Assessment of left atrial function: does it offer added value?

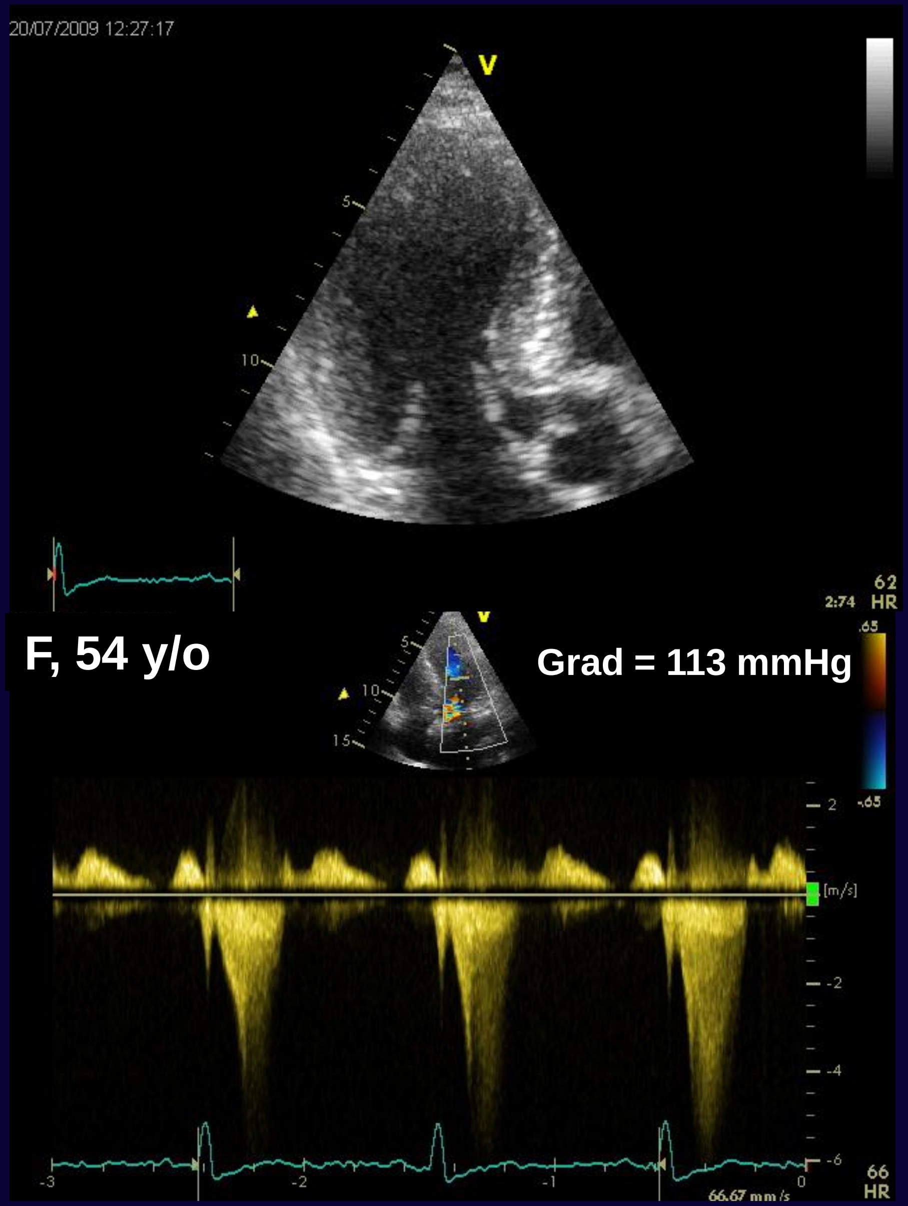
Bogdan A. Popescu, Monica Rosca

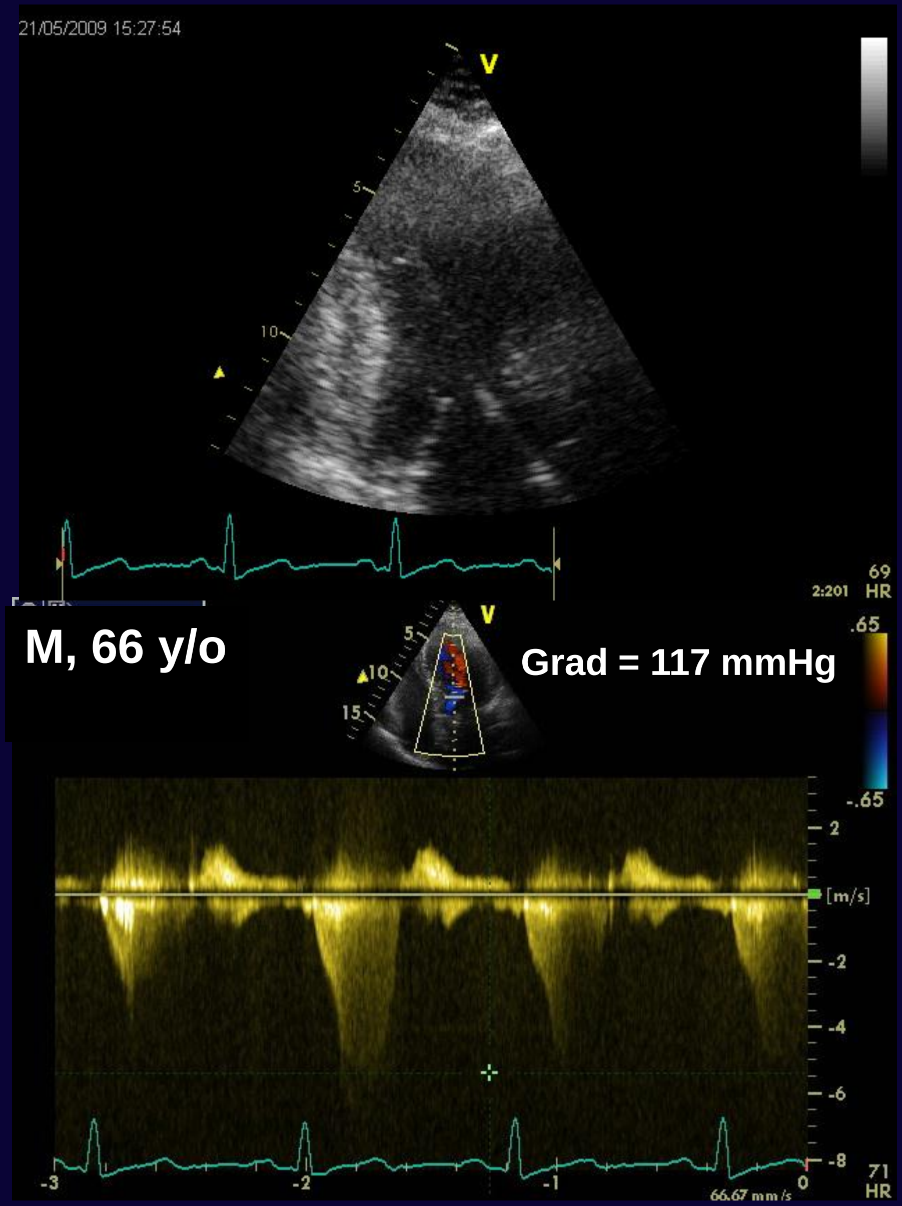
"Carol Davila" University of Medicine and Pharmacy

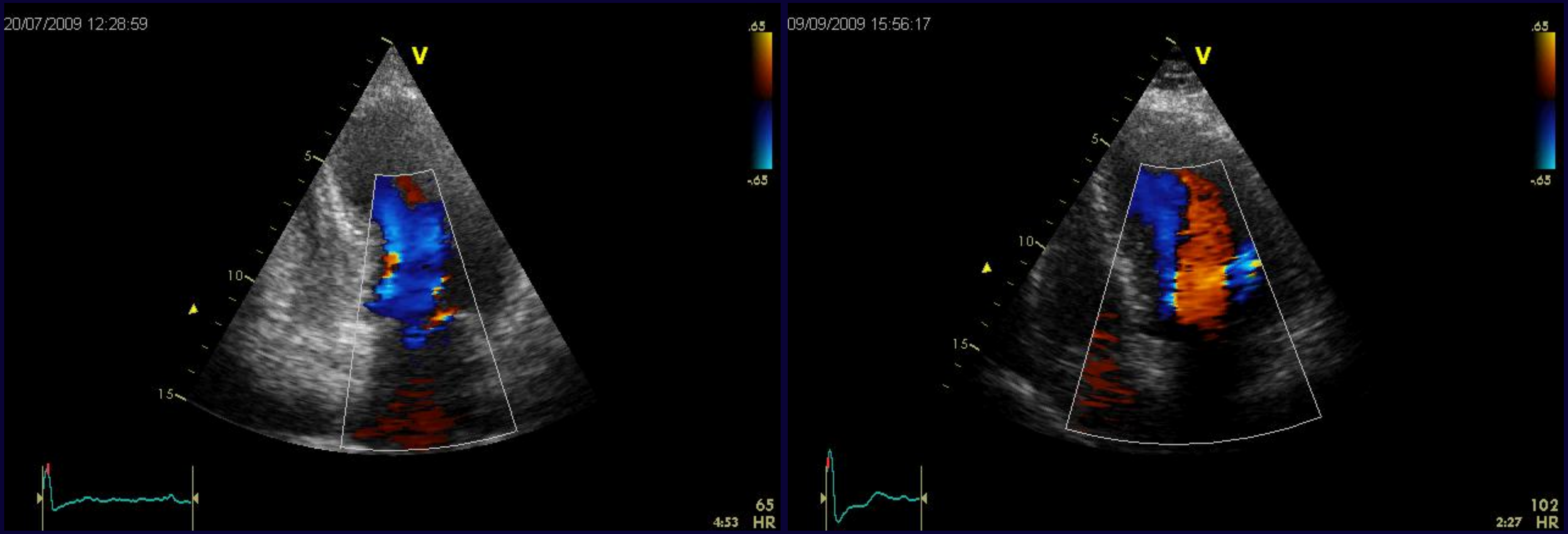
Bucharest, Romania

EAE Course, Sofia, April 2012

Case presentation






20/07/2009 12:28:59
V
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-.65
5
10
15
65
4:53 HR
09/09/2009 15:56:17
V
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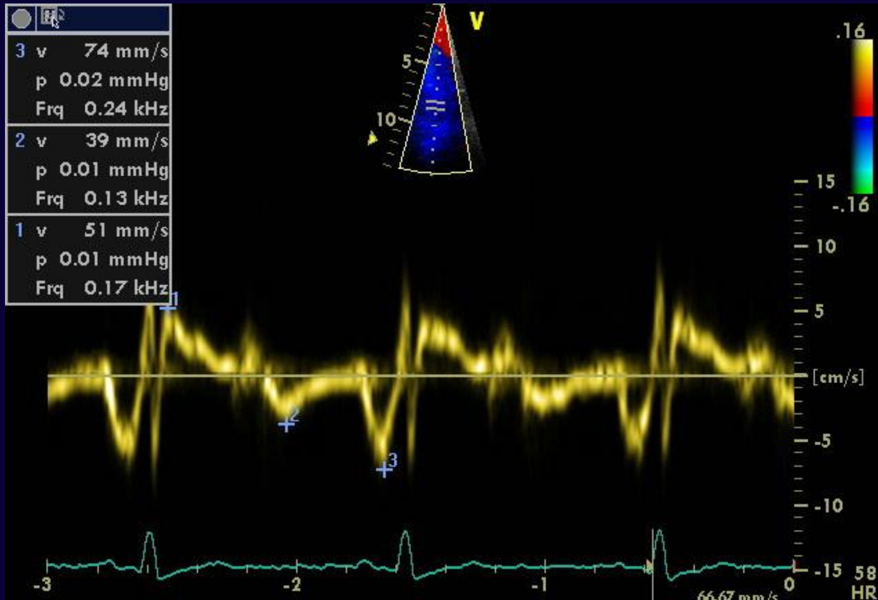
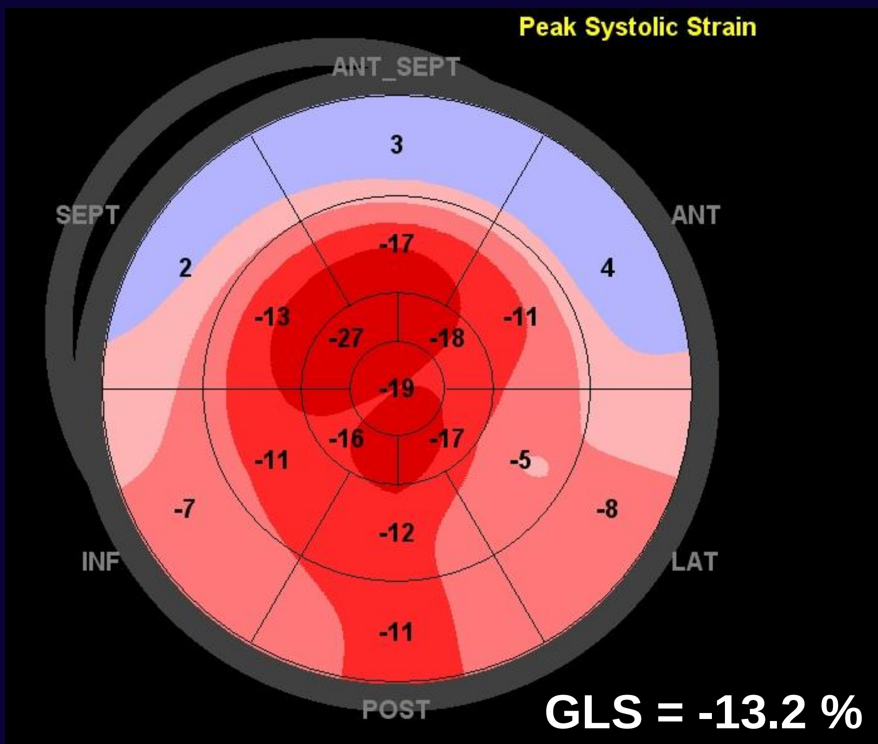
10
15
102
2:27 HR


3 v 74 mm/s
p 0.02 mmHg
Frq 0.24 kHz
2 v 39 mm/s
p 0.01 mmHg
Frq 0.13 kHz
1 v 51 mm/s
p 0.01 mmHg
Frq 0.17 kHz
[cm/s]
66.67 mm/s
58
HR


3 v 36 mm/s
p 0.01 mmHg
Frq 0.12 kHz
2 v 54 mm/s
p 0.01 mmHg
Frq 0.18 kHz
1 v 55 mm/s
p 0.01 mmHg
Frq 0.18 kHz
[cm/s]
66.67 mm/s
71
HR


Peak Systolic Strain
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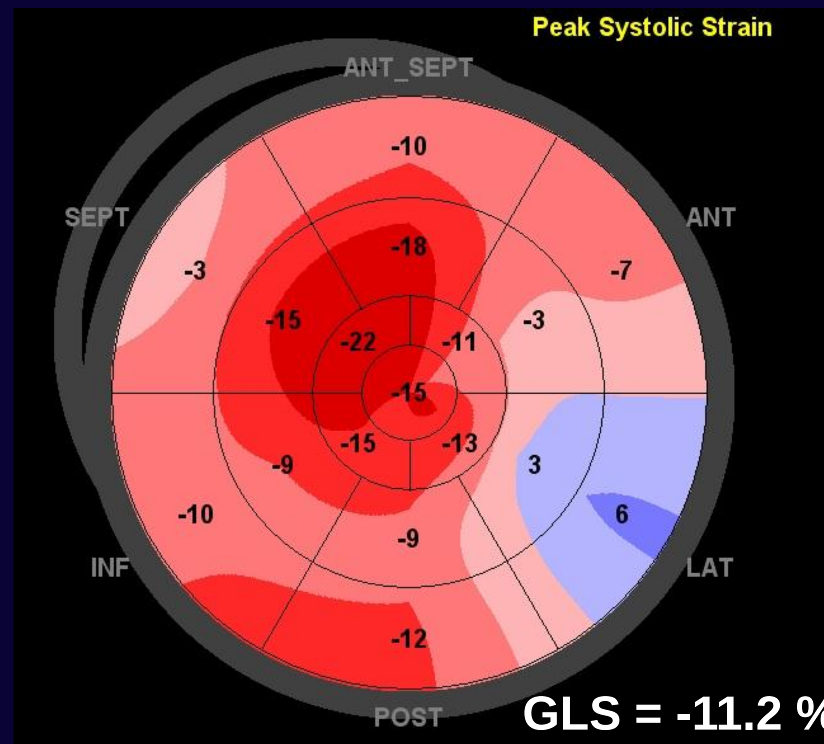
GLS = -13.2 %


