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THE LEFT ATRIUM – HOW CAN ECHO HELP US?

Dr. Dragos COZMA

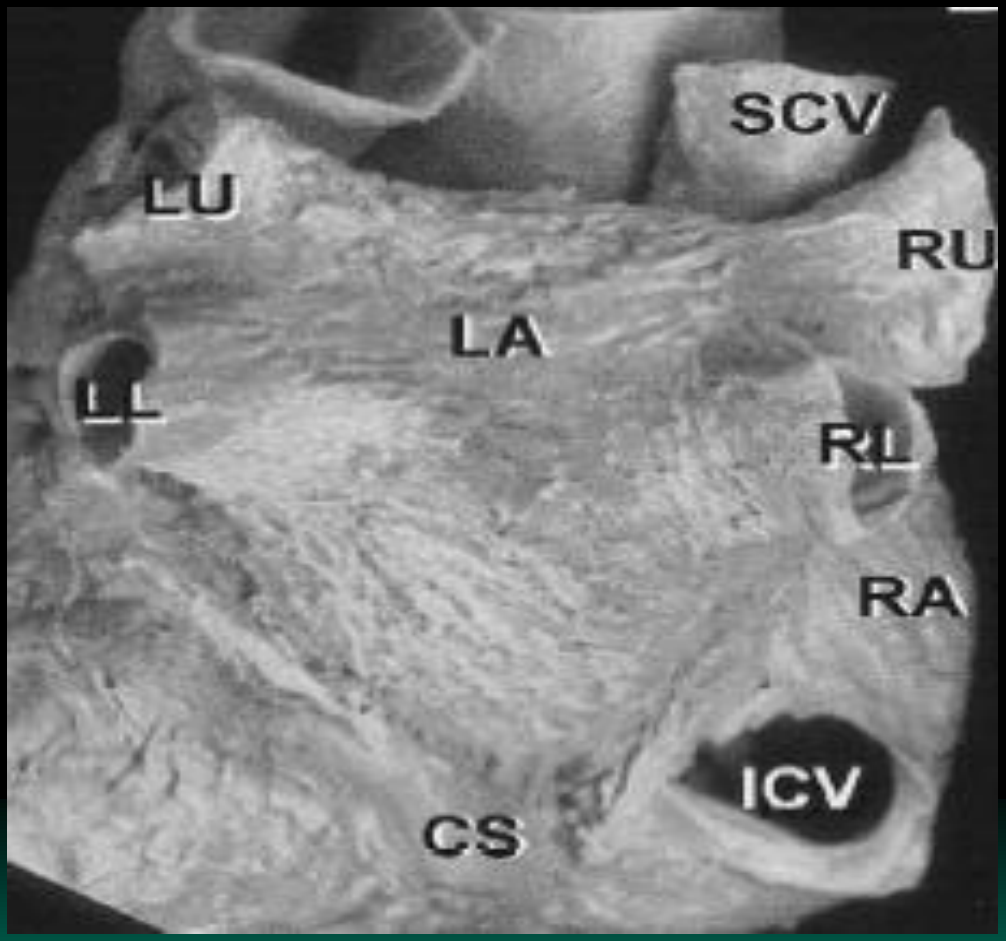
BACKGROUND

- **Left atrium (LA) dilation can occur in a broad spectrum of cardiovascular diseases including hypertension, left ventricular dysfunction, mitral valve disease and AF.**

- **In general, two major conditions are associated with LA dilation: pressure and volume overload.**

LA & PULMONARY VEINS

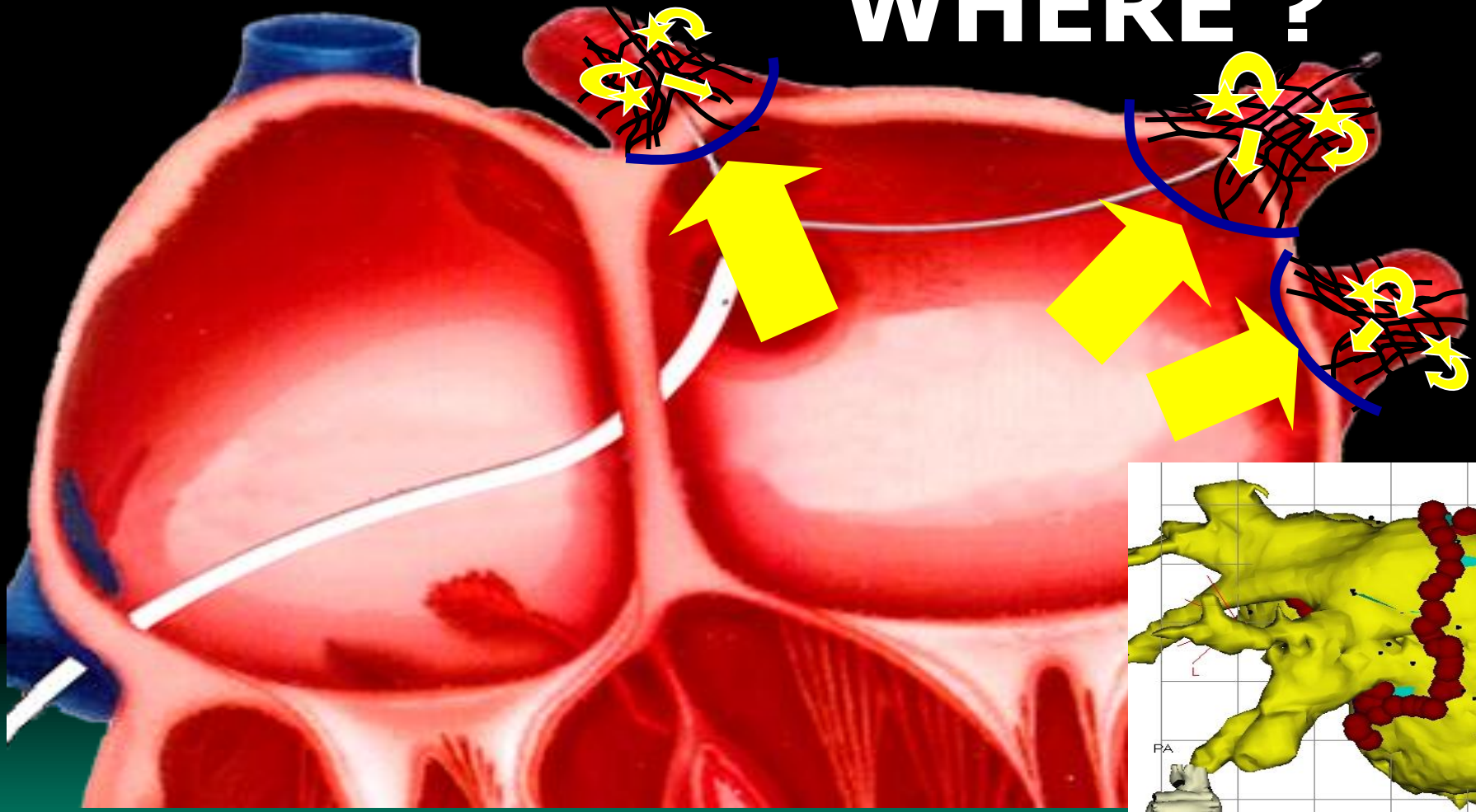
- The pulmonary veins (PV) in the human heart enter the LA at the four "corners"
- "pillow shaped" human LA

