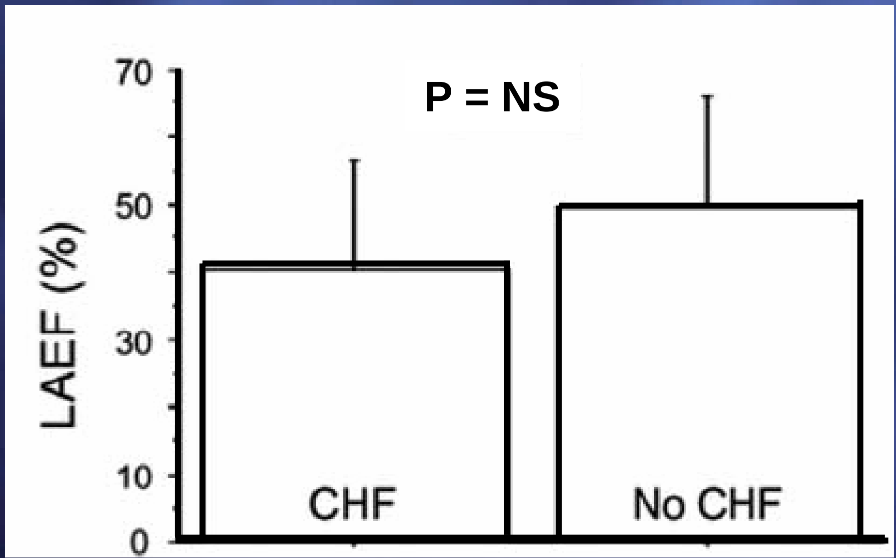
EJE 2006, 7:199

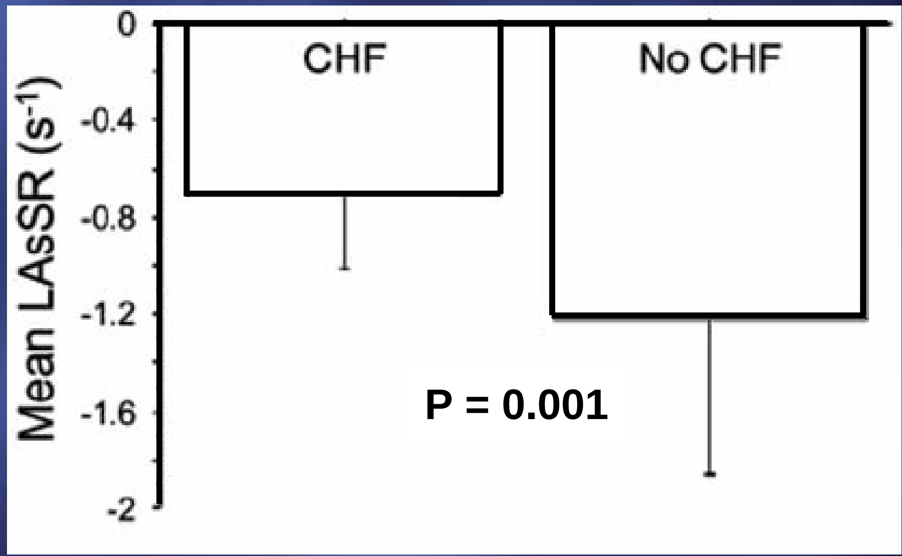
LA Strain Rate in Amyloidosis



EHJ 2005, 26:173