Peak Systolic Strain
ANT_SEPT
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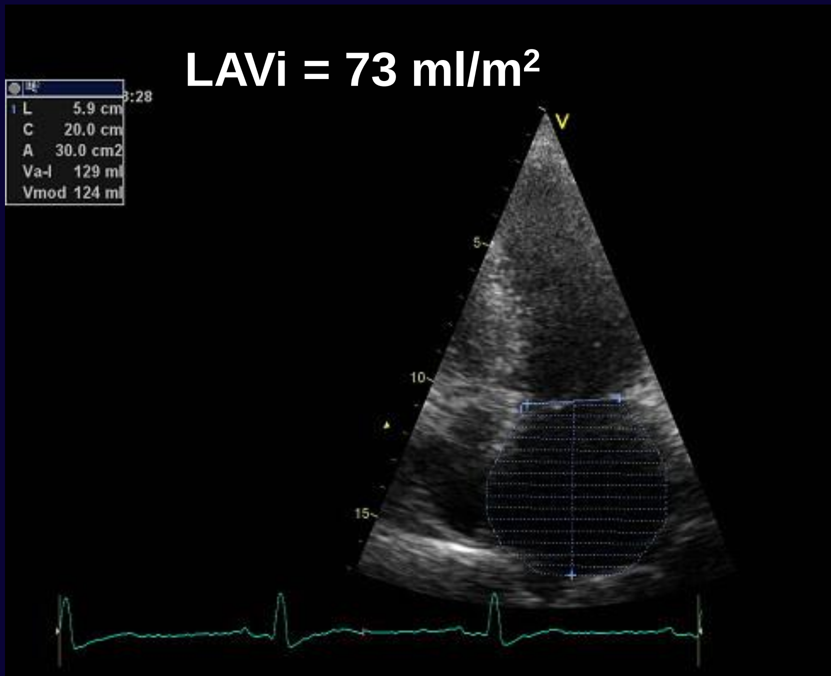
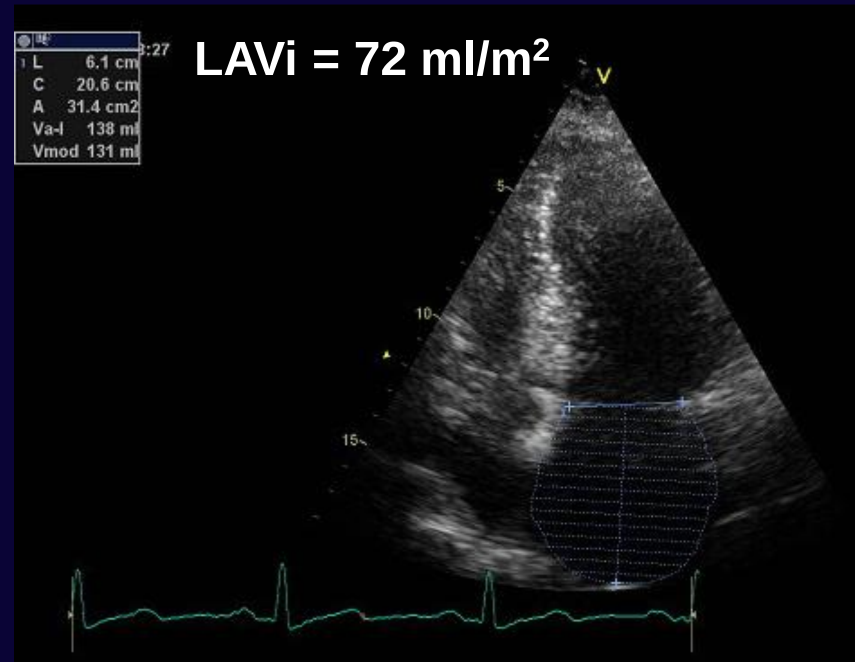
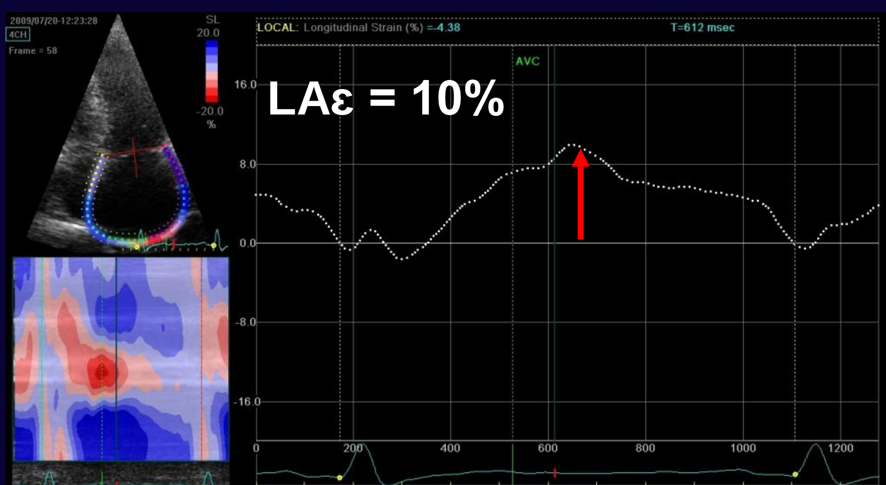
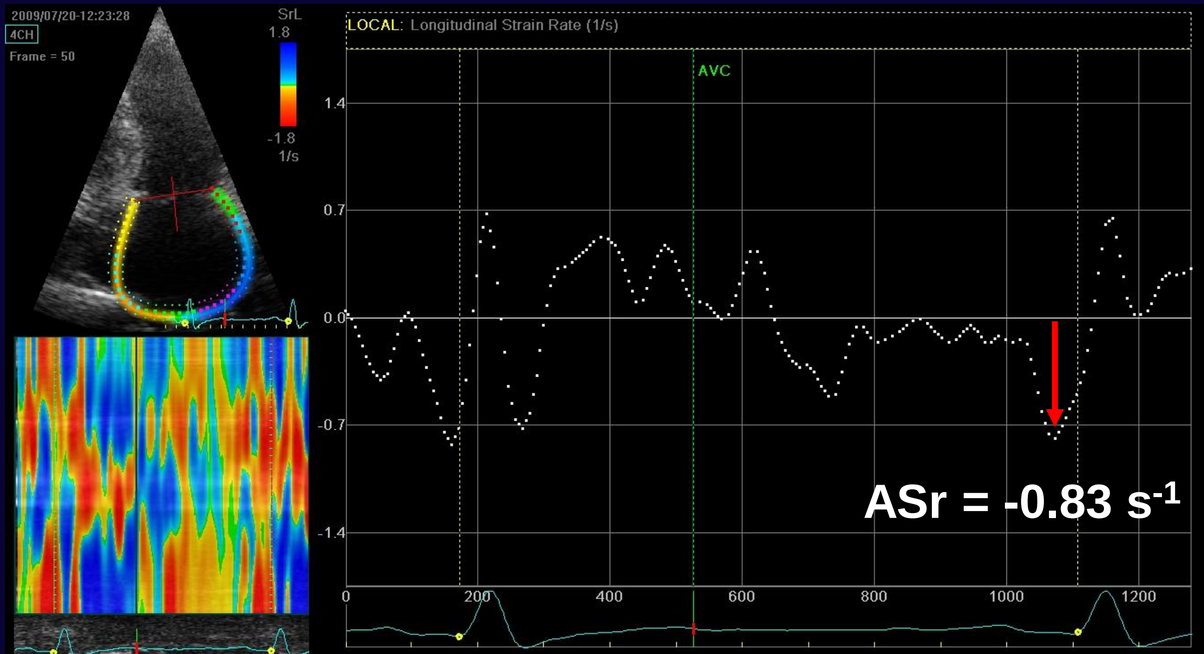
GLS = -11.2 %


LAVi = 73 ml/m²
L 5.9 cm
C 20.0 cm
A 30.0 cm2
Va-l 129 ml
Vmod 124 ml


LAVi = 72 ml/m²
L 6.1 cm
C 20.6 cm
A 31.4 cm2
Va-l 138 ml
Vmod 131 ml

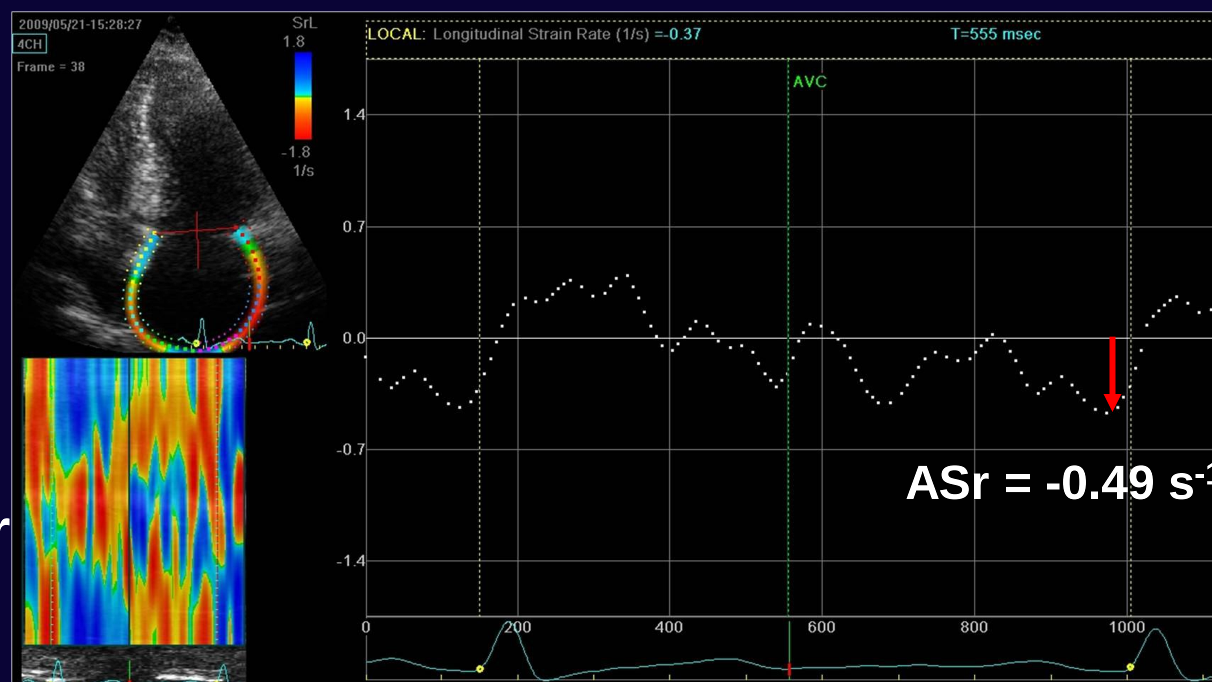

LAε = 10%
LOCAL: Longitudinal Strain (%) =-4.38
T=612 msec
AVC


LAε = 7.8%
LOCAL: Longitudinal Strain (%) =-4.38
T=570 msec
AVC



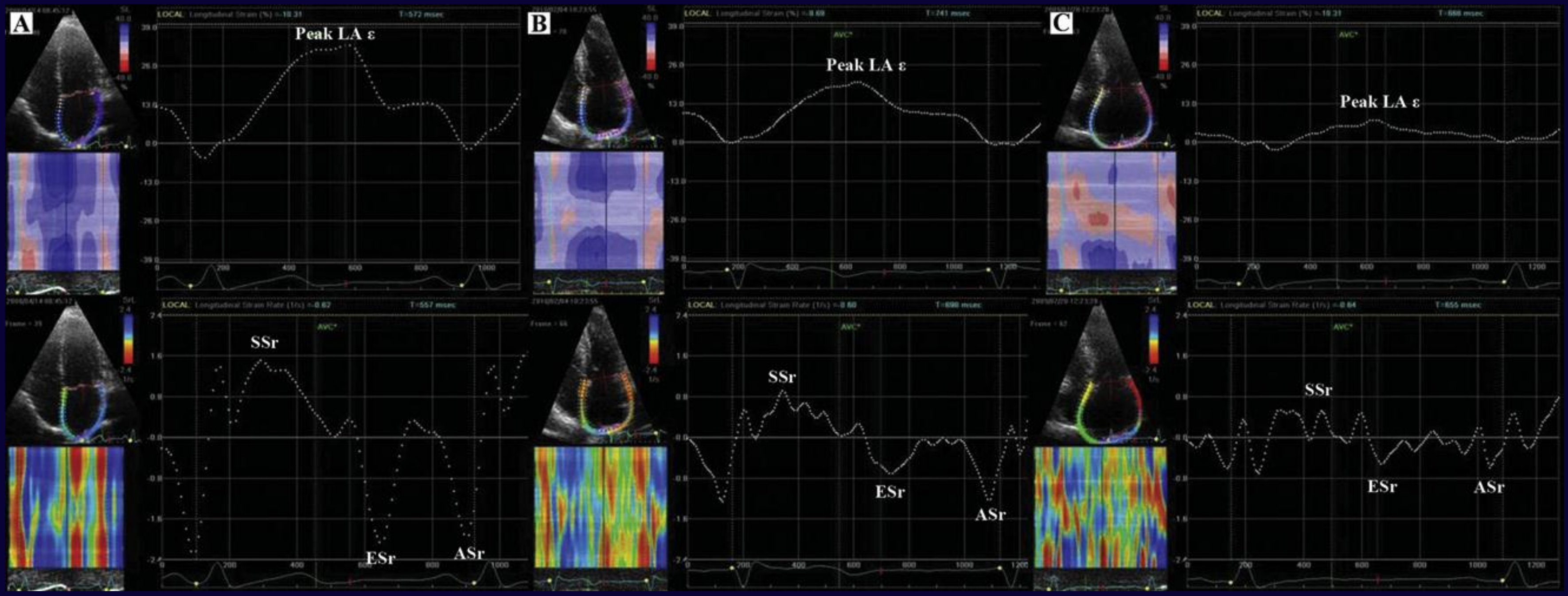
NYHA II

Sinus rhythm after 1 year follow-up



NYHA III

Atrial fibrillation after 1 year follow-up



normal subject — asymptomatic HCM — symptomatic HCM

Table 4 Correlates of symptomatic status in patients with hypertrophic cardiomyopathy