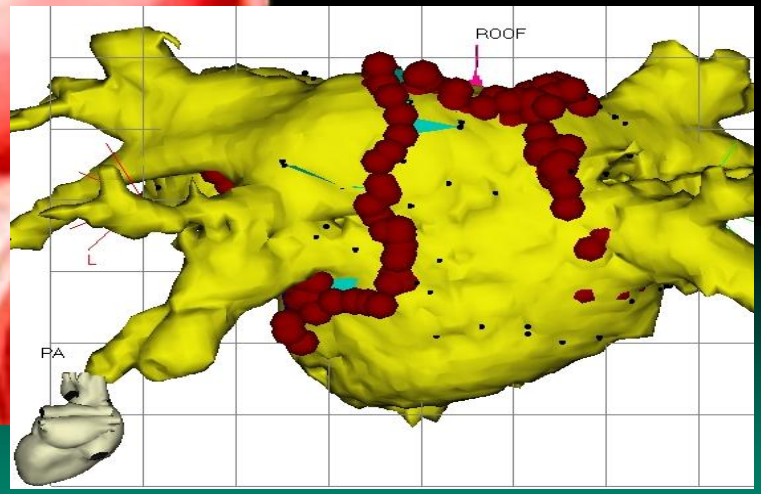


LA muscular fibers extend to the PV !!!

BACKGROUND - LA dilation

WHERE ?





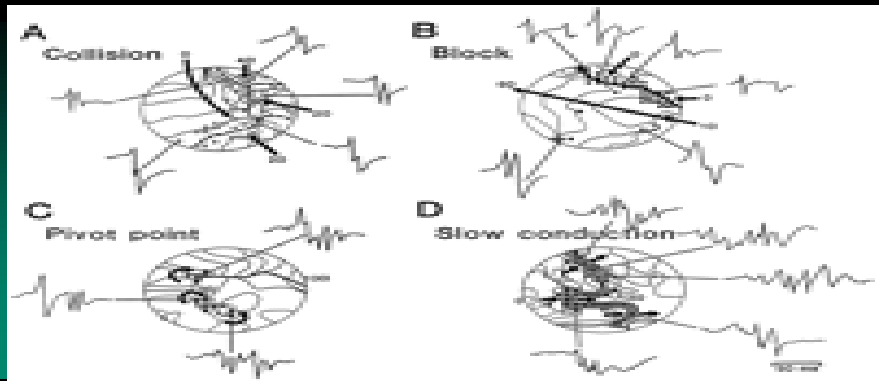
dilation „stretch” of the PV

– electroanatomical substrate for AF

BACKGROUND - LA dilation

- **Altered load** => changes in myocardial segment length => **stretch** and progressive geometrical rearrangement of myocytes, restructuring of the atrial wall and **changing of atrial shape**

- The electroanatomical substrate of dilated atria is characterized by increased non-uniform anisotropy and **slowing of conduction**, promoting reentrant circuits.



Allessie MA, Camm J, et al. **Circulation 2001**
Konings KTS, et al. **Circulation 1997**
Cozma et al PACE 2005

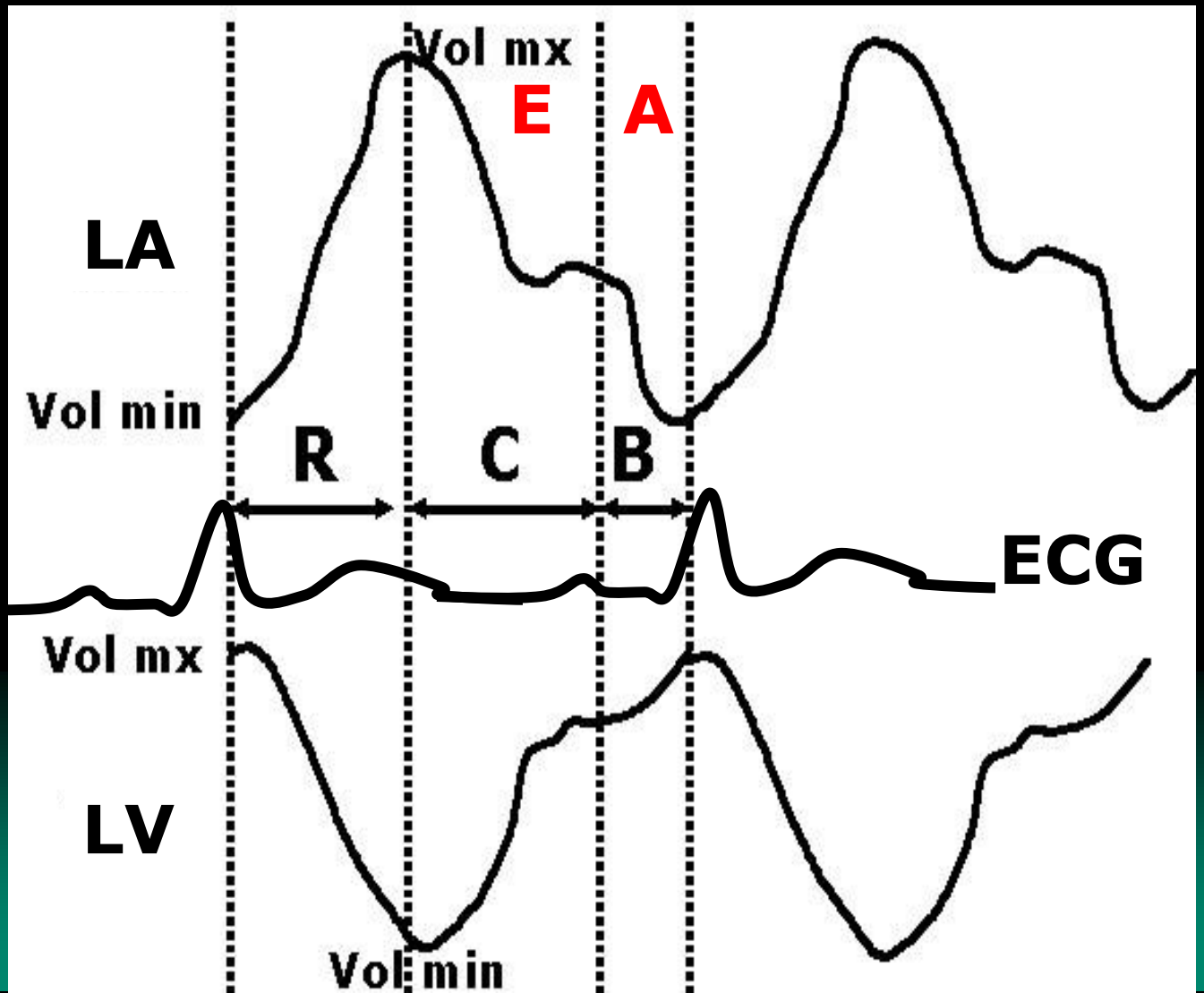
CARDIAC PERFORMANCE AND LA

As the outer contour of the heart is relatively constant, as is the apex, and the atria is attached to the PV, the atrioventricular plane has to be the piston of a reciprocating pump expanding the atria while the ventricle shortens

LA performance is complex and includes functioning as a reservoir, conduit, and booster pump at different stages of the cardiac cycle.