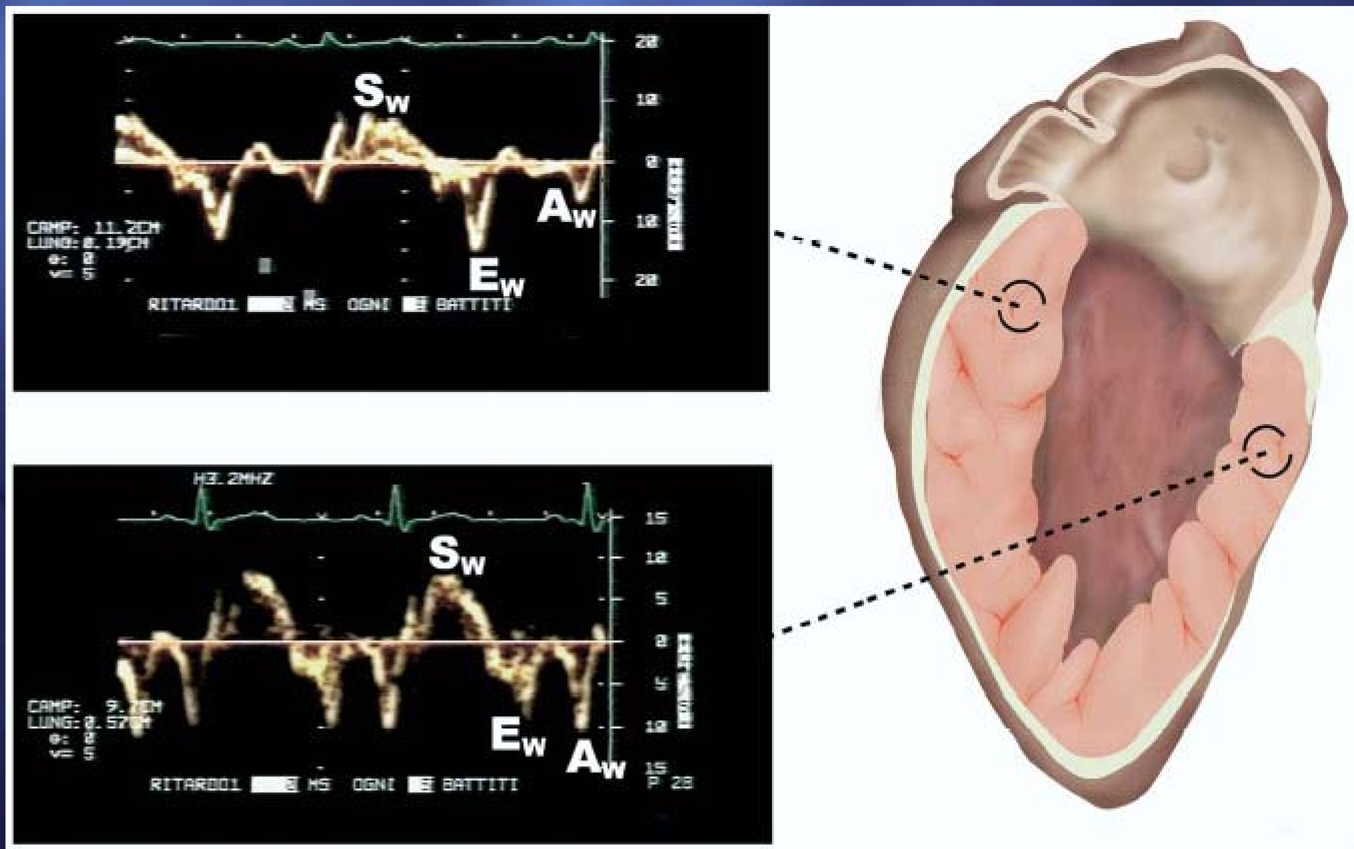
LA Strain Rate in Amyloidosis





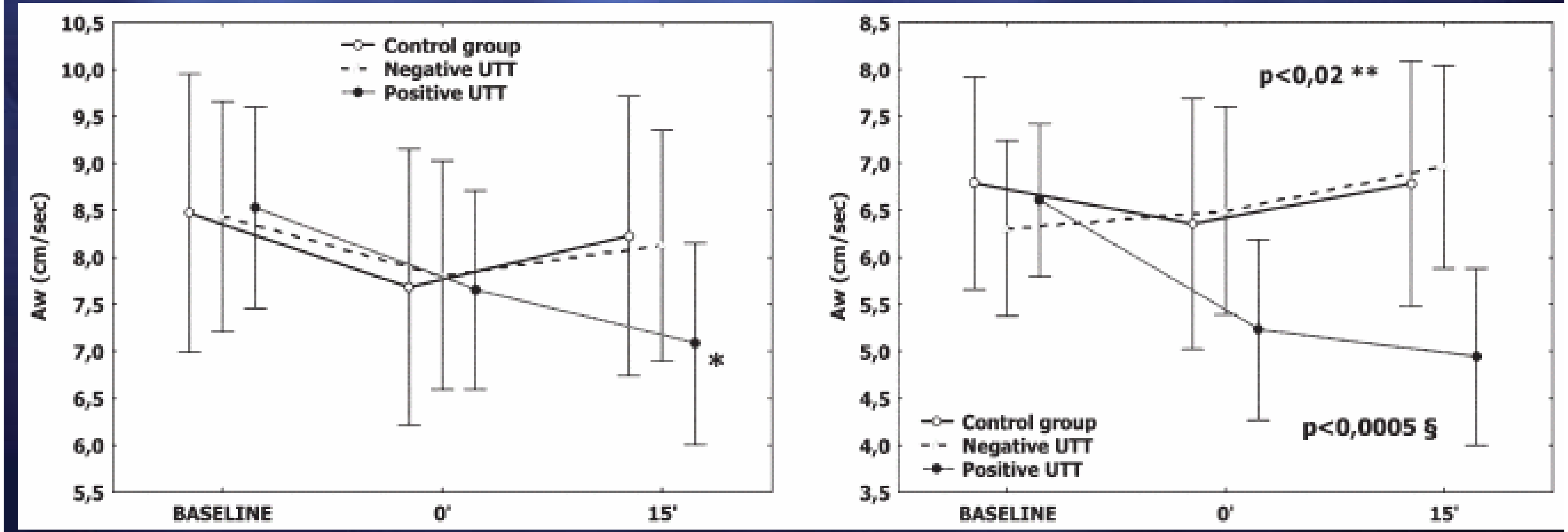
EHJ 2005, 26:173

Atrial Function