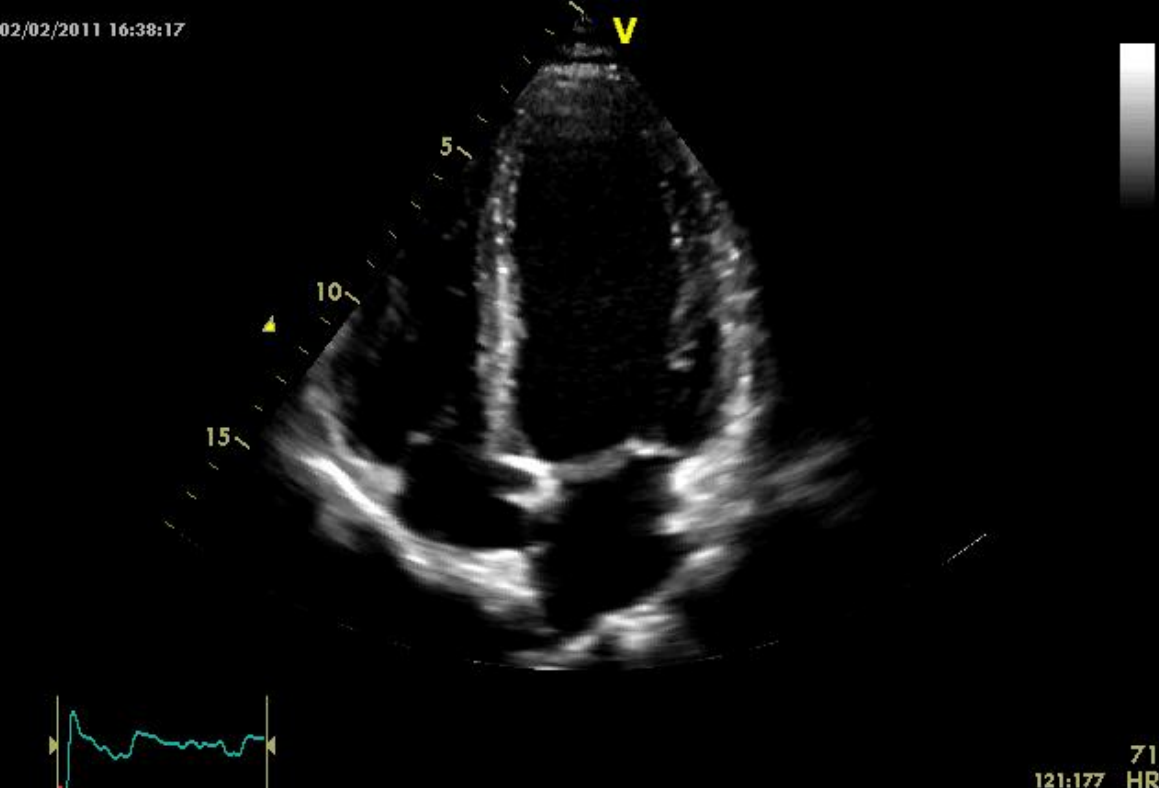
Variables	Univariate analysis OR	95% CI	P	Multivariable analysis P
Age	1.027	0.983-1.073	.23	-
LVε	1.215	0.954-1.549	.11	.49
LAVi	1.091	1.018-1.170	.01	.34
ASr	3.377*	1.349-8.616	.009	.04
MR degree	2.277	0.969-5.353	.056	.10
Presence of LV outflow tract obstruction (Y/N)	0.476	0.118-1.929	.29	-
Peak LV outflow tract gradient	1.010	0.981-1.041	.49	-

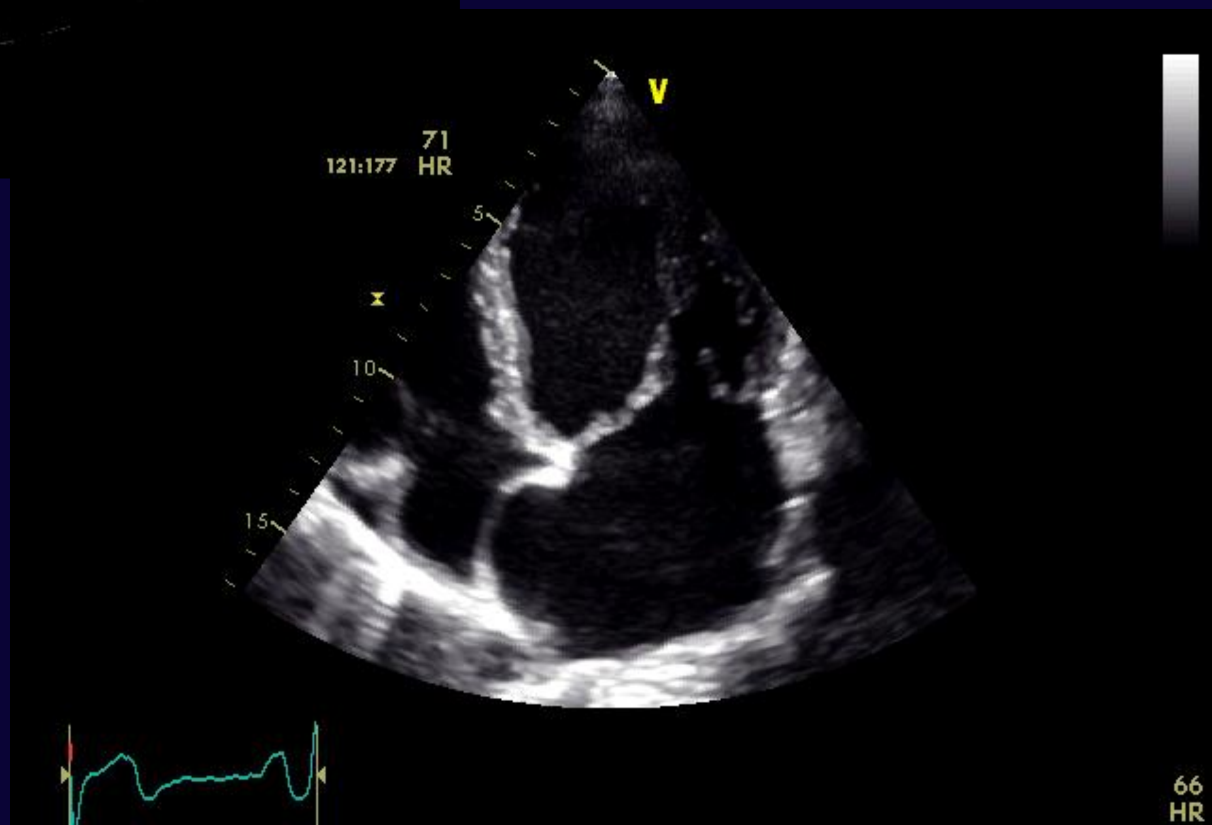
Symptoms of heart failure were related to the severity of LA dysfunction.

Rosca M, Popescu BA et al. *JASE 2010*

Importance of left atrial function

- The mechanical function of the left atrium plays an important role in the overall cardiovascular performance
- The LA contributes up to 30% of total LV stroke volume in normal subjects
- The atrial contribution is particularly important in the setting of LV dysfunction, where this percentage may become higher
- The loss of atrial contribution to LV filling and stroke volume in atrial fibrillation often leads to symptomatic deterioration


02/02/2011 16:38:17
V
5
10
15


71
121:177 HR
V
5
10
15
66
HR

The left atrium and cardiovascular outcome

- The LA is an important determinant of cardiovascular morbidity and mortality

- This was shown both in the general population (LA size correlated with cardiovascular diseases or adverse clinical outcomes), and in patients with various pathological conditions

Pritchett AM, et al. *J Am Coll Cardiol* 2003;41:1036-1043.
Benjamin EJ, et al. *Circulation* 1995;92:835-841.
Rossi A, et al. *J Am Coll Cardiol* 2002;40:1425-1430.
Reed D, et al. *Circulation* 1991;84:23-34.
Cabin HS, et al. *Am J Cardiol* 1990;65:1112-1116.
Moller JE, et al. *Circulation* 2003;107:2207-2212.

Left atrial function

The key function of the left atrium is to modulate left ventricular filling and cardiovascular performance

LA function	Timing in cardiac cycle
Reservoir	Ventricular systole
Conduit	Early diastole
Pump	End diastole

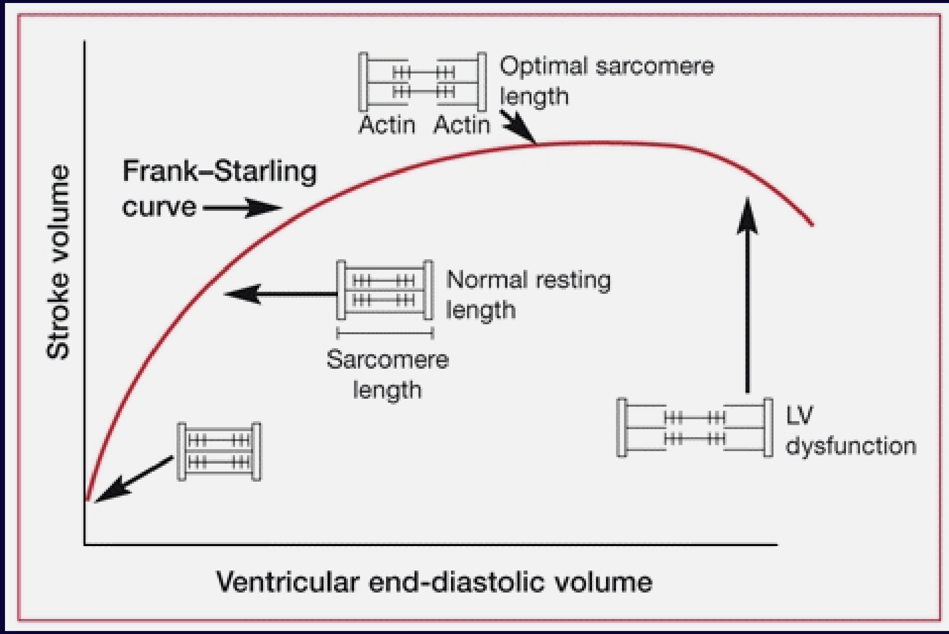
In addition:

- volume sensor of the heart, releasing natriuretic peptides
- contains receptors for various reflexes

Pathophysiology

The Frank-Starling mechanism is also operative in the LA (LA output increases as atrial diameter increases, which contributes to maintaining a normal stroke volume)

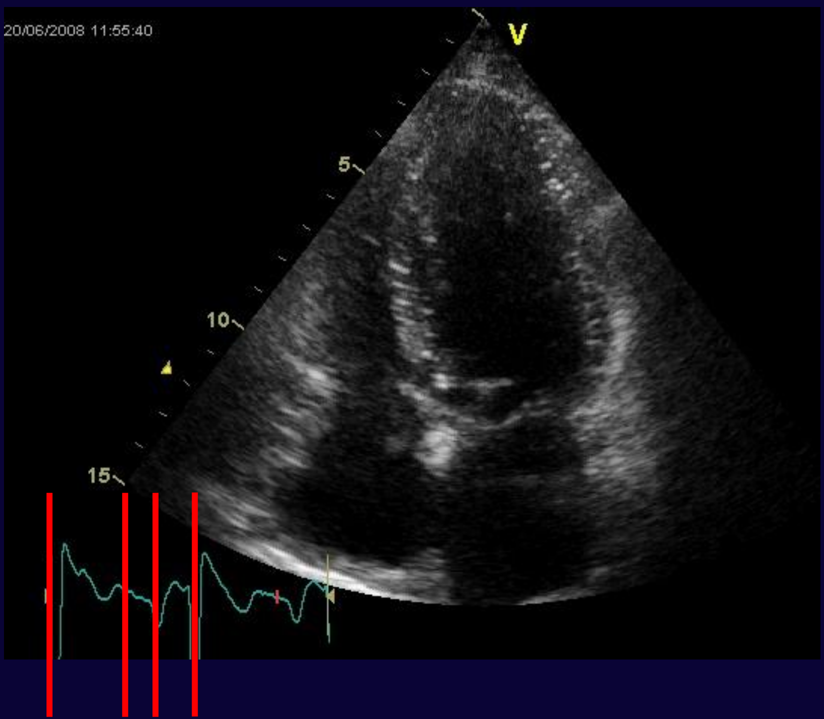
Payne RM et al. *J Appl Physiol* 1971



LA active emptying might decrease in the presence of severe LA dilation as the optimal Frank-Starling relationship is exceeded

Pagel PS et al. *Anesthesiology* 2003

Pathophysiology



LV systole and LA relaxation
early LV diastole and diastasis
late LV diastole

Reservoir function

Modulated by:

- LV contraction
- RV systolic pressure
- *LA relaxation*
- *LA chamber stiffness*

Conduit function

Modulated by:

- LV relaxation
- LA afterload

Contractile function

Modulated by:

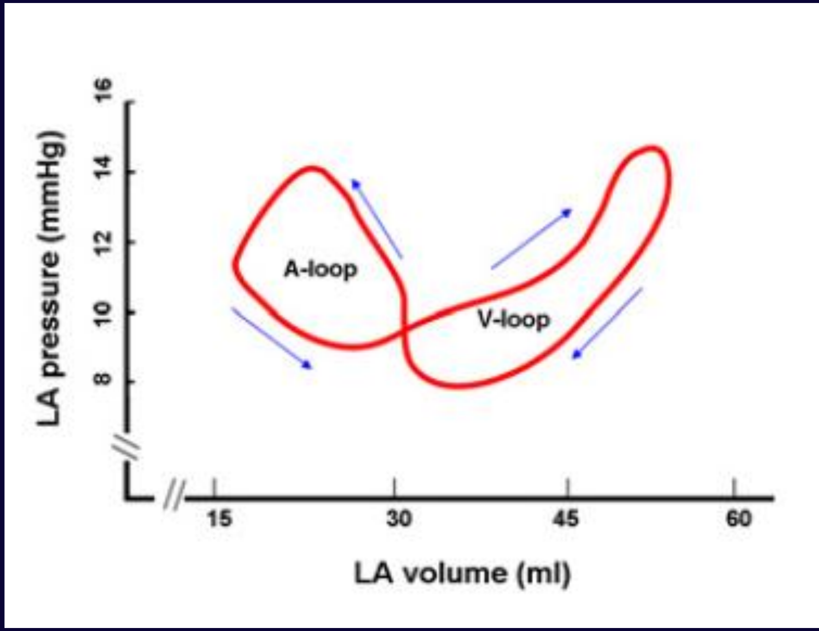
- LV compliance
- LA afterload (LV filling pressures)
- LA preload
- *Intrinsic LA contractility*

LA function assessment

Invasive assessment

- LA pressure-volume relationship

  – gold standard



Rosca M, et al. *Heart 2011*

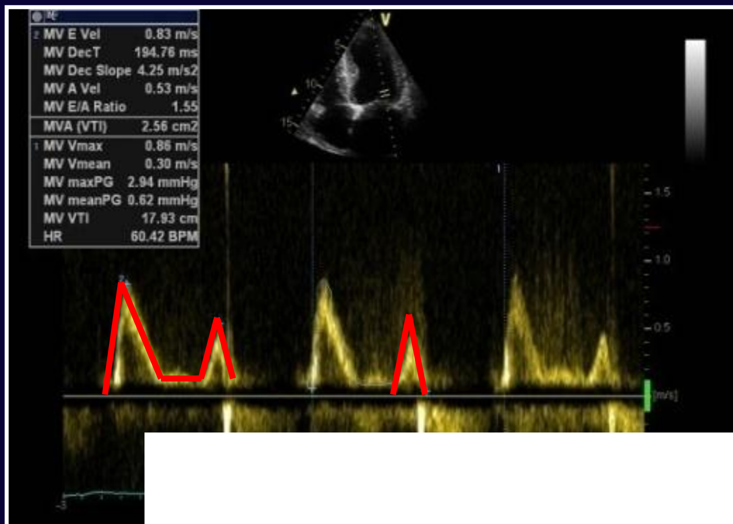
Echocardiographic assessment

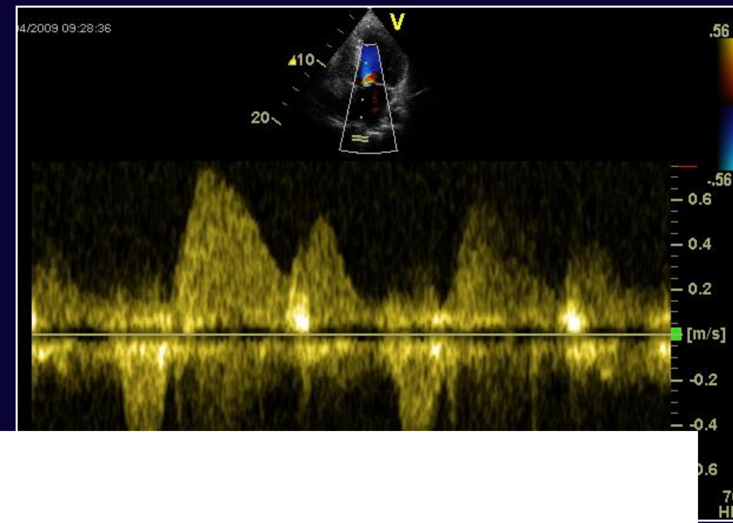
- Conventional parameters
- New techniques (TDI/STE/3D echocardiography)