LA/LV VOL VARIATION & CARDIAC CYCLE

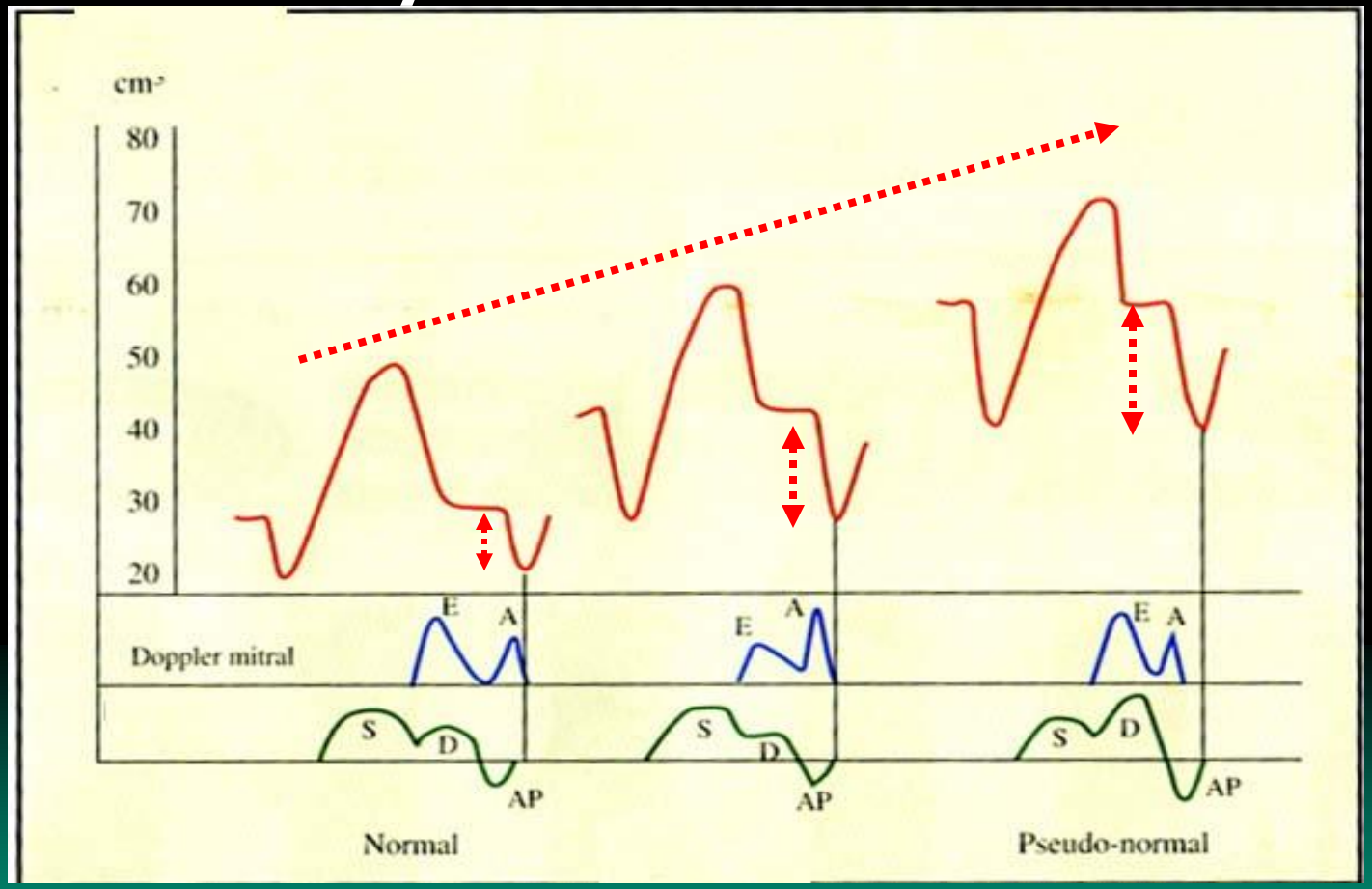
deformation of both chambers are reciprocating,



- **Rezervoir** LA filling during LV systole
- **Conduit** LA emptying while passive LV filling
- **Booster pump** LA emptying while active LV filling

WHY SHOULD WE MEASURE LA?

Close correlation between LA volume and the severity of diastolic dysfunction



↑ LV pres

↑ LA Vol

WHY SHOULD WE MEASURE LA?

- LA enlargement is a significant predictor of death in both men and women.

Benjamin EJ, et al The Framingham Heart Study. Circulation 1995

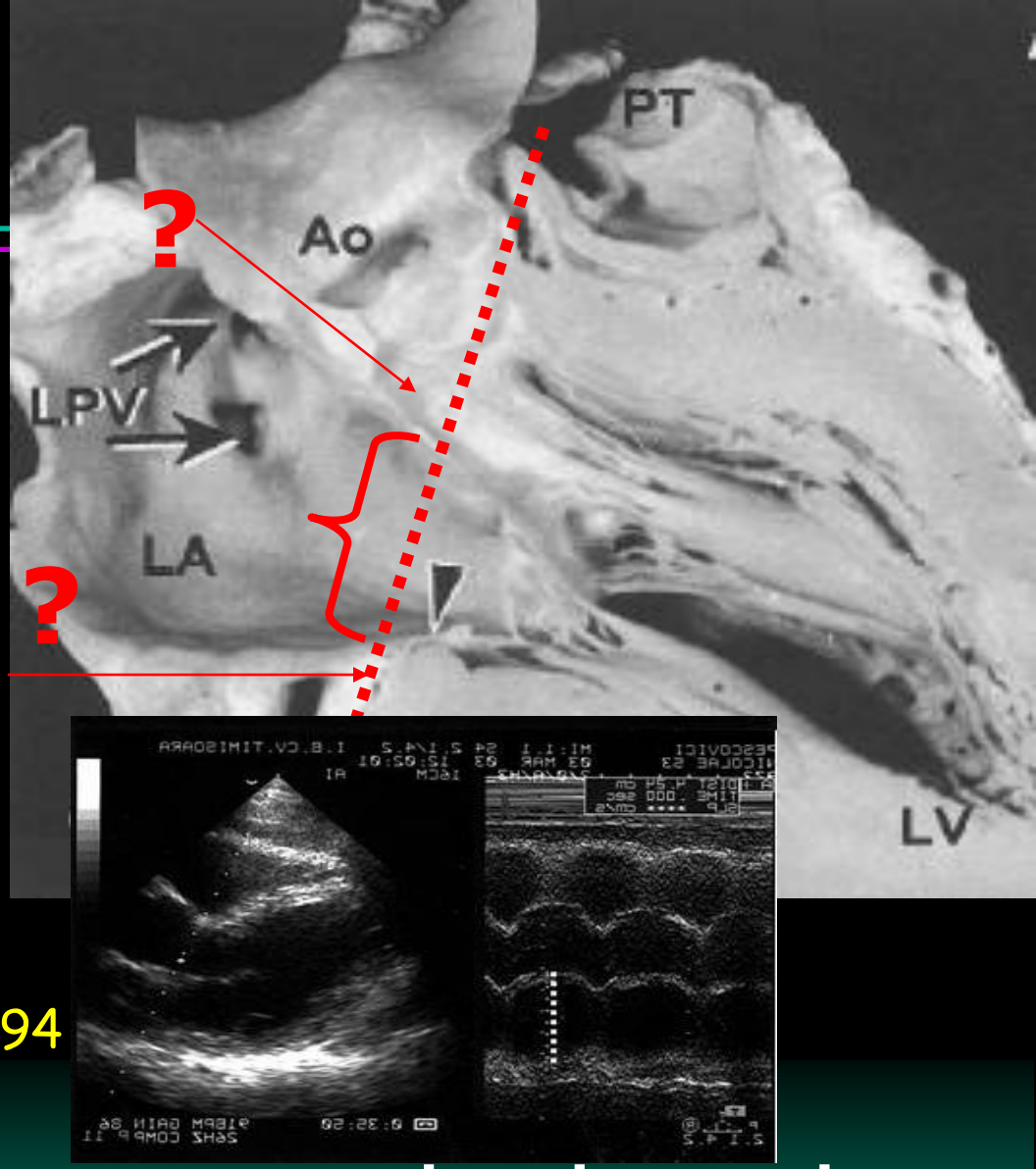
- Patients with a severely increased LA (>40 ml/m^2) have the highest risk for the development of cardiovascular events

Tsang TS, et al. J Am Coll Cardiol 2006

HOW TO EVALUATE LA dilation ?