in Neurally Mediated Syncope



AJC 2006, 97:1017

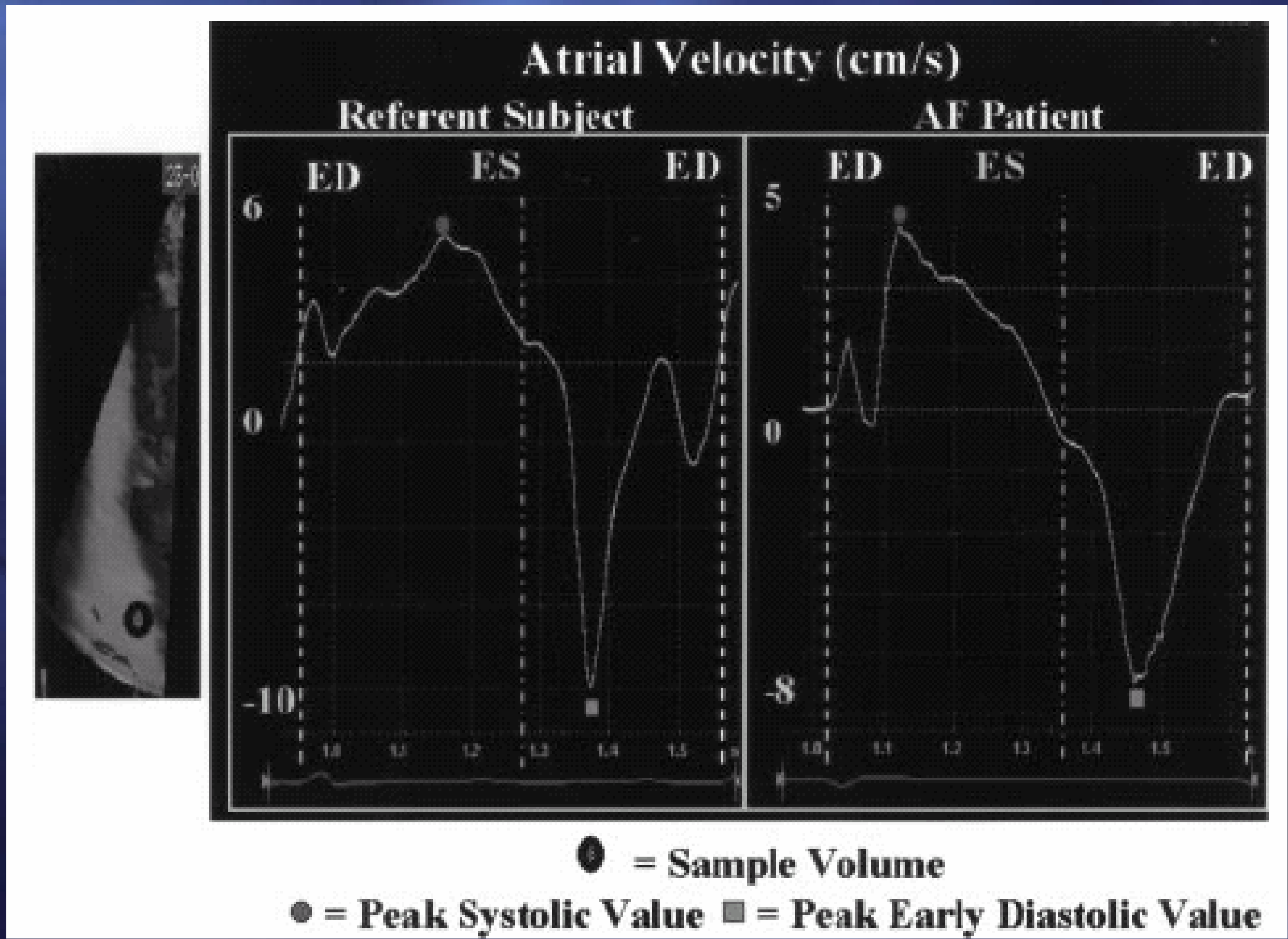
Atrial Function in Neurally Mediated Syncope