Assessment of LA function by echocardiography

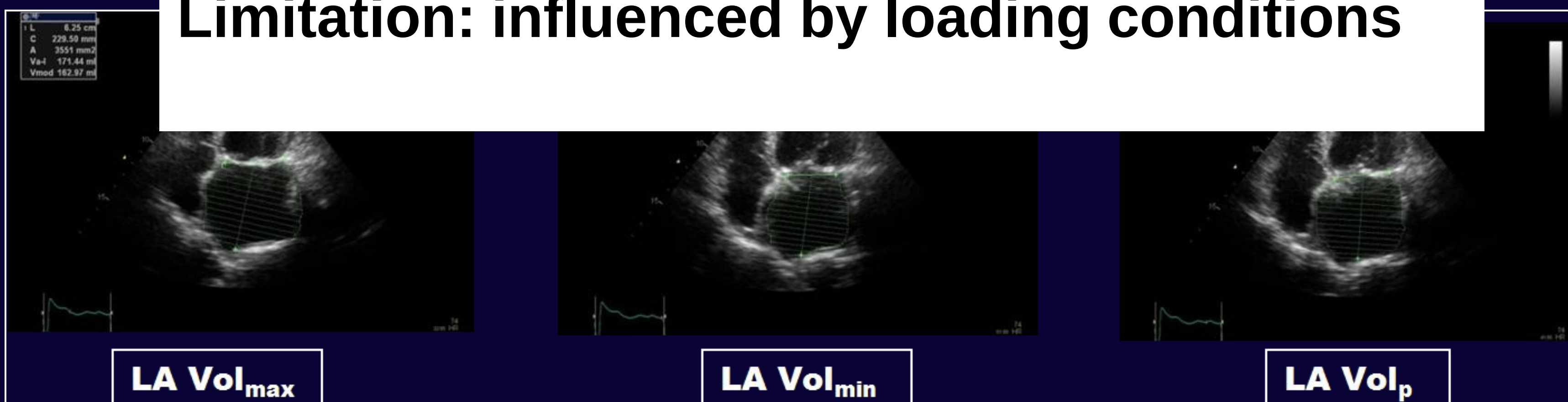
- PW Doppler of transmitral flow
- PW Doppler of pulmonary venous flow
- Left atrial phasic volumes
- Myocardial velocities (TDI)
- Atrial deformation imaging (TDI/STE)

Conventional LA echocardiographic parameters





Limitation: influenced by loading conditions



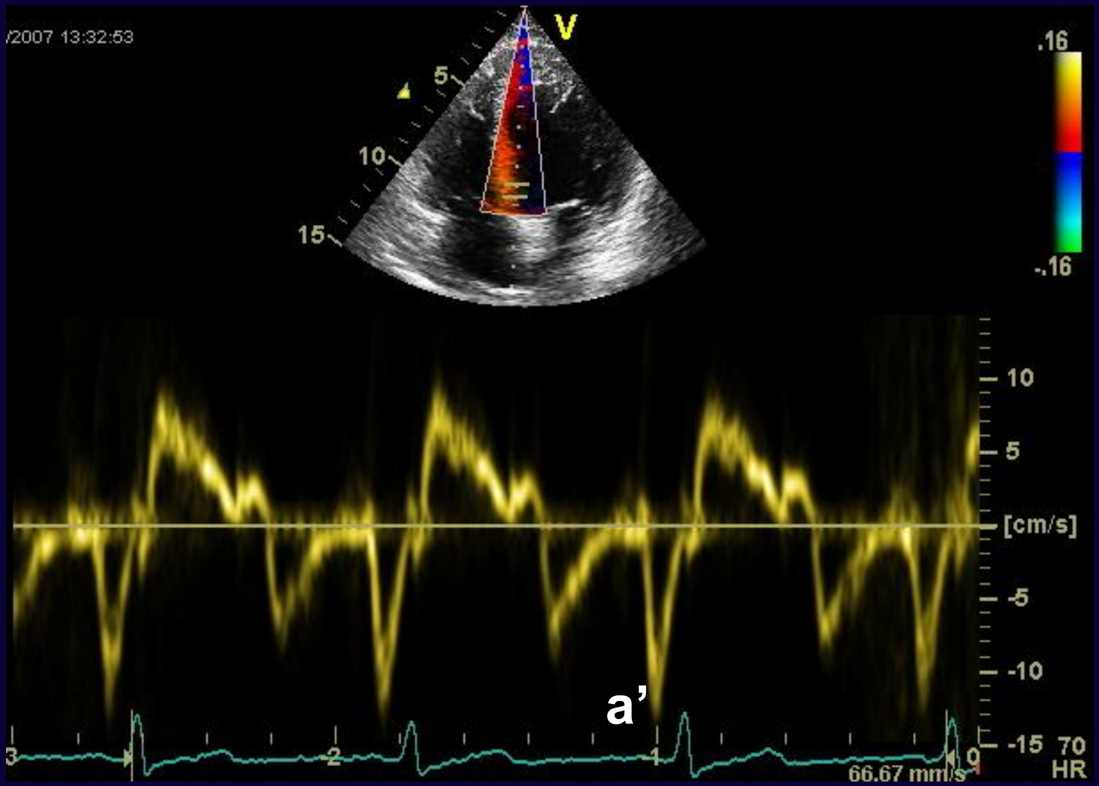
LA expansion index = $(Vol_{max} - Vol_{min})/Vol_{min} x100$ **- reservoir**

LA passive emptying fraction = $(Vol_{max} - Vol_{p})/Vol_{max} x100$ **- conduit**

LA active emptying fraction = $(Vol_{p} - Vol_{min})/Vol_{p} x100$ **- contractile**

Myocardial velocities

• TDI allows the measurement of myocardial velocities, providing a less load dependent measure of both LV systolic and diastolic function.



Contractile function

Peak a’ wave velocity

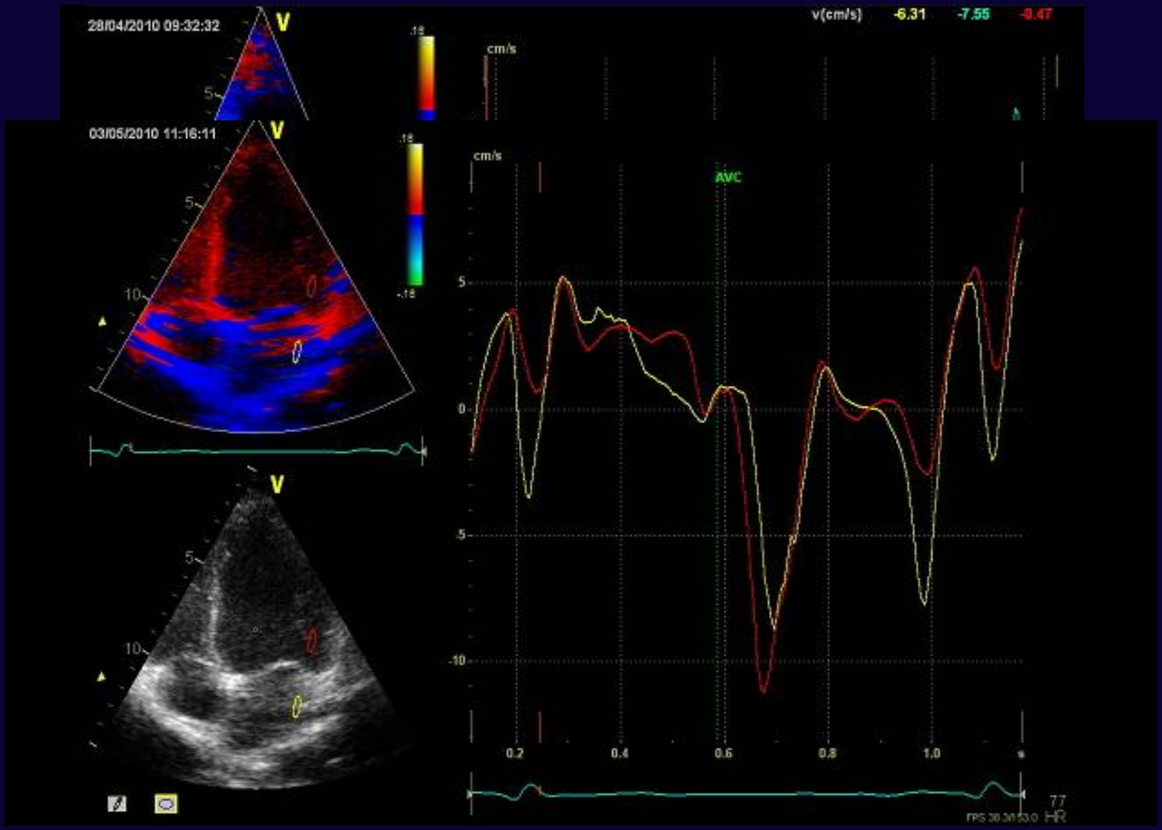
- marker of atrial function

Limitations:

- angle dependent, influenced by translation and tethering

Regional LA function by TDI

Color TDI allows the simultaneous assessment of several atrial segments



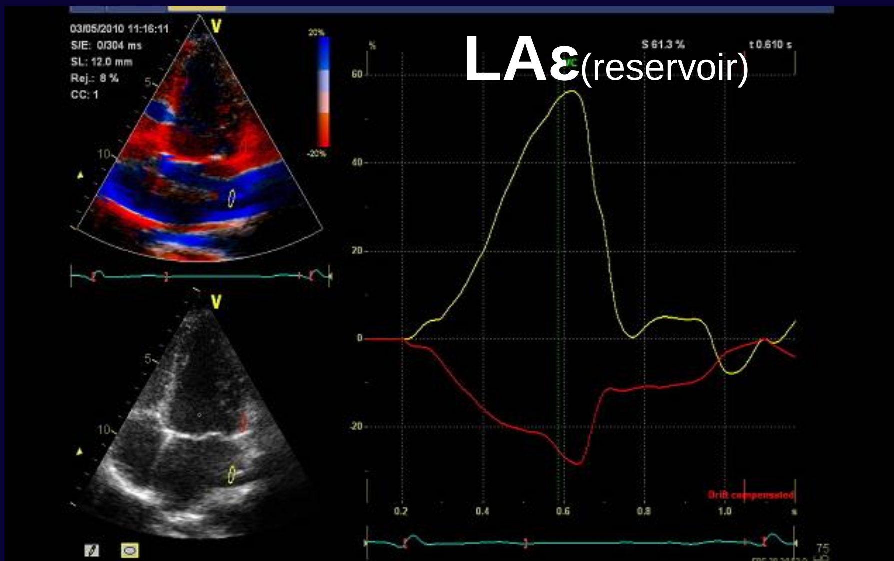
Parameters:

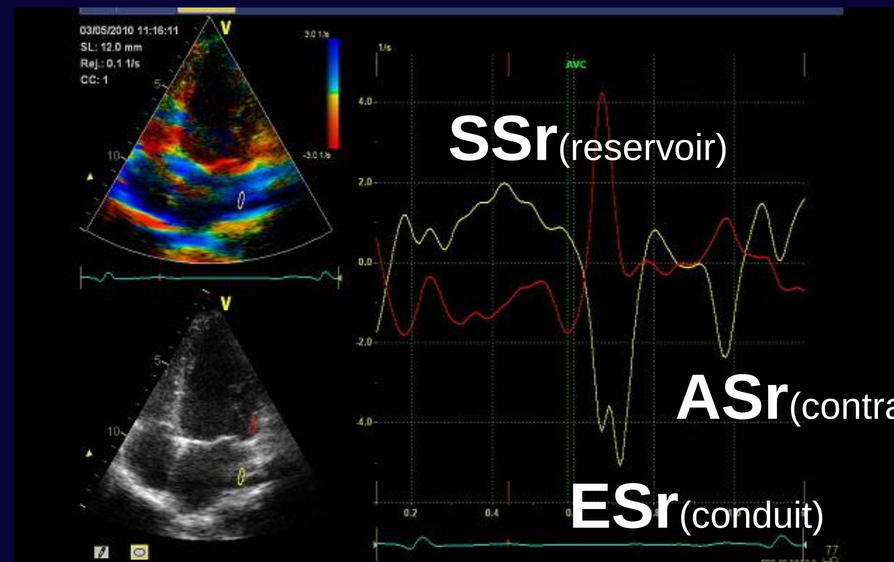
- velocities of different atrial segments
- atrial electomecanical delay

Limitations:

- inability to distinguish atrial contraction from mitral annular and ventricular motion

LA deformation imaging by TDI





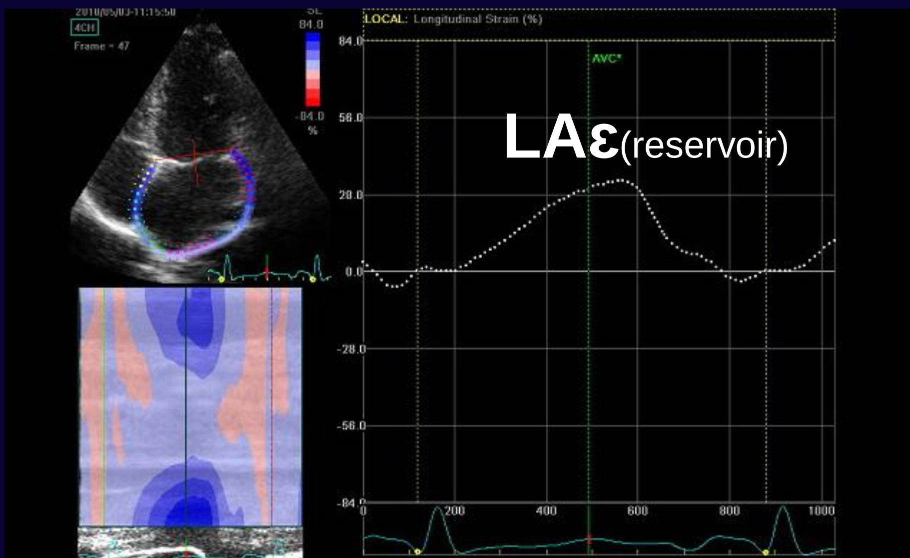
The technique has a good site specificity

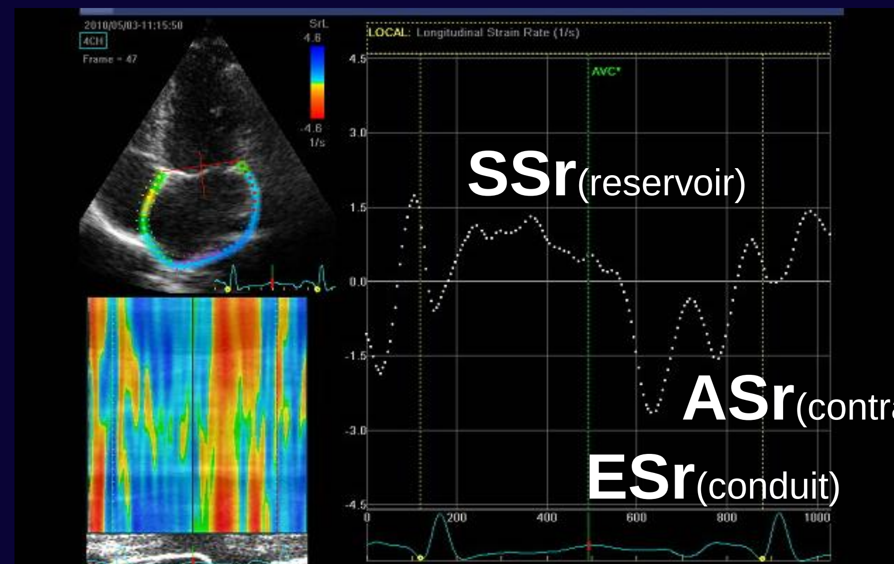
- the longitudinal shortening and lengthening of the LA are opposite in time to those of the LV

Limitations

- angle dependent
- time-consuming (the wall-by-wall sampling limits the use in clinical practice)

LA deformation imaging by STE





Angle-independent tool for a thorough assessment of LA performance

Limitations

- dependent on image quality
- STE has not been validated for LA function assessment

Atrial strain and strain rate imaging - TDI/STE

Indicator	Intra-observer variability			Inter-observer variability		
	Mean	95%CI	(%)	Mean	95%CI	(%)
Peak ε CT (%)	−24.5	±2.6	10.61	−25.3	±2.9	11.46
ε−CT (%)	−17.9	±1.6	9.44	−17.5	±1.8	10.22
Peak ε R (%)	71.5	±4.9	6.85	71	±5.2	7.31
ε−R (%)	66	±4.1	6.24	65	±4.1	6.3
Peak ε CD (%)	−54	±6.3	11.62	−52.9	±7.6	14.36
ε−CD (%)	−47	±3.1	6.59	−47	±3.1	6.58
Peak SR CT (s^{-1})	−4.86	±0.12	2.47	−4.7	±0.1	2.12
Peak SR ER (s^{-1})	4.68	±0.66	14.17	4.73	±0.86	18.28
Peak SR LR (s^{-1})	5.72	±0.98	17.12	5.53	±1.71	31
Peak SR CD (s^{-1})	−7.58	±1.82	24.11	−7.15	±1.93	27

Sirbu et al. *EJE* 2006;7:199.