DIMENSIONS

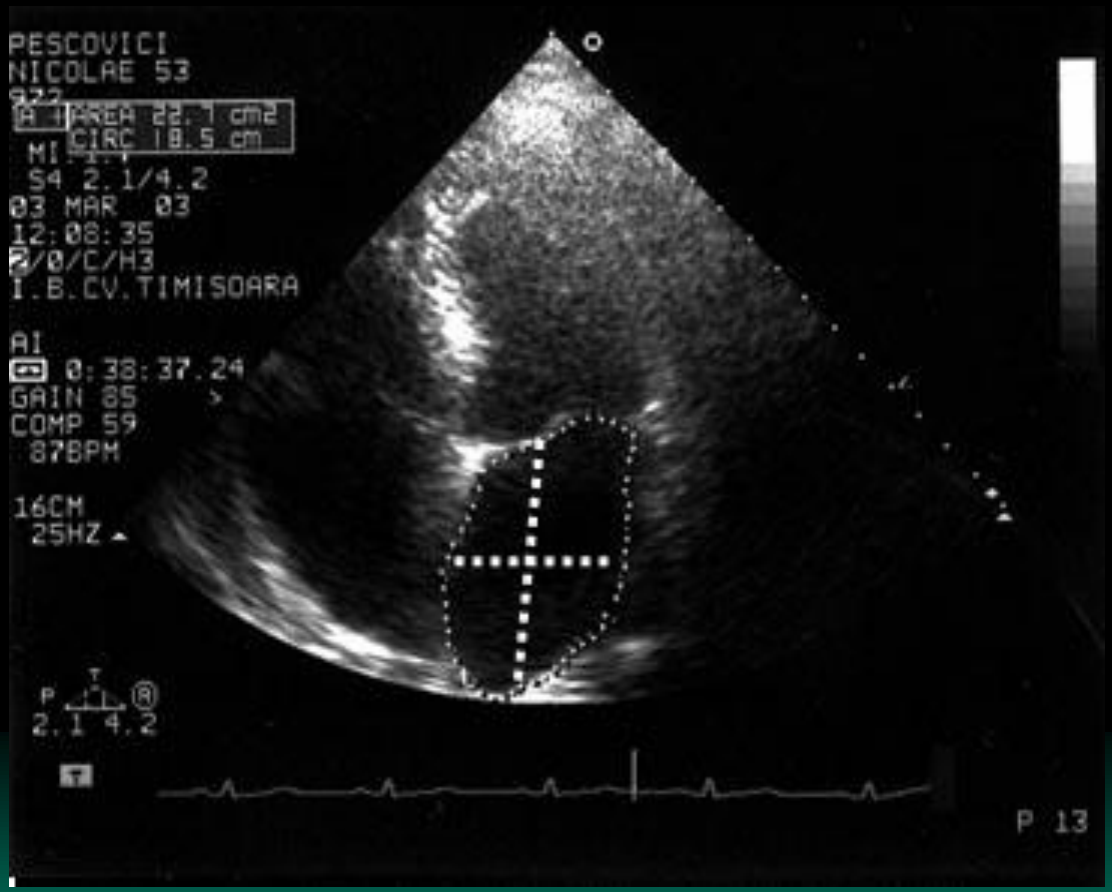
PARASTERNAL LA



the Framingham Heart study. Circulation 1994

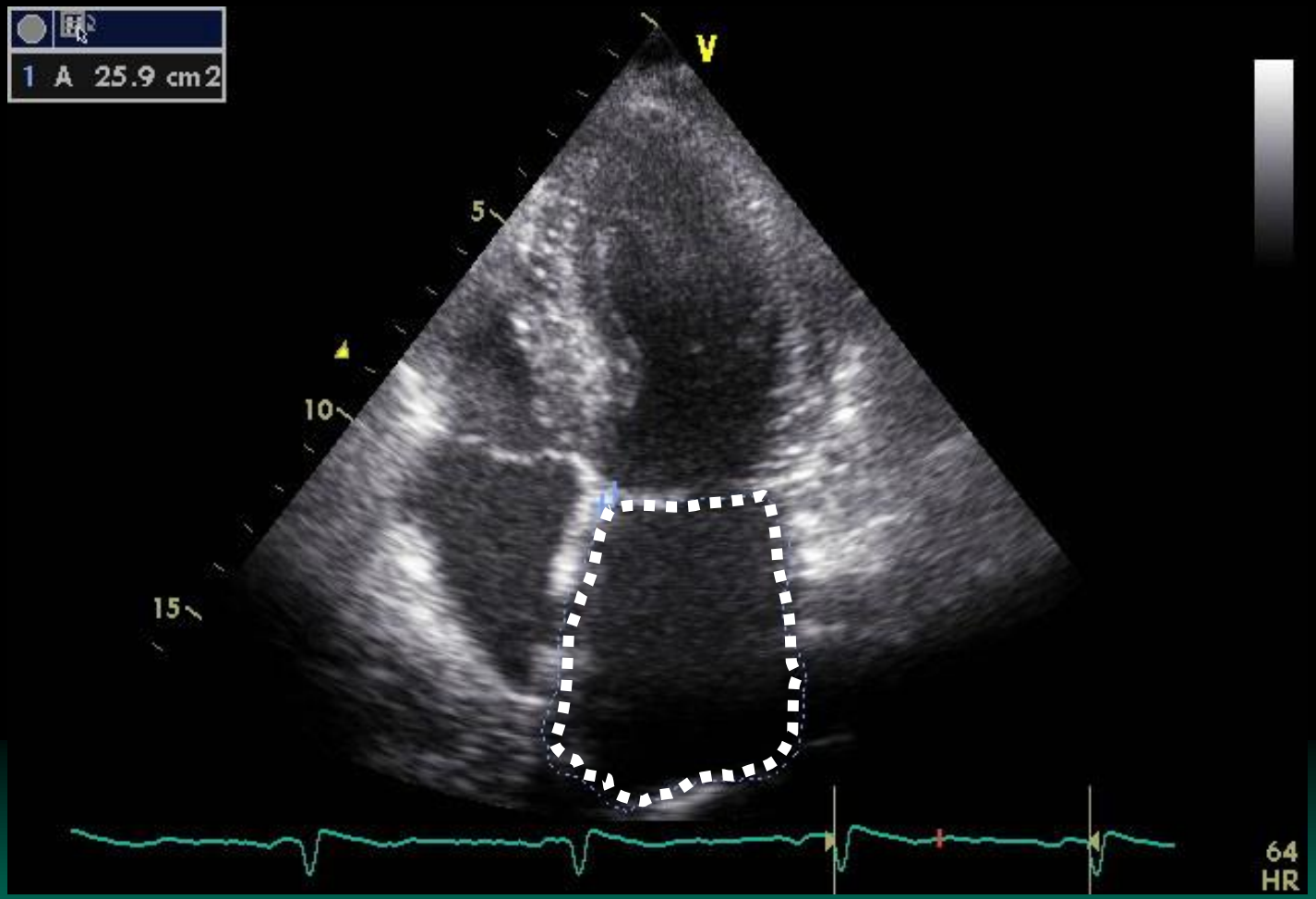
Long-axis section through heart approximating to the two chamber echocardiographic parasternal plane.