Inf. Wall **Ant. Wall**

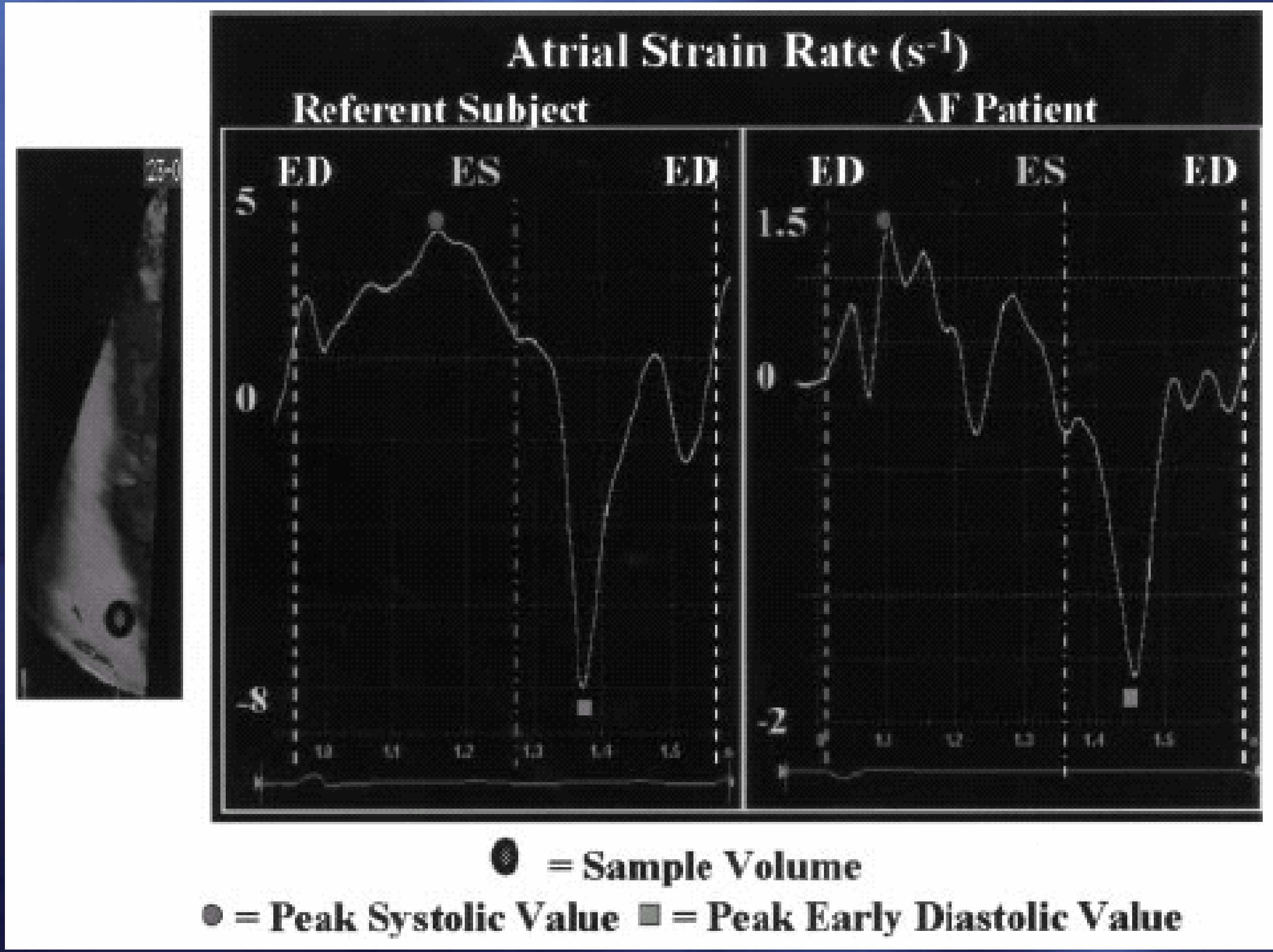
AJC 2006, 97:1017

Prediction of SR Maintenance After Cardioversion in Lone AF