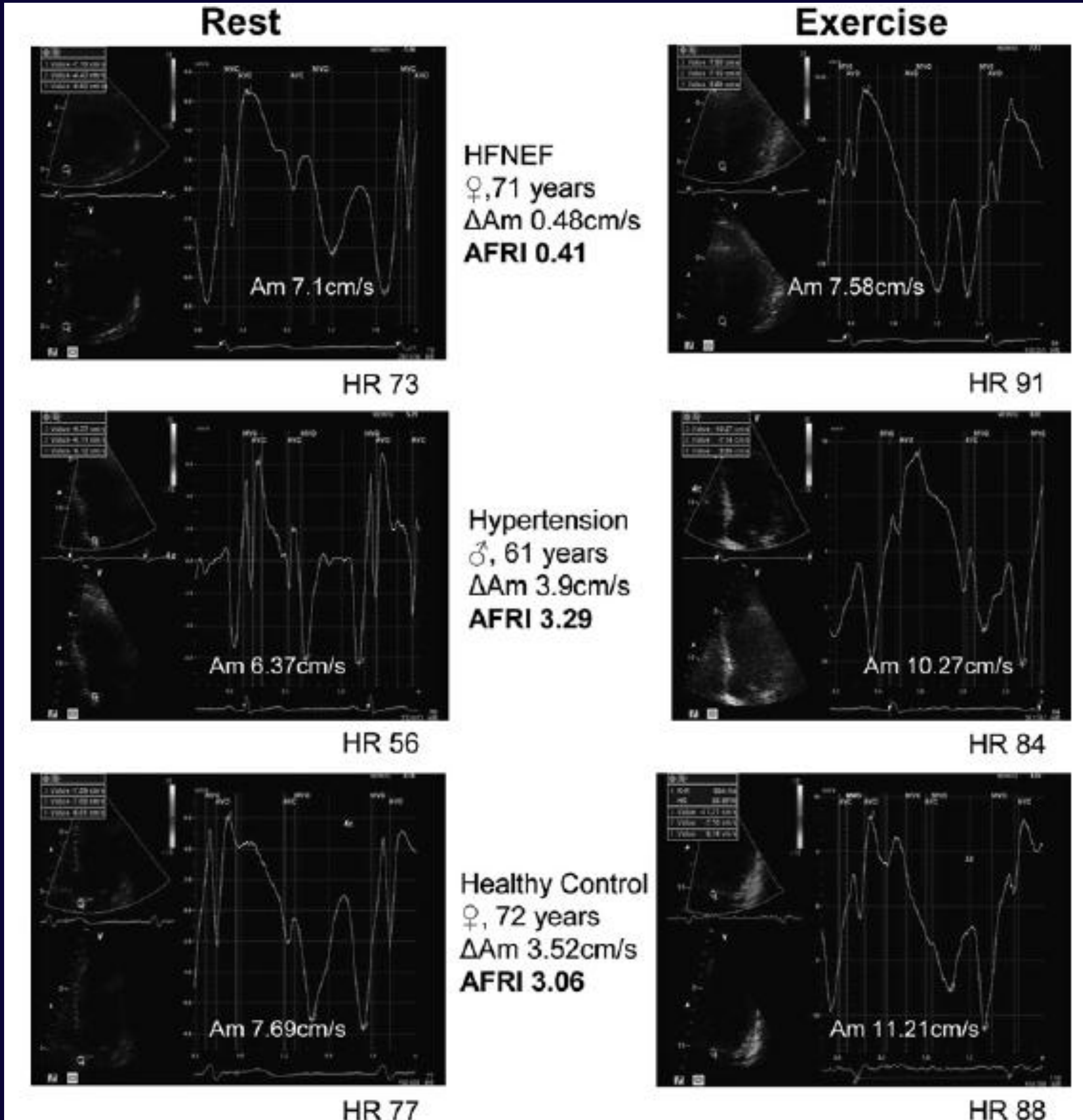
Parameter	Interobserver		Intraobserver	
	Change in mean (%)	95% CI	Change in mean (%)	95% CI
Velocity (cms^{-1})	−5.7	(−5.8 to −5.6)	−7.8	(−8.0 to 7.7)
Strain (%)	−6.5	(−6.6 to −6.5)	−4.6	(−4.7 to −4.5)
Strain rate (s^{-1})	2.5	(2.4–2.6)	−1.9	(−2.0 to −1.9)

Vianna-Pinton et al. *JASE* 2009;22:299.

Clinical applications

- Left ventricular dysfunction
- Cardiomyopathies
- Valvular heart disease
- Atrial fibrilation

LA function in patients with LV dysfunction

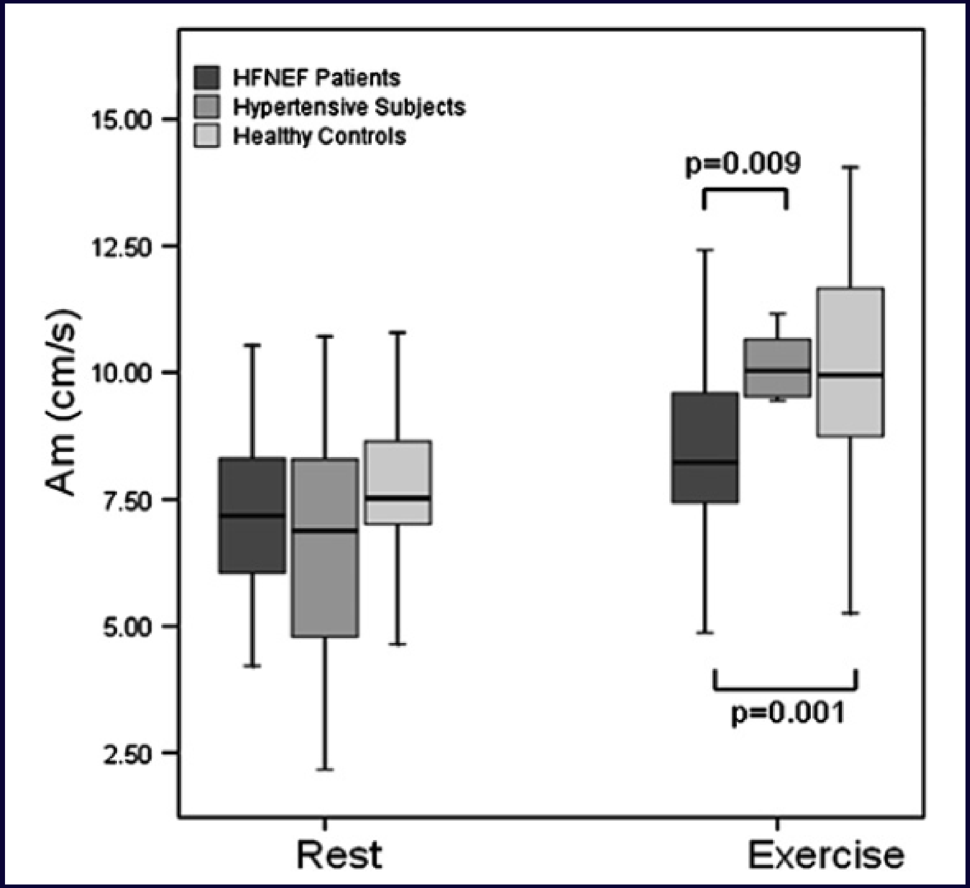


Mitral annular velocities were assessed using colour TDI.

- **systolic**
- **early diastolic**
- **late diastolic (a')**

Tan at al. *Heart* 2010;96:1017.

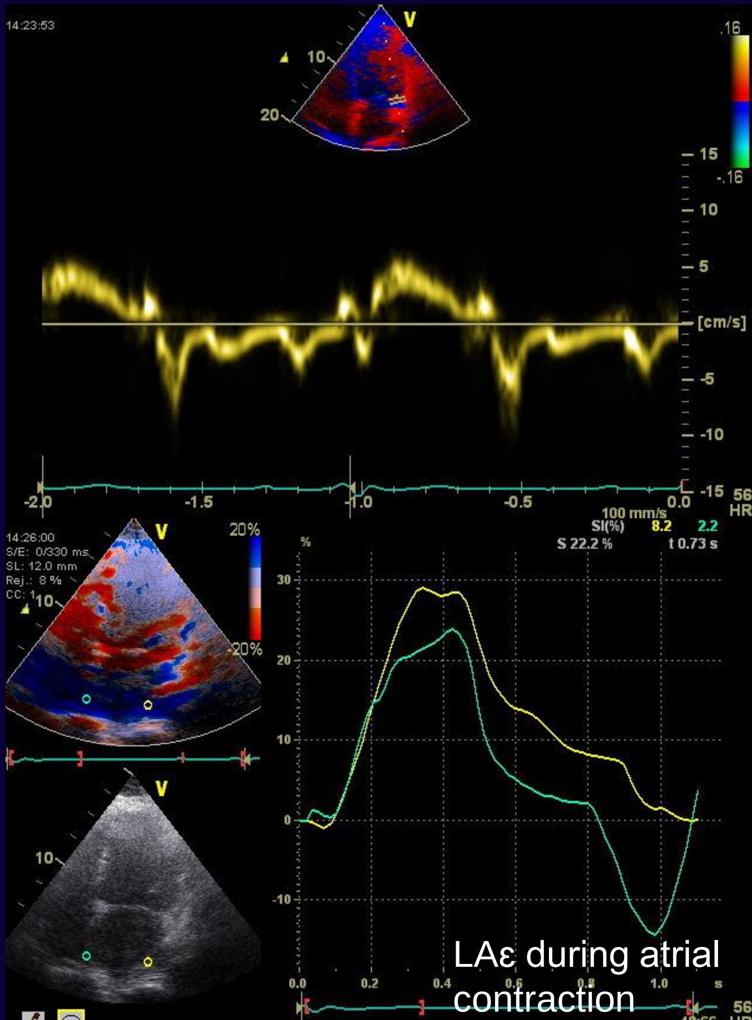
LA function in patients with LV dysfunction

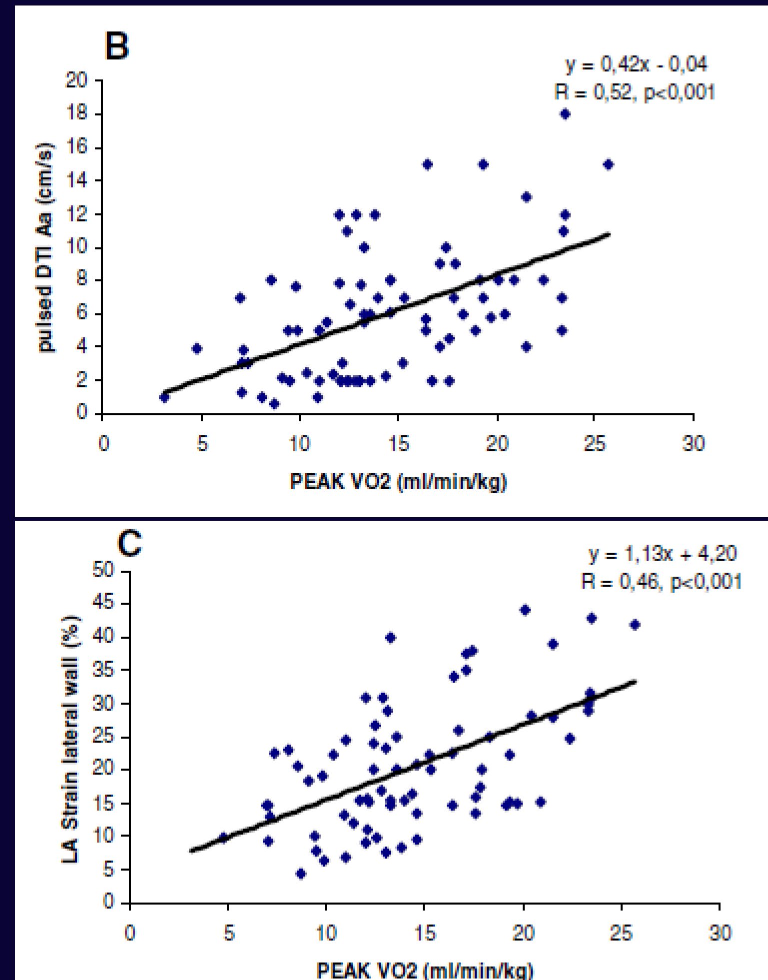


Hypertensive subjects w/o HF appear to be able to compensate for their increased E/E’ on exercise by increasing a’, which HFNEF patients failed to achieve.

Tan at al. *Heart* 2010;96:1017.

LA function in patients with LV dysfunction





75 patients with LV systolic dysfunction, CHF, NYHA class II to III.

Donal et al. *JASE* 2008;21:703.