Other LA linear dimensions



- **short- and long-axis (lateral and superoinferior) dimensions in apical four chamber view (inner edge to inner edge)**

LA area



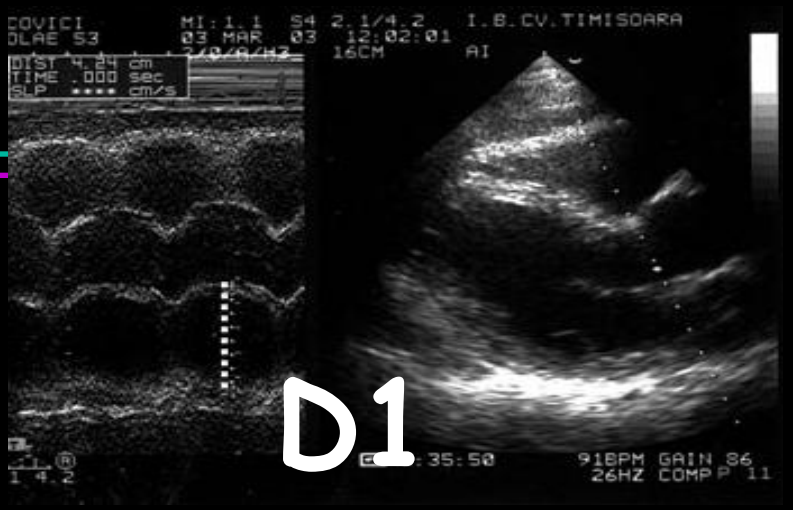
two-dimensional planimetry in the apical 4-chamber view by tracing the endocardial border cavity

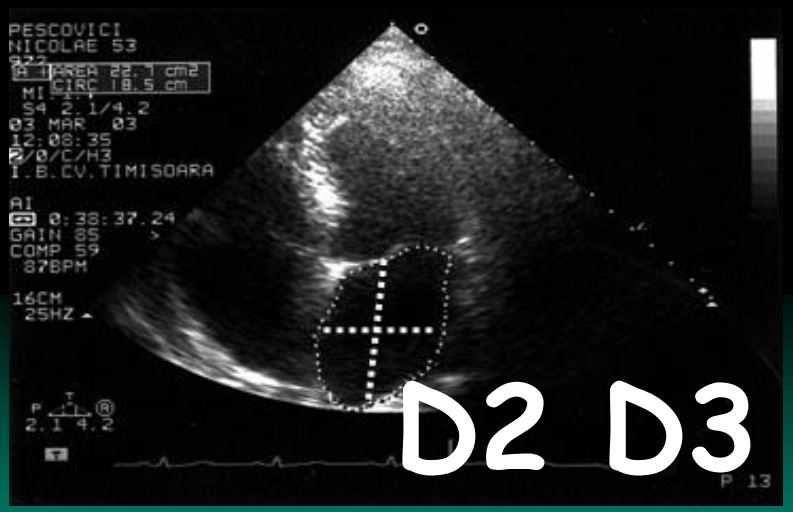
LA VOLUME

LA VOLUME

- **The ellipsoid model assumes that the LA can be adequately represented as a prolate ellipse**

- **π/6 (D1 x D2 x D3).**





Pritchett AM, J Am Coll Cardiol. 2003

LA VOLUME ellipsoid model

- Volume determined using linear dimensions is very dependent on selection of the location and direction of the minor axis dimensions

- has been shown to significantly underestimate (~40%) LA volume.

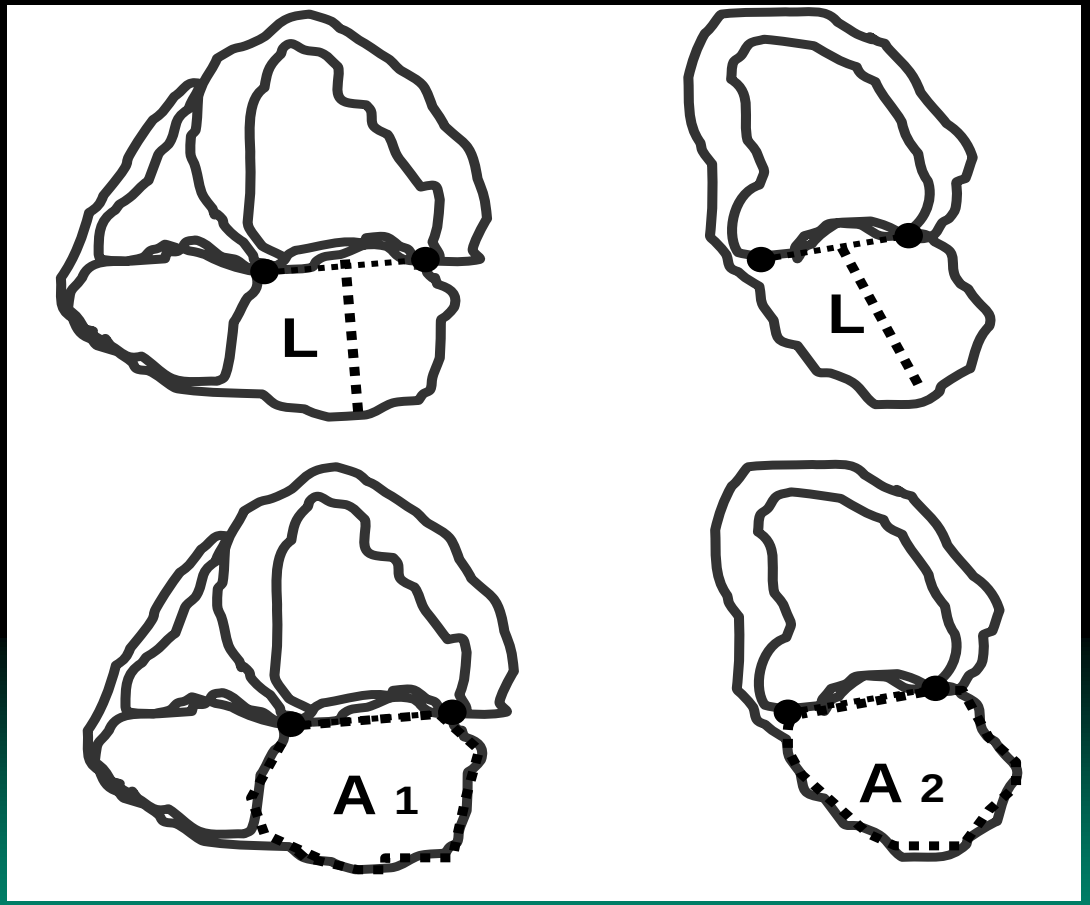
Khankirawatana B et al Am Heart J 2004
Baczynska A et al Eur J Echocardiogr 2004

LA VOLUME

biplane area-length formula

8πL/3 (A1xA2)