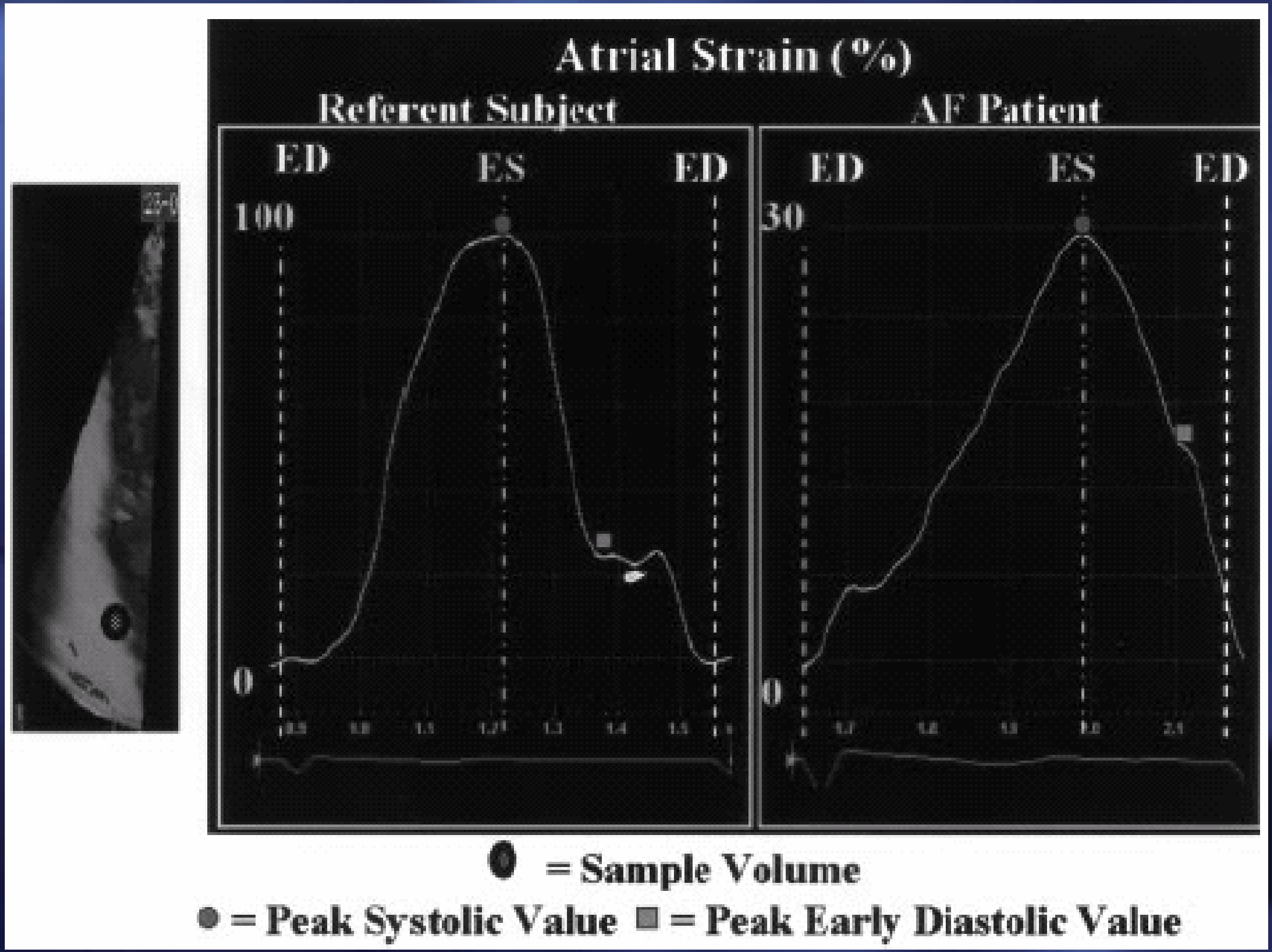
Circulation 2005, 112: 387

Prediction of SR Maintenance After Cardioversion in Lone AF



Circulation 2005, 112: 387