LA function in patients with LV dysfunction

Stepwise Linear Multivariate Analysis

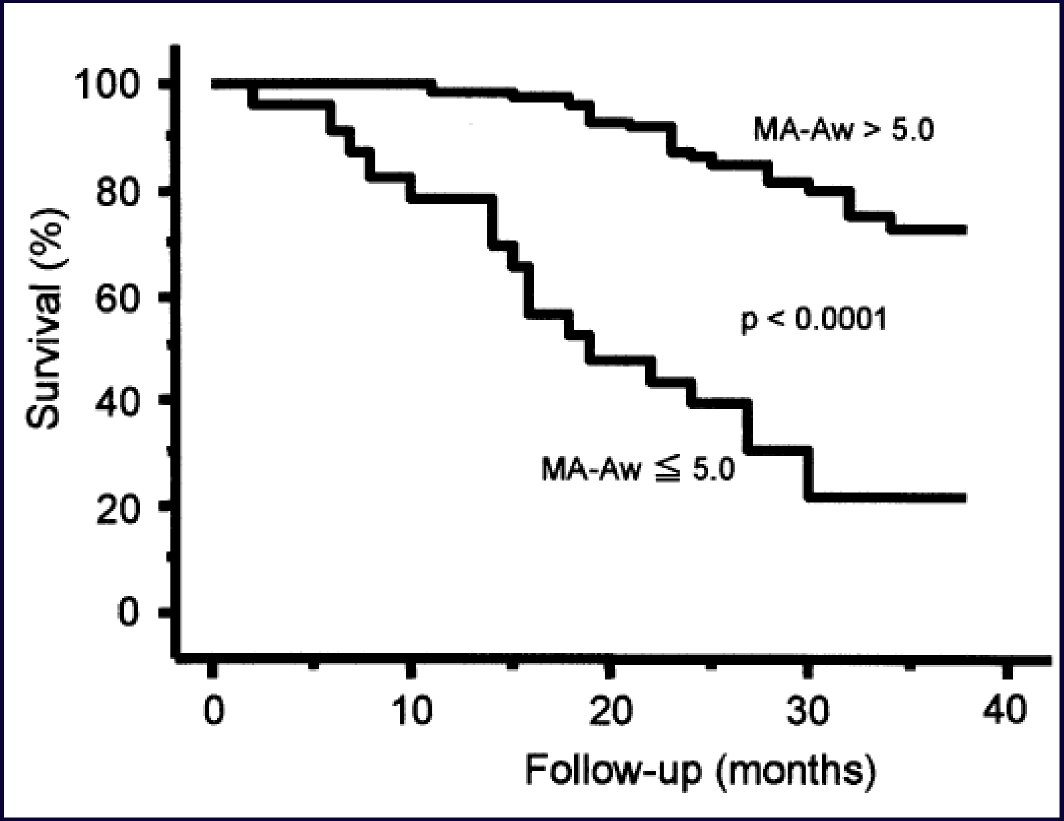
Predictors of maximal workload Echocardiographic parameters that were independently associated with maximal workload at a *P* value of less than .05 were included in the model. The best prediction was obtained associating pulsed DTI Aa peak velocity with peak strain in the RV free wall and isovolumic relaxation time (milliseconds) ($R^2 = 34.3$).

Predictors of peak O_2 Using the same stepwise protocol, the best predictive parameter of peak O_2 was the ratio E/Ea ($R = 0.53$, $F = 7.7$, $P = .01$). After including LA volume and Aa ($R^2 = 54.6$) or peak strain in the LA septal wall ($R^2 = 50.2$) into the model, the correlation became stronger.

Adding a' peak velocity in resting echocardiographic evaluation of patients with CHF could be useful.

Donal et al. *JASE* 2008;21:703.

LA function in patients with LV dysfunction

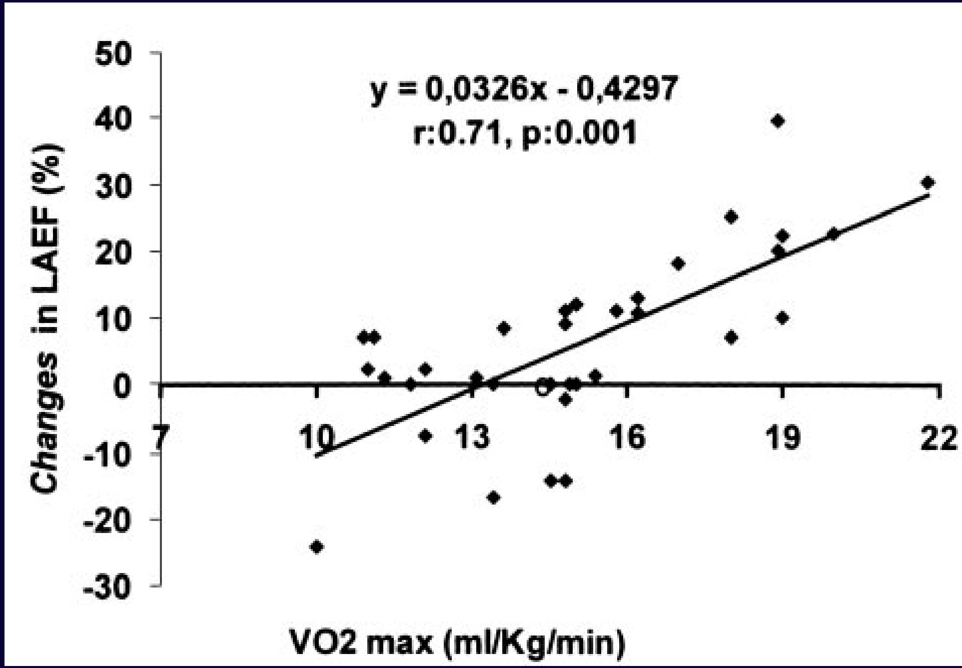


MA-Aw was recorded in 96 patients with LV systolic dysfunction who were followed for 29 ± 10 months.

- **MA-Aw < 5 cm/s was the most powerful predictor of cardiac death or hospitalization for worsening HF compared with clinical, hemodynamic, and the other echocardiographic variables.**

Yamamoto et al. *JASE* 2003;16:333.

LA function in cardiomyopathies



36 consecutive pts with DCM were studied.

After inotropic stimulation

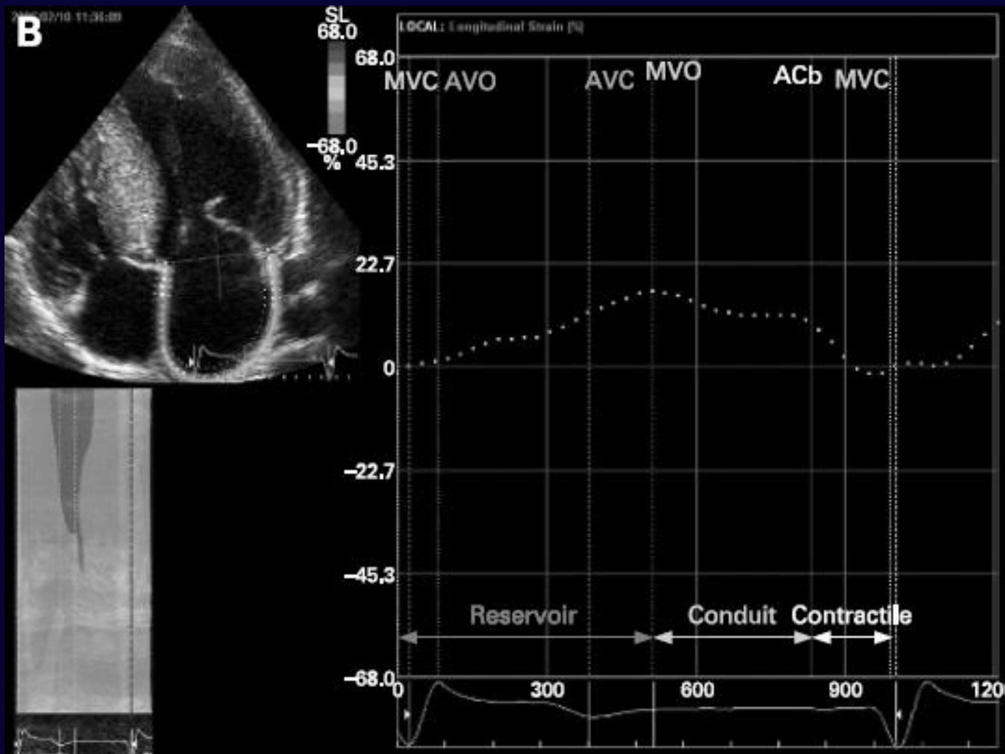
LAEF ↑ ⟶ VO_2 > 14 mL/kg/min

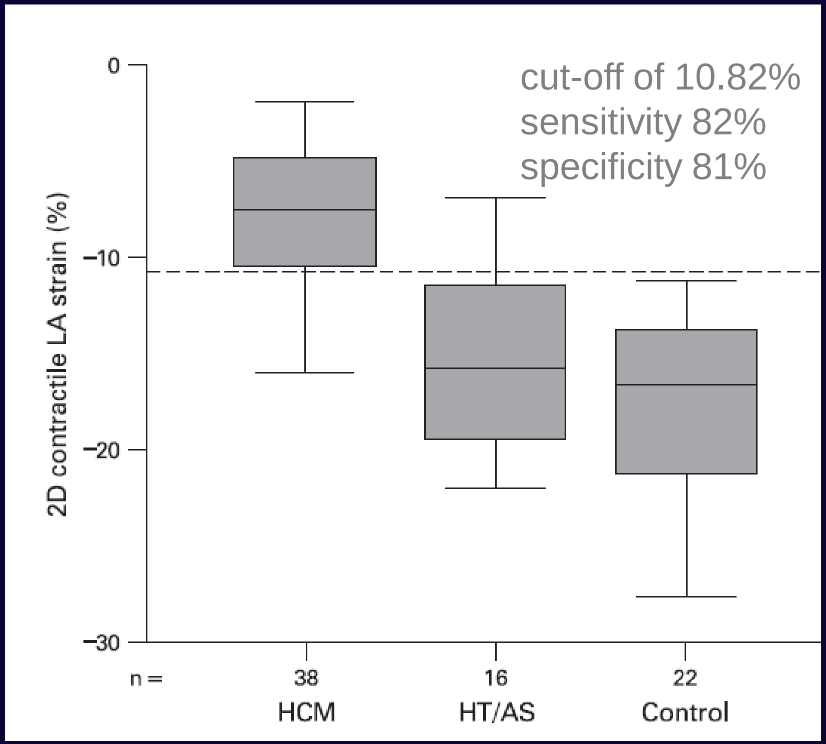
LAEF ↓ ⟶ VO_2 < 14 mL/kg/min

LA contractile reserve impairment might be an earlier finding in the process of heart failure.

Paraskevaidis et al. *Chest* 2002;122:1340.

LA function in cardiomyopathies

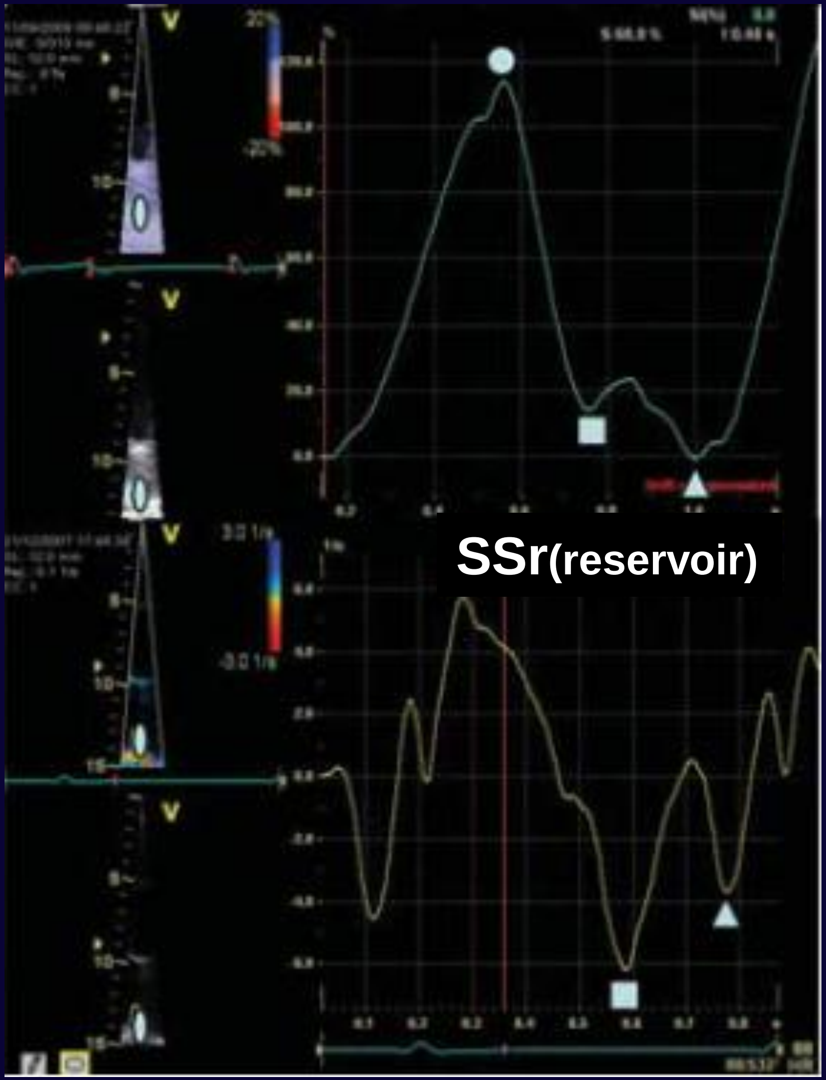




- LA longitudinal function is reduced in HCM compared to non-HCM LVH and healthy controls.
- 2D atrial strain has an additive value in differentiating HCM from non-HCM LVH and it is more reproducible than TDI strain.

Paraskevaidis et al. *Heart* 2009;95;483.

LA function in valvular heart disease



Mitral stenosis

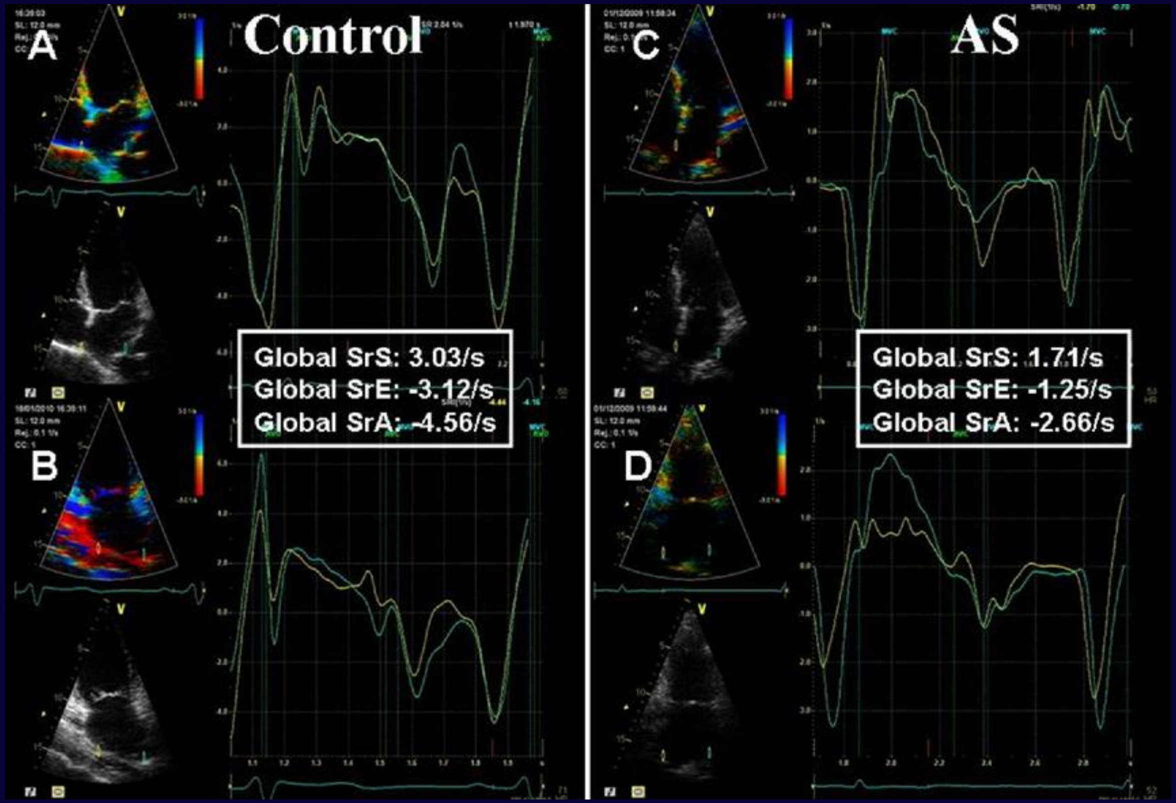
In multivariate analysis (including age, LAV, MVA, and LA SR average), the best predictor of events in pts with MS was LA peak systolic SR.

In ROC analysis a cut-off value of 1.69 s^{-1} for LA peak systolic SR was associated with a sensitivity of 88%, a specificity of 80.6%, an area under the ROC curve of 0.85 in predicting events.