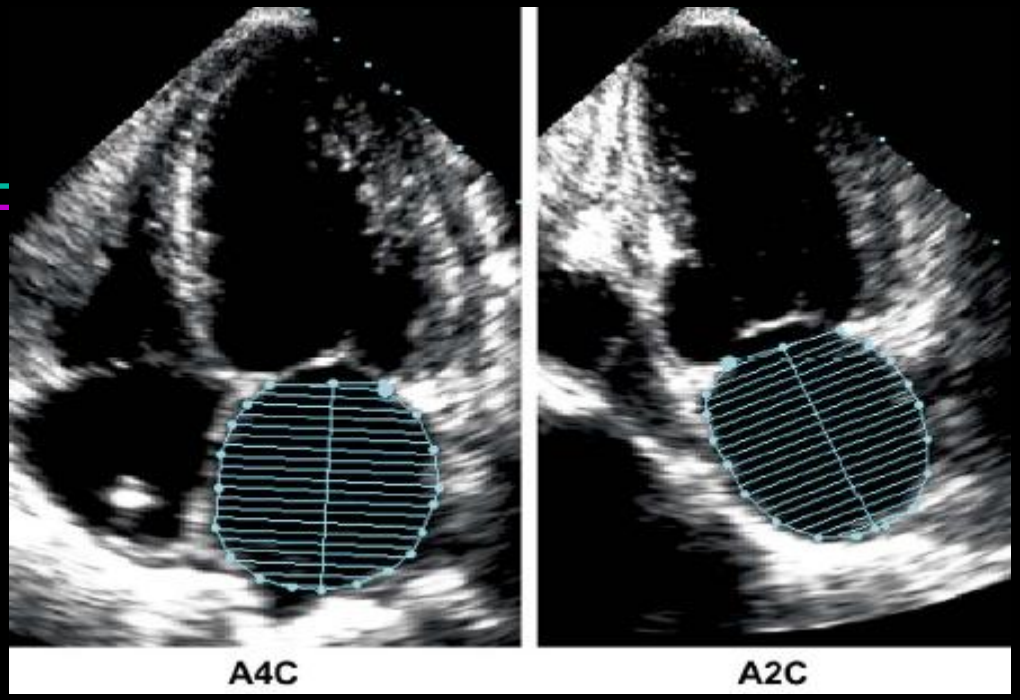
A1 and A2 represent the maximal planimetered LA area apical 4-2 C-views.
L - LA long-axis length



Rodevan O,
Int J Cardiovasc Imaging 1999

shortest of these two L measurements is used in the formula.

LA VOLUME

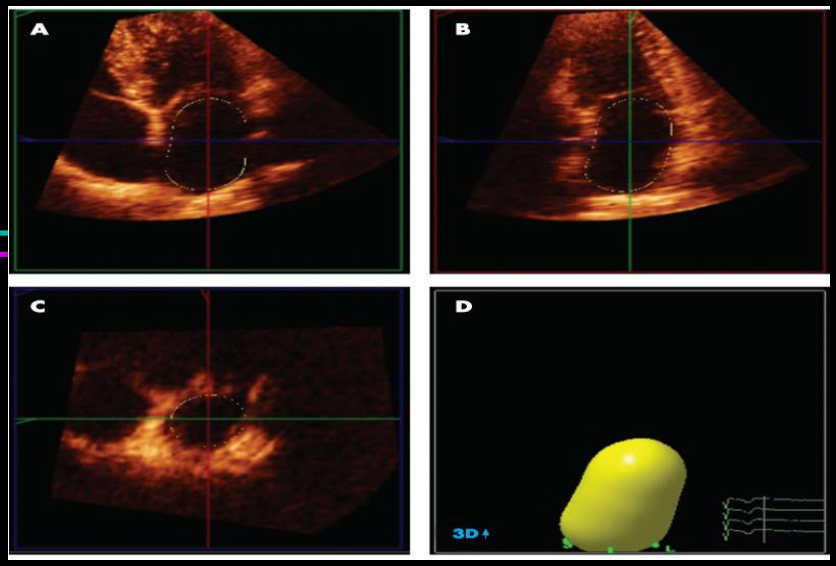


may also be measured using Simpson's rule, similar to its application for LV

- **The volume of the entire LA can be derived from the sum of the volume of the individual disks.**
- **The formula is integrated with the aid of a computer and the calculated volume provided by the software package online**

Khankirawatana B, Am Heart J 2004

LA VOLUME



- Three-dimensional echocardiography should provide the most accurate evaluation of LA volume and has been validated against MRI.

Khankirawatana B, J Am Soc Echocardiogr 2002

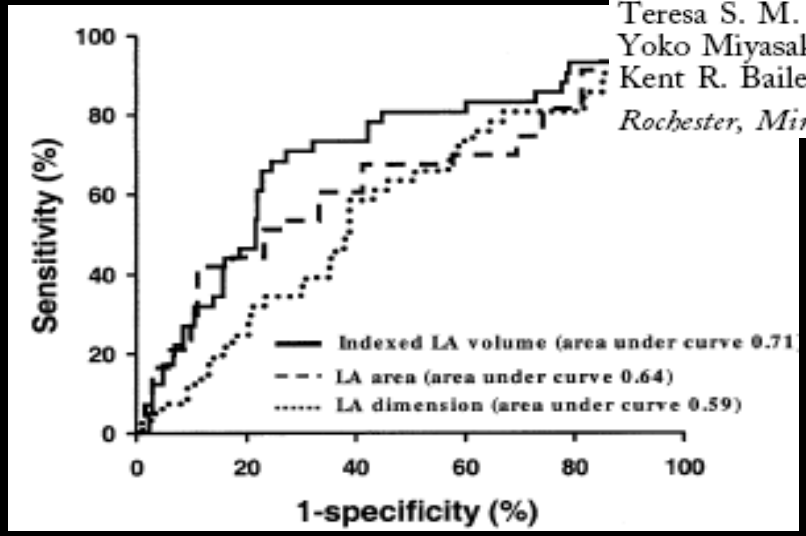
- However to date no consensus exists on the specific method that should be used for data acquisition and there is no comparison with established normal values.

LIMITS REFERENCE

	Reference Range	Mildly Abnormal	Moderately Abnormal	Severely Abnormal
Atrial dimensions				
LA diameter (cm)	2.7–3.8	3.9–4.2	4.3–4.6	≥4.7
LA diameter/BSA (cm/m^2)	1.5–2.3	2.4–2.6	2.7–2.9	≥3.0
RA minor axis dimension (cm)	2.9–4.5	4.6–4.9	5.0–5.4	≥5.5
RA minor axis dimension/BSA (cm/m^2)	1.7–2.5	2.6–2.8	2.9–3.1	≥3.2
Atrial area				
LA area (cm^2)	≤20	20–30	30–40	>40
Atrial volumes				
LA volume (ml)	22–52	53–62	63–72	>73
LA volume/BSA (ml/m^2)	22 ± 6	29–33	34–39	≥40

Lang et al, Eur J Echocardiography 2006

LA VOLUME / AREA or DIAMETER?



Prediction of Cardiovascular Outcomes With Left Atrial Size

Is Volume Superior to Area or Diameter?