Prediction of SR Maintenance After Cardioversion in Lone AF



Circulation 2005, 112: 387

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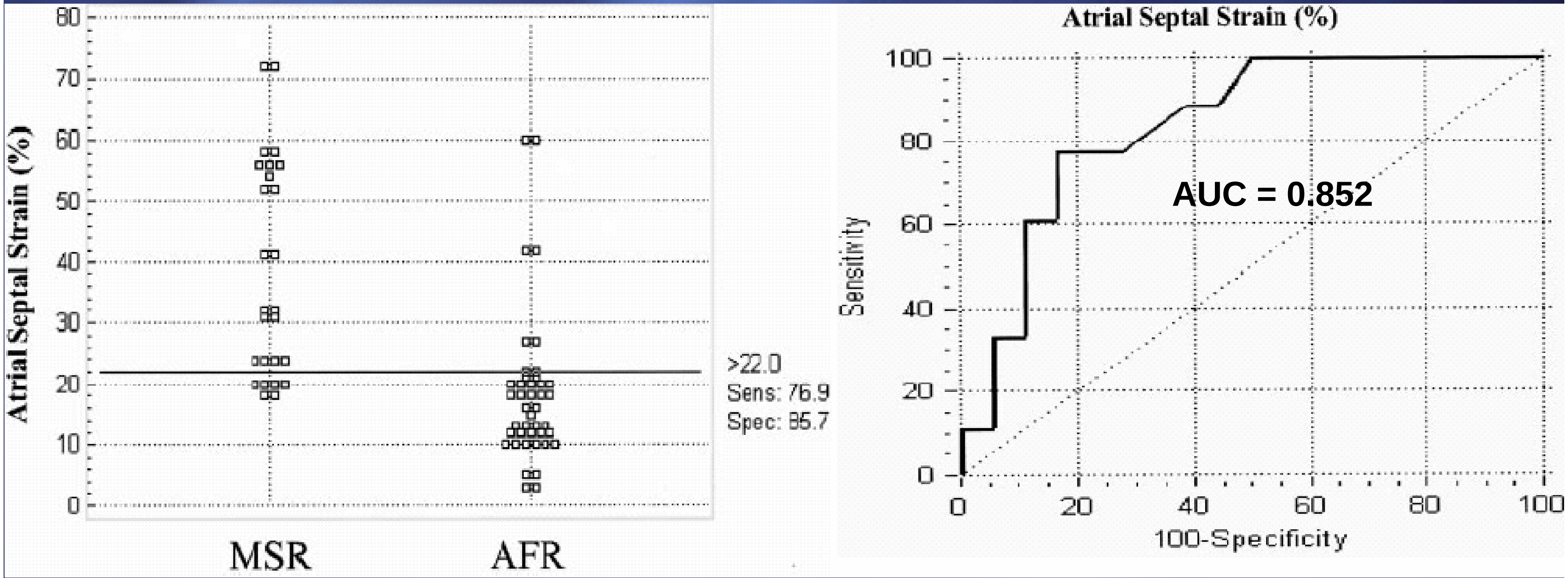