Caso et al. *EJE* 2009;10:753.

LA function in valvular heart disease

Aortic stenosis

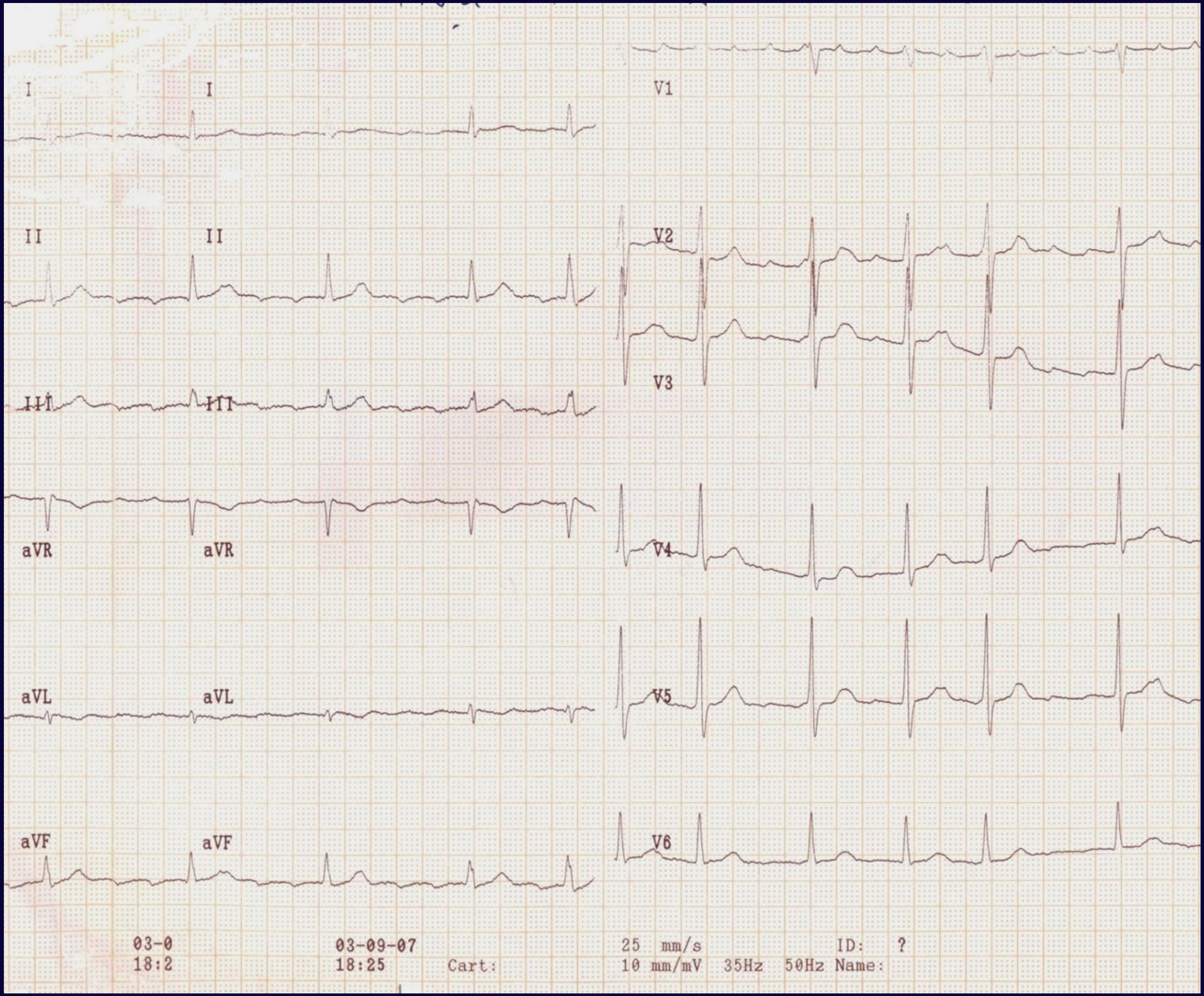


- **In patients with severe AS, the 3 components of LA function are reduced**
- **Active LA dysfunction is related to the AS severity**
- **The impact of reduction in LA active function on the clinical status need further studies.**

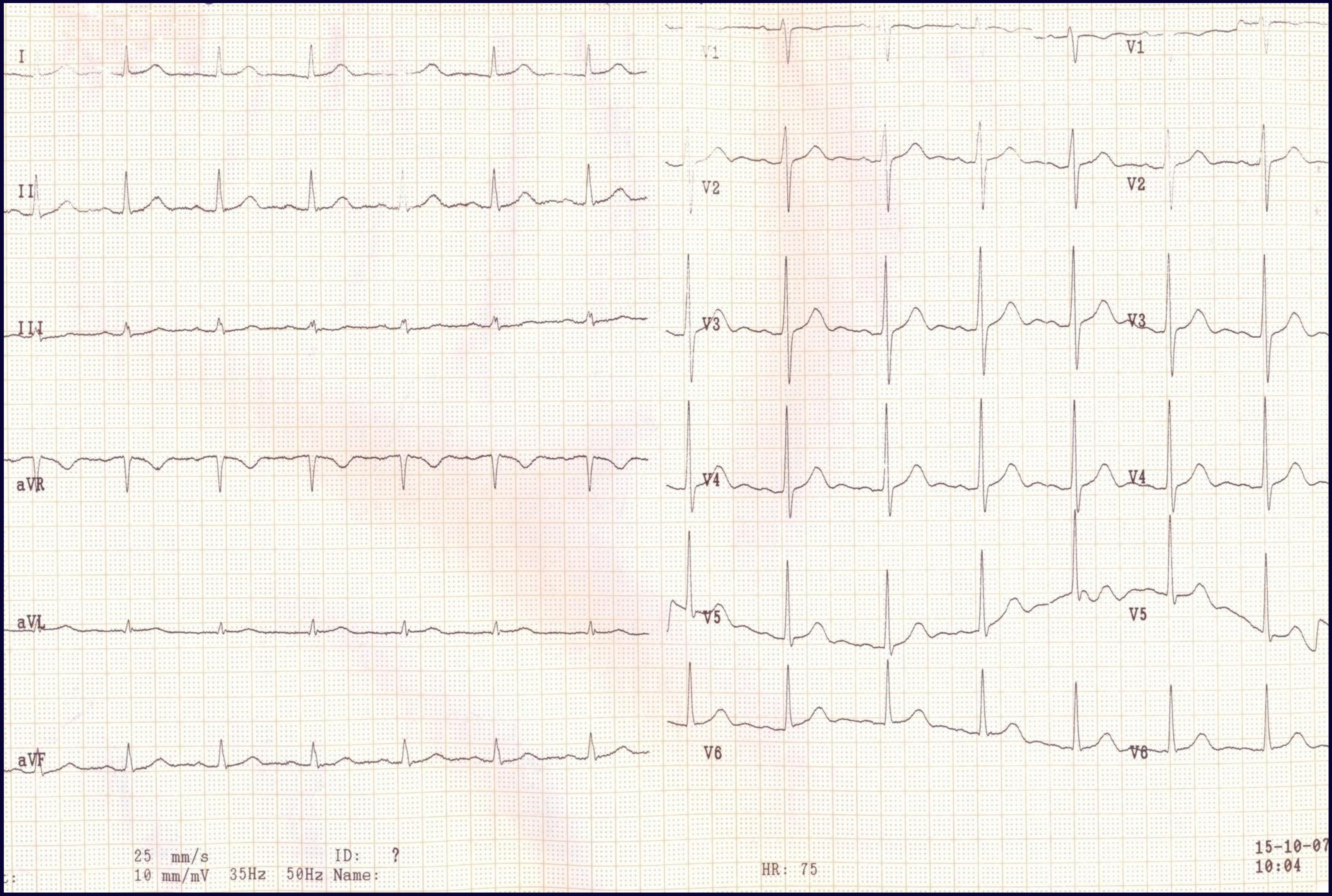
O'Connor K. *Am J Cardiol* 2010;106:1157.