Teresa S. M. Tsang, MD, FACC,*† Walter P. Abhayaratna, MBBS, FRACP,*† Marion E. Barnes, MS,† Yoko Miyasaka, MD, PHD, FACC,*† Bernard J. Gersh, MB, CHB, DPHIL, FACC,* Kent R. Bailey, PHD,‡ Stephen S. Cha, MS,‡ James B. Seward, MD, FACC*†

Rochester, Minnesota

	%	Hazards Ratio	p Value†
Left atrial dimension			
>40 mm	74	9.8	0.002
Indexed left atrial diameter			
Mildly increased	23	2.9	<0.0001
Moderately increased	11	4.1	
Severely increased	4	2.6	
Left atrial area			
Mildly increased	68	3.0	0.001
Moderately increased	6	6.2	
Severely increased	—	—	
Indexed left atrial volume			
Mildly increased	31	2.3	<0.0001
Moderately increased	23	3.5	
Severely increased	32	9.0	

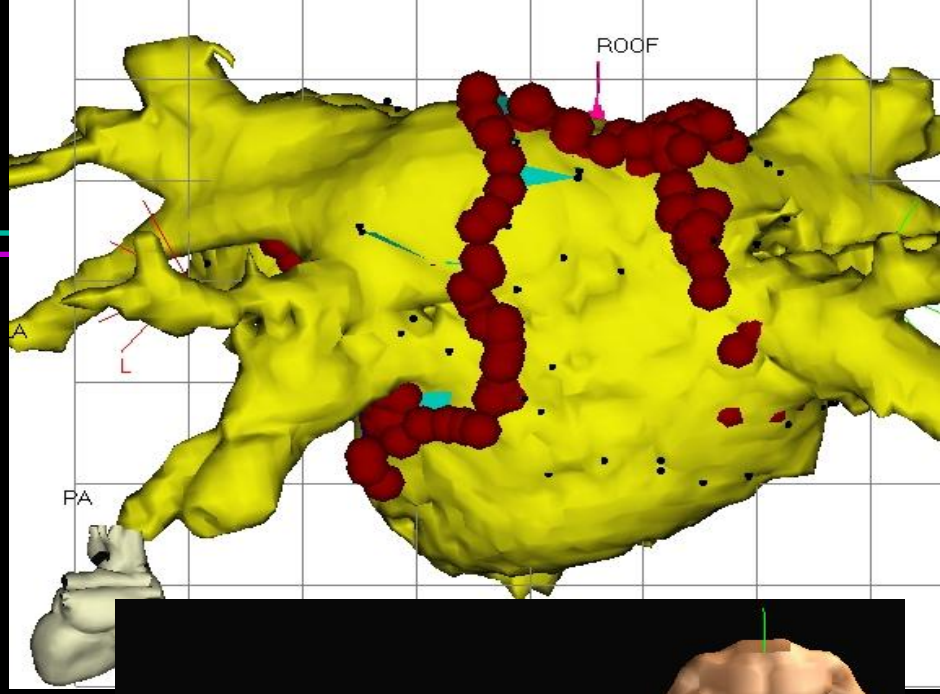
Indexed LA volume is a more robust cardiovascular risk marker than LA area or diameter in patients who are in sinus rhythm

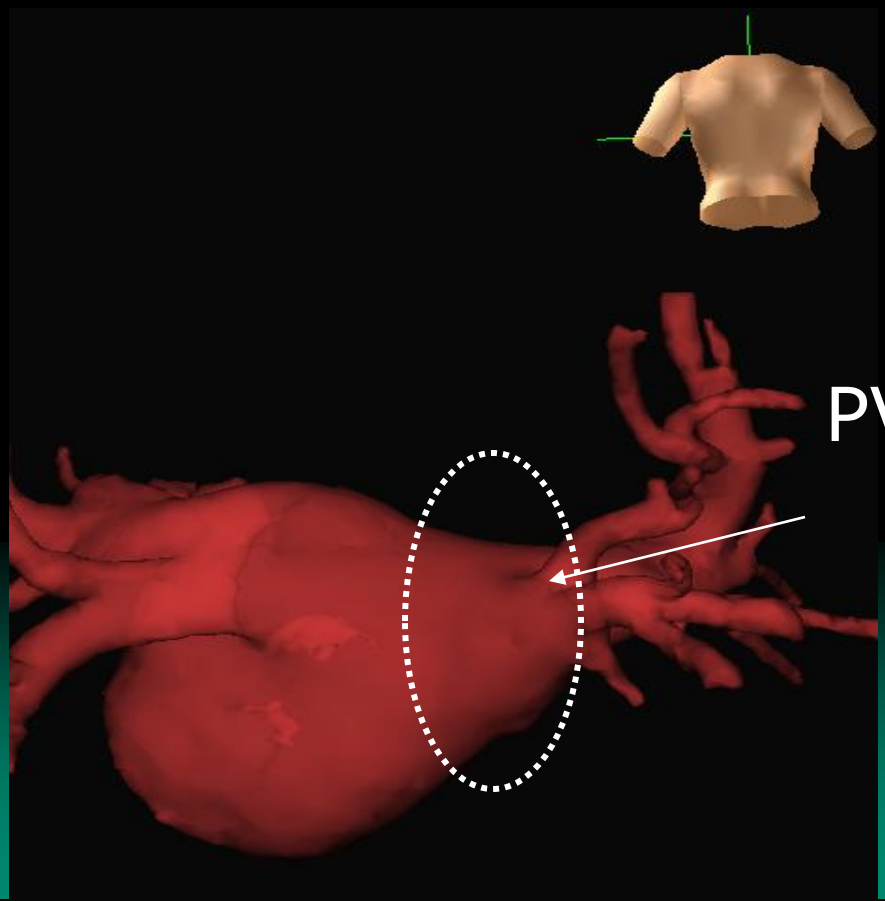
However, in patients with AF, the predictive utility of LA size for future cardiovascular events seemed unsatisfactory

Why?