Circulation 2005, 112: 387

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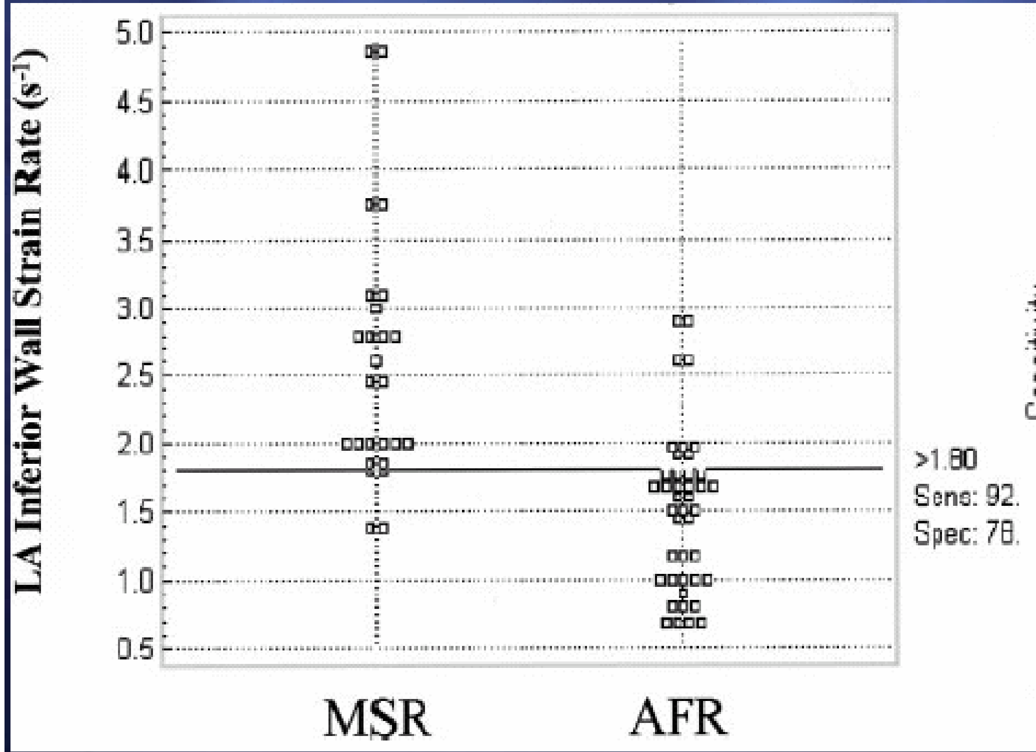

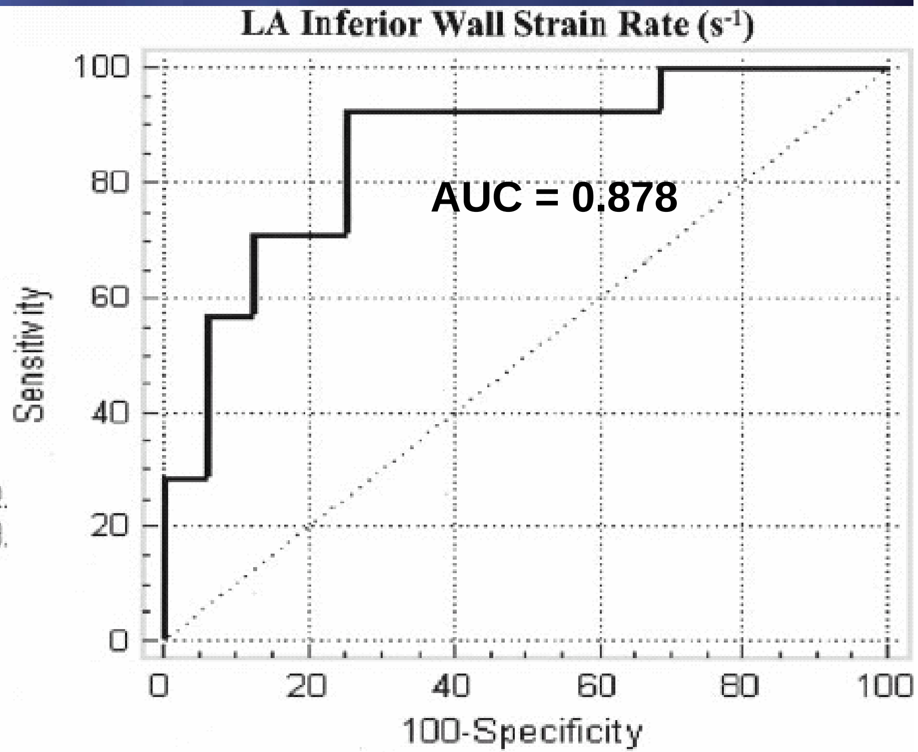

Circulation 2005, 112: 387

Summary

- **Echo measurements for LA function**
  - Feasible, multiple parameters
    Which is optimal?
  - Load dependent, especially LV load.
    LA contractility ≠ LA contraction

- **parameters**
  - Simple - Mitral A, a’, Strain, SR
  - Complex
    - Volumes
    - Derived indices – LA ejection force, kinetic energy

Summary

- LA size quantitation, especially LA volume (?) helps in clinical situations.
- LA myocardial velocity, strain, and SR may be promising in potential clinical application.
- Future studies
  - Validation for LA indices
  - Age, gender, HR effects
  - Medium to large scale study