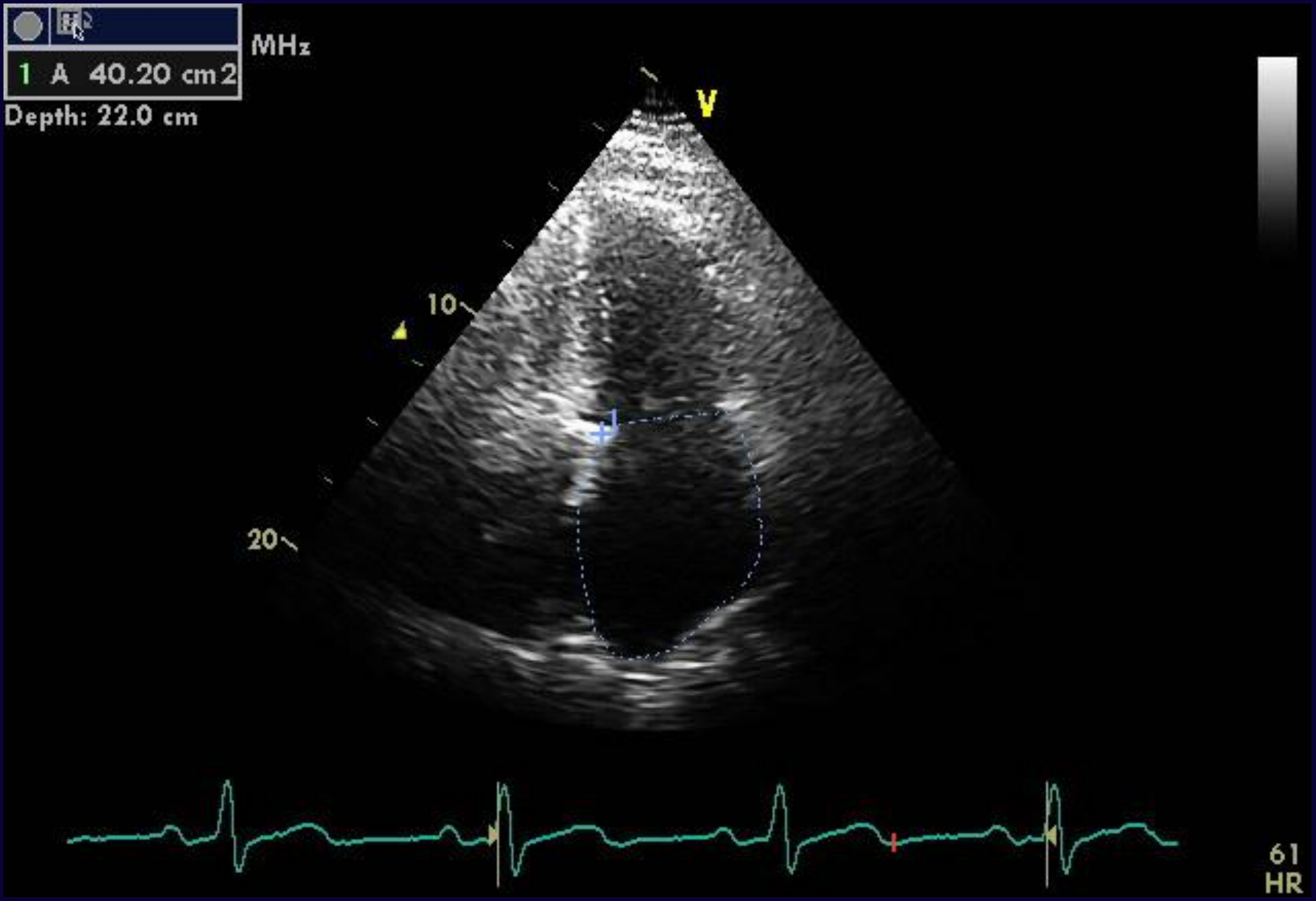
Case presentation

55 y/o man



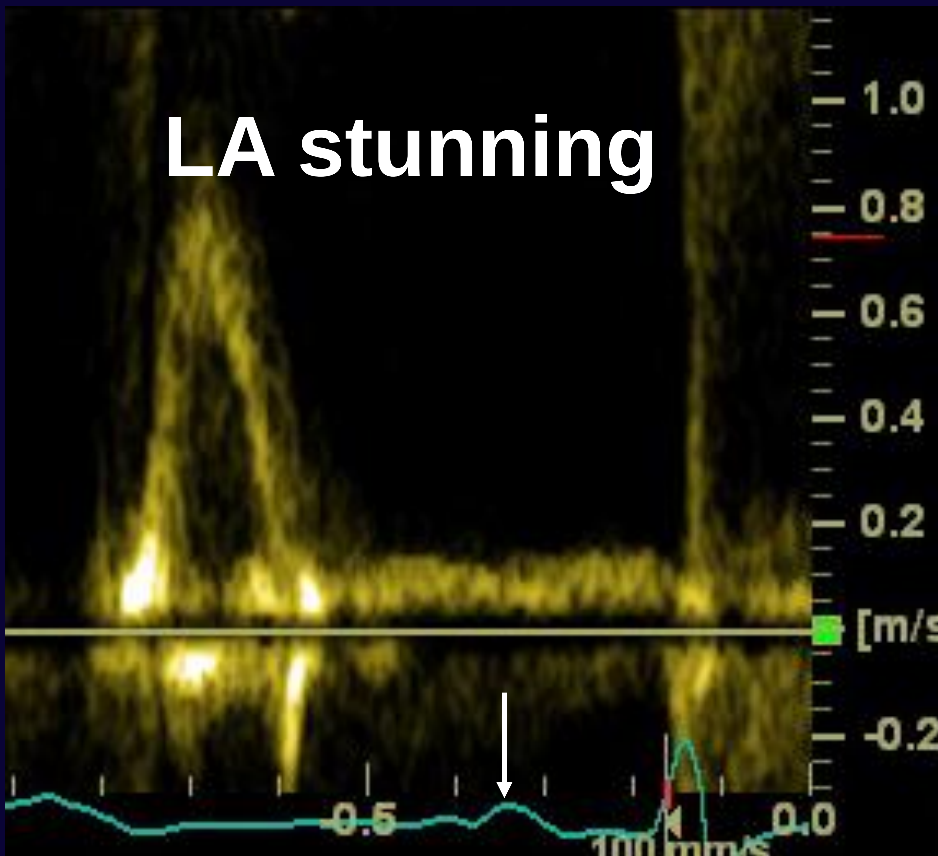
Same patient after 4 weeks



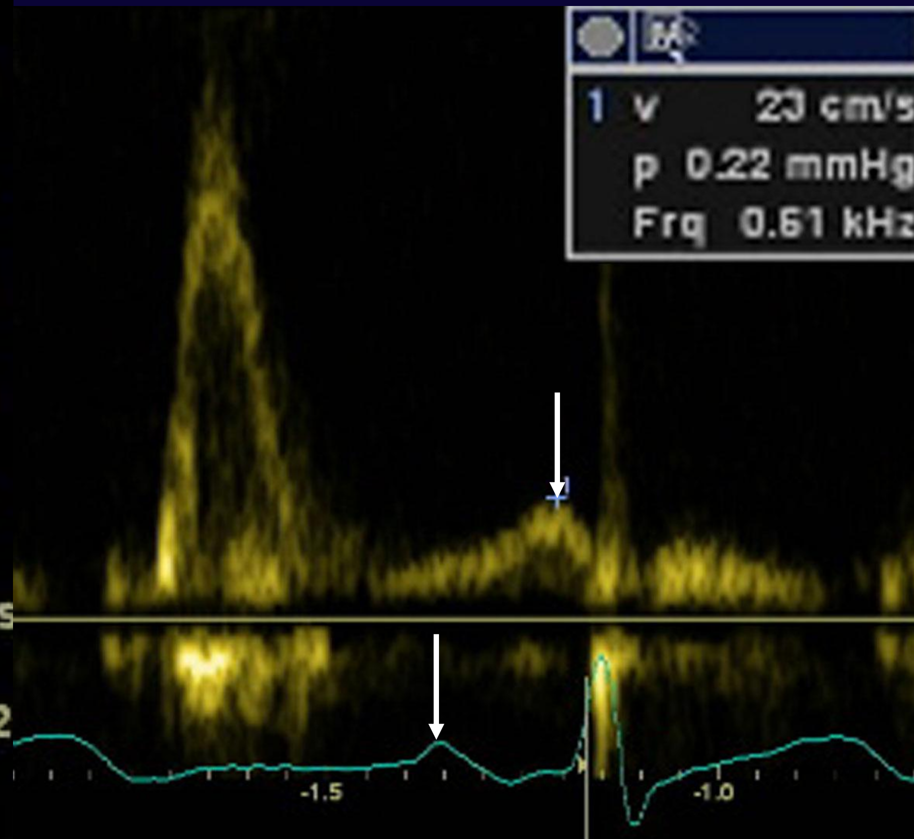


MHz
1 A 40.20 cm2
Depth: 22.0 cm
V
10
20
61
HR

PW Doppler mitral inflow



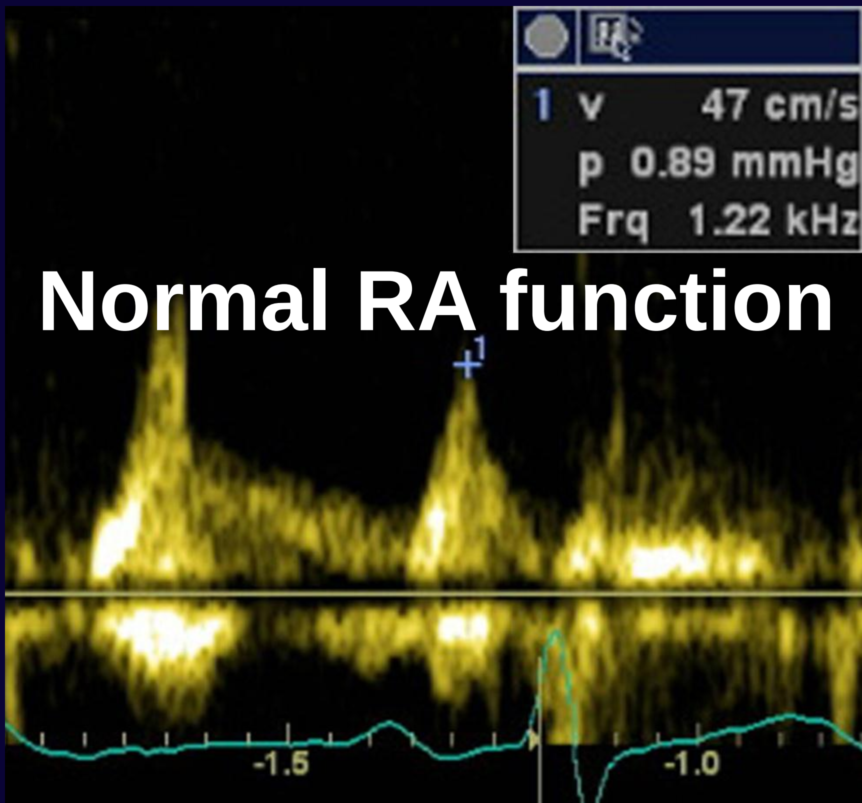
3 days after spontaneous cardioversion to NSR



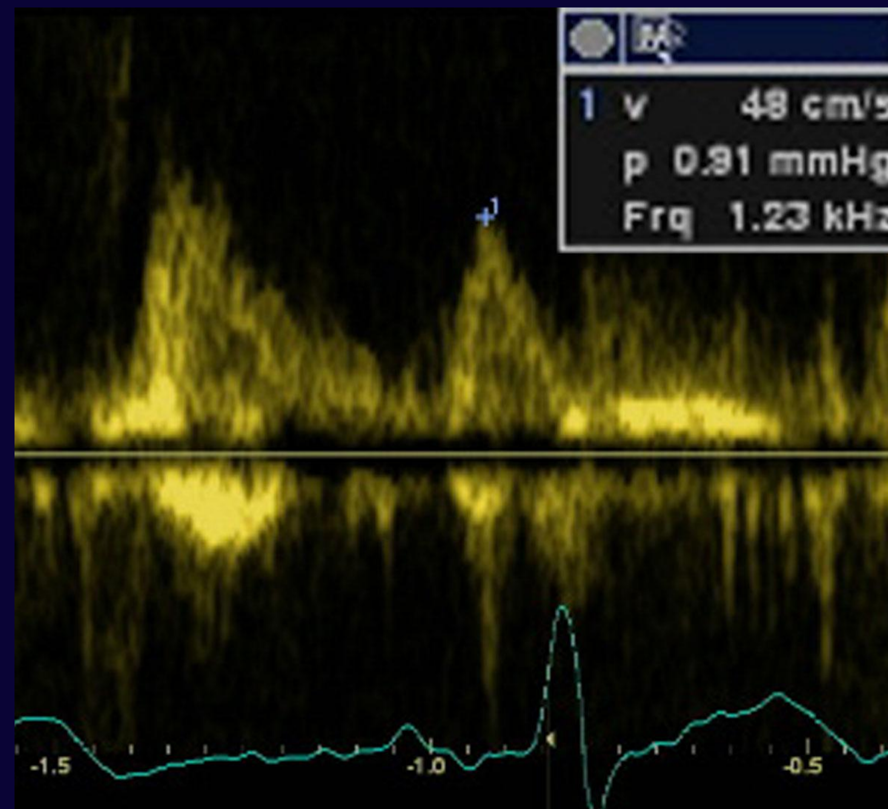
3 days later

Popescu BA, et al. *Rom J Cardiol* 2008

PW Doppler tricuspid inflow



Normal RA function

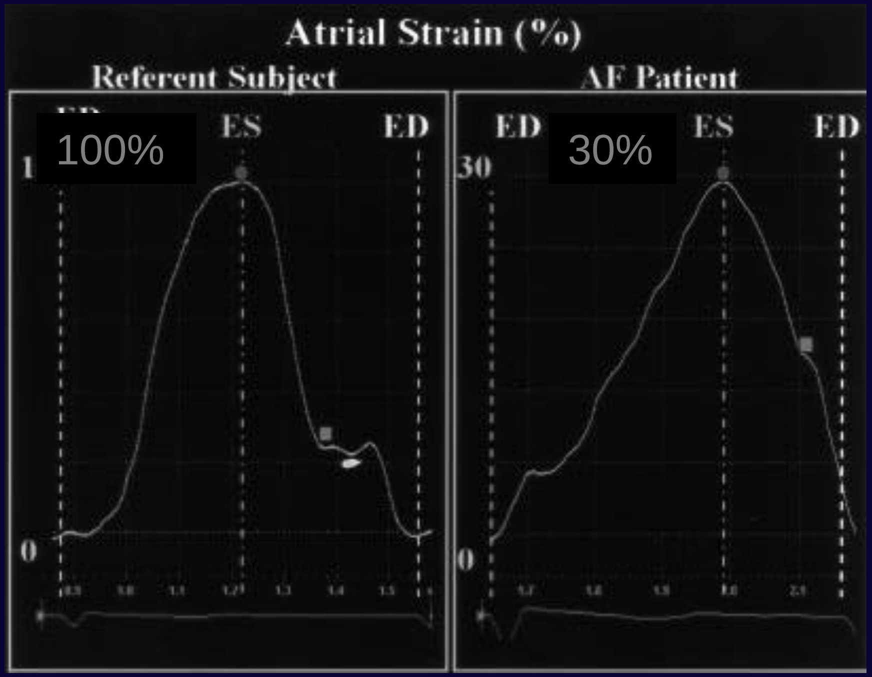


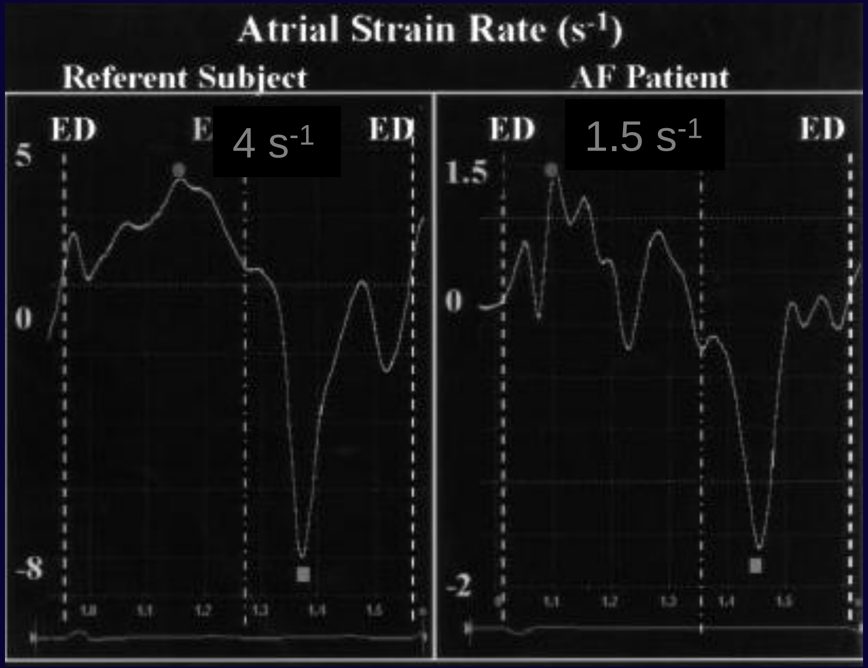
Dissociated LA stunning

LA function in atrial fibrillation

Atrial myocardial properties assessed by myocardial velocities, strain and strain rate imaging are reduced in patients with AF.

- **65 pts, lone AF; FU: 9 mo after cardioversion**





Di Salvo et al. *Circulation* 2005;112:387.

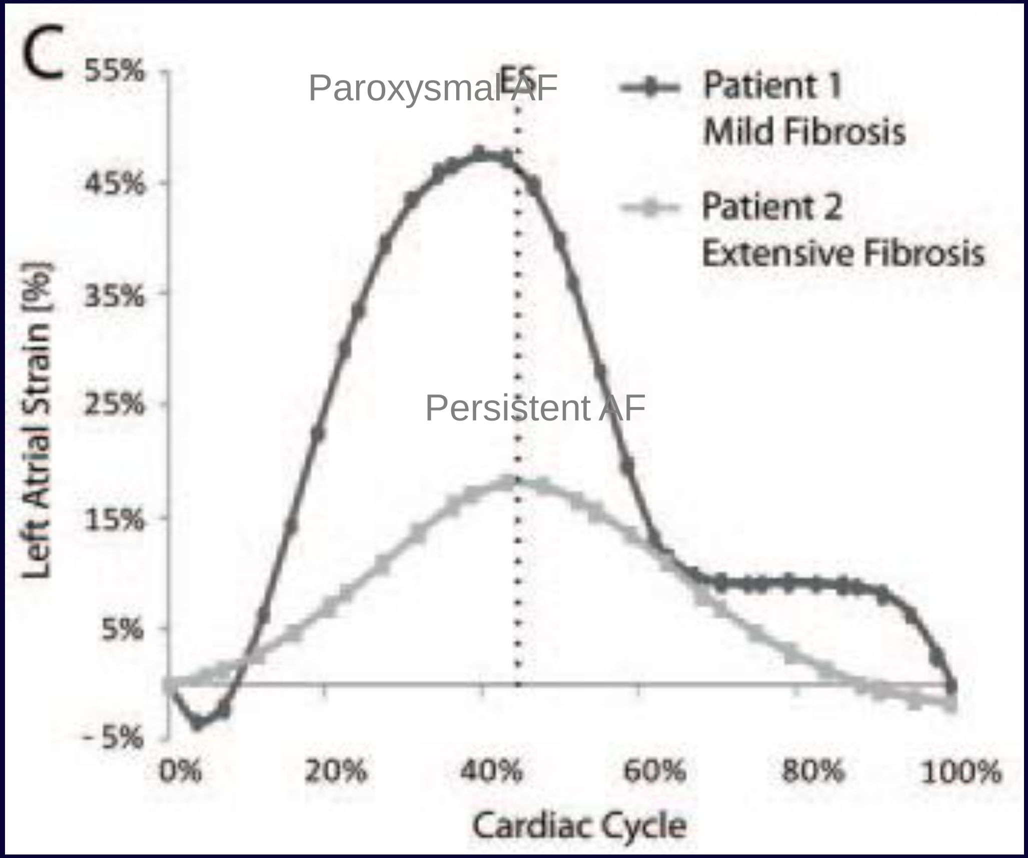
LA function in atrial fibrillation

	MSR Patients (n=25)	AFR Patients (n=40)	*P*
Age, y	60±11	57±11	0.6
Male sex, %	72	77	0.8
BSA, m^2	1.8±0.2	1.9±0.2	0.7
AF duration, wk	8.2±2.9	8.6±2.6	0.5
Previous history of AF, %	65	64	0.3
Systolic blood pressure, mm Hg	136±12	134±9	0.4
Diastolic blood pressure, mm Hg	81±8	79±7	0.3
Heart rate, bpm	93±24	85±19	0.1
IVS end-diastole, cm	1.1±0.1	1.1±0.1	>0.9
LV end-diastole, cm	5.0±0.4	5.0±0.5	>0.9
PW end-diastole, cm	1.1±0.1	1.1±0.1	>0.9
LV ejection fraction, %	54±3	54±5	>0.9
LV mass index, g/m	135±22	131±16	0.4
LA, cm	4.5±0.3	4.4±0.5	0.4
LA maximal volume, mL	66.5±16	62.7±18	0.4
LA compliance index, %	32±7	29±10	0.2
Pulmonary artery wedge pressure, mm Hg	7±6	8±7	0.6
LA appendage peak velocity flow, cm/s	39±12	32±15	<0.01

	Peak Systolic Value		
	MSR Patients (n=25)	AFR Patients (n=40)	*P*
Atrial septum			
Velocity, cm/s	3.9±1.9	3.4±1.4	0.2
S, %	37±18	19±14	<0.0001
SR, s^{-1}	2.7±0.7	1.4±0.8	<0.0001
LA lateral wall			
Velocity, cm/s	3.2±1.9	2.7±1.4	0.2
S, %	39±26	18±13	<0.0001
SR, s^{-1}	3±1.7	1.3±0.9	<0.0001
RA free wall			
Velocity, cm/s	5±2.3	4.3±2	0.2
S, %	58±44	33±23	0.003
SR, s^{-1}	3.8±1.6	2.3±1.6	<0.0001
LA inferior wall			
Velocity, cm/s	3.7±1.8	2.9±1.9	0.2
S, %	33±27	17±9	0.0007
SR, s^{-1}	2.7±1	1.6±0.6	<0.0001
LA anterior wall			
Velocity, cm/s	3.9±2	3±1.6	0.1
S, %	24±13	13±10	0.0002
SR, s^{-1}	2.1±0.6	1.4±0.8	0.0003

Di Salvo, et al. *Circulation* 2005;112:387.

LA function in atrial fibrillation



- **LA wall fibrosis** by delayed-enhancement MRI is inversely related to LA strain/SR, and these are related to the AF burden.

Noninvasive imaging of LA fibrosis may be helpful in:

- **predicting the risk of AF**
- **guiding therapeutic strategies**
- **predicting the outcomes in patients with AF**

Kuppahally S et al. *Circ Cardiovasc Imaging* 2010;3:231.

Conclusions

• An accurate assessment of LA function remains cumbersome.

• LA EF requires a skillful acquisition technique and calculations that are not routinely performed.

• The newer parameters assessed by TDI/STE are reproducible and probably more sensitive than traditional ones.

• A thorough evaluation of atrial function

  - may assist in the early detection of “subclinical disease”
  - could refine risk stratification
  - could guide therapy

• The extent of reversibility of LA remodeling with medical therapy, and the impact of such changes on outcomes need further studies.


Thank you!