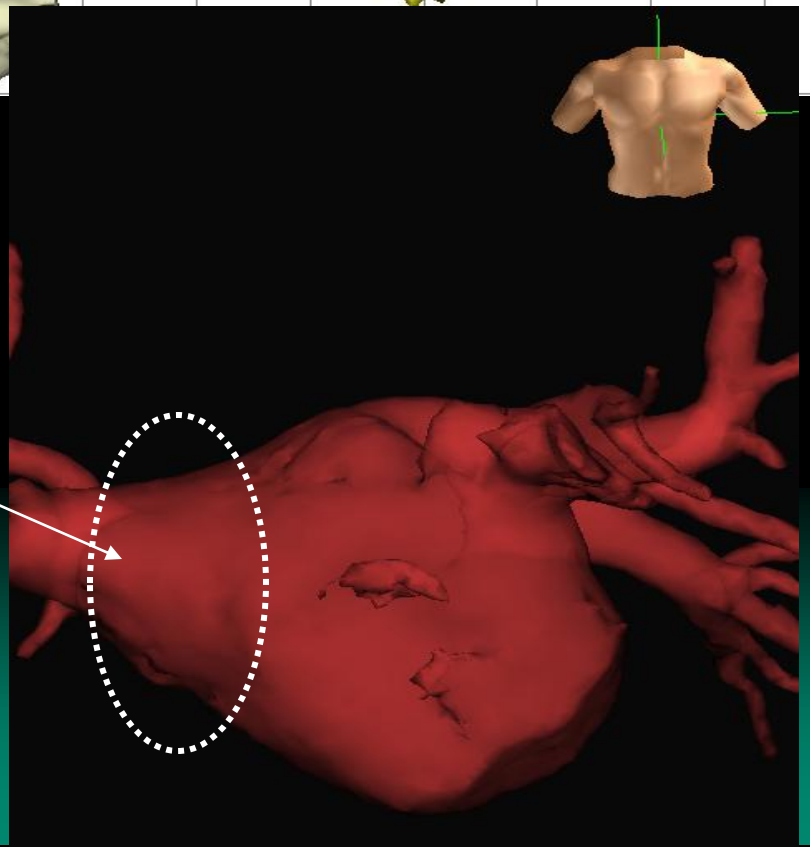
LA real shape

Real border LA - PV

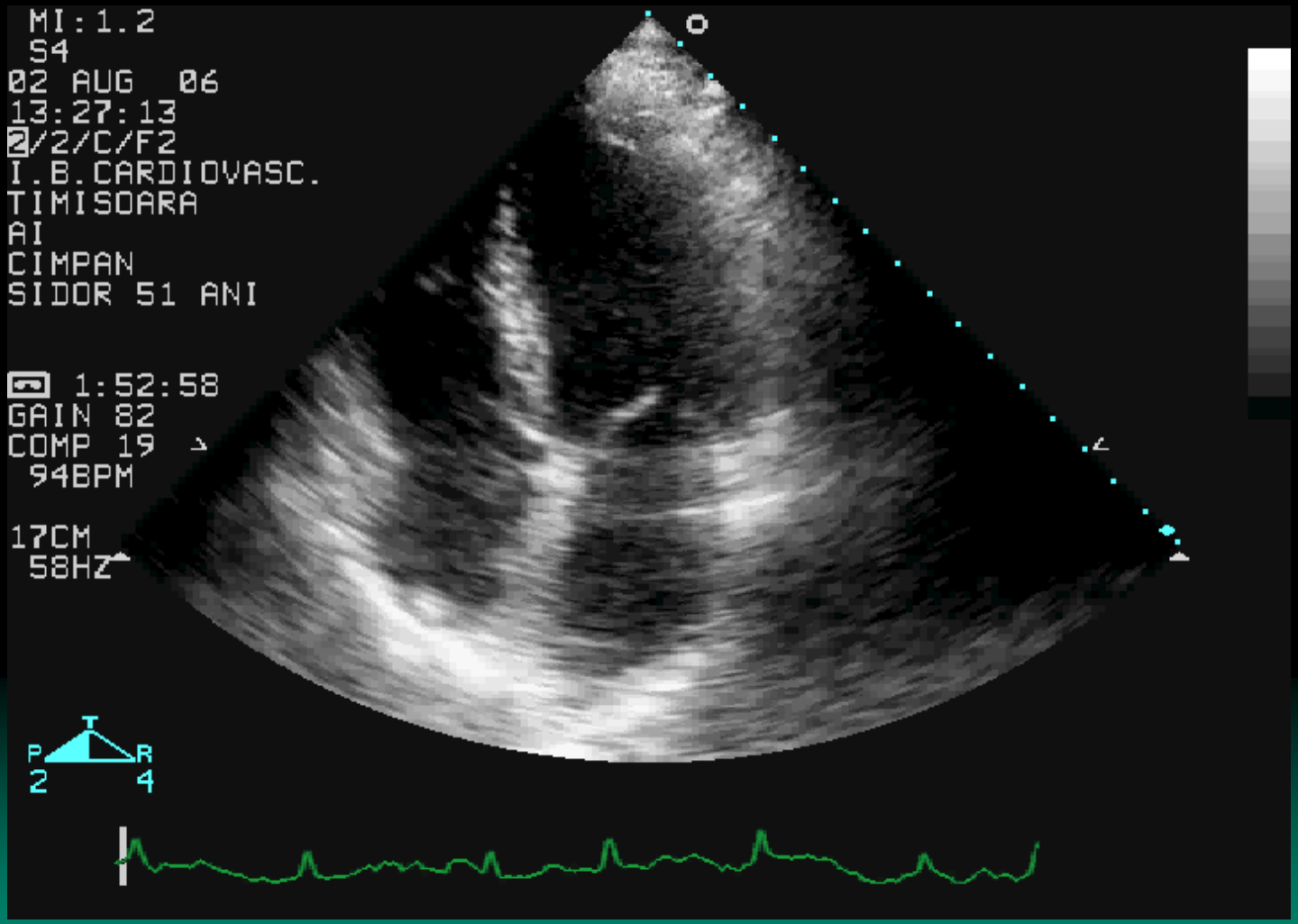


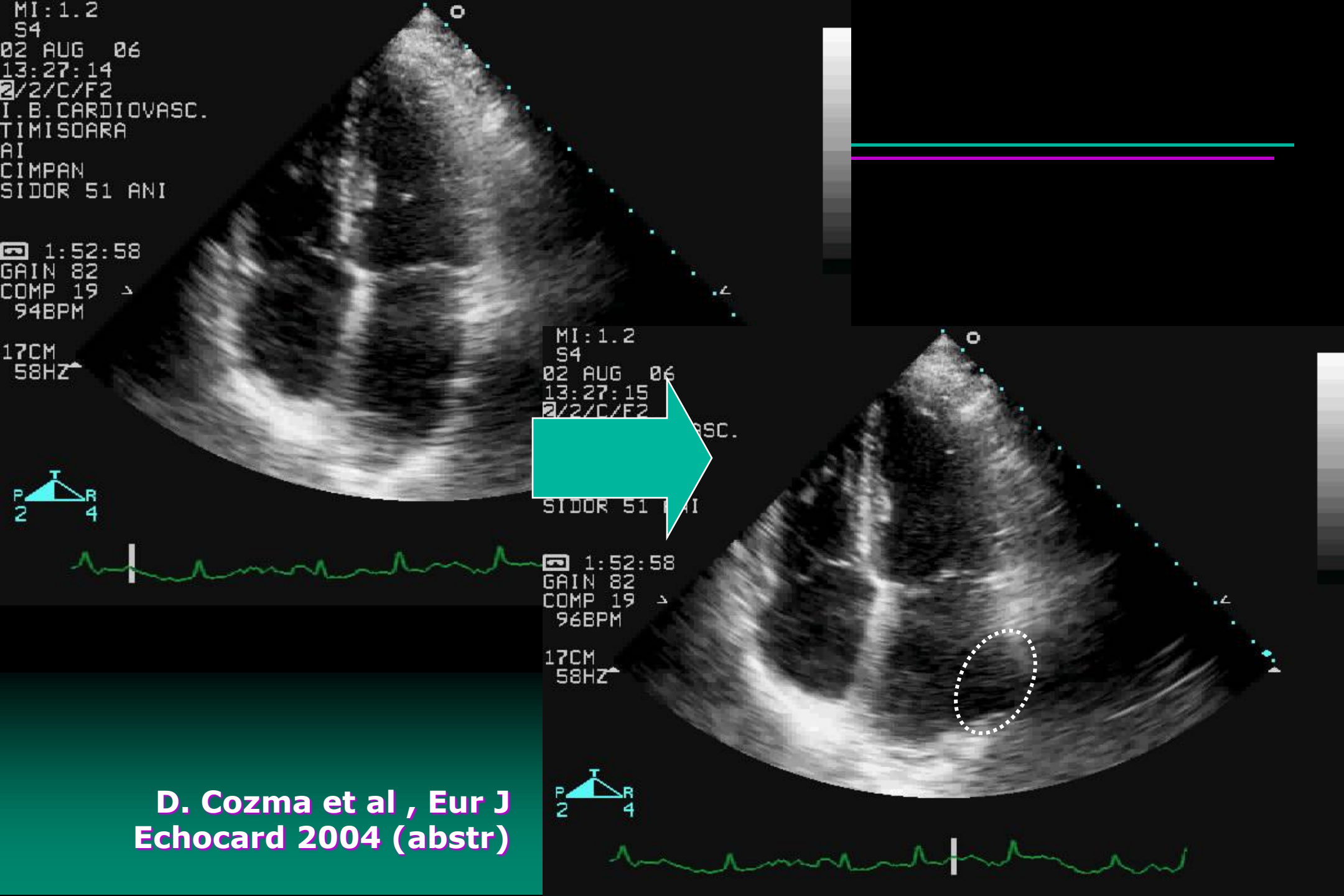


PV antrum



LA real shape ?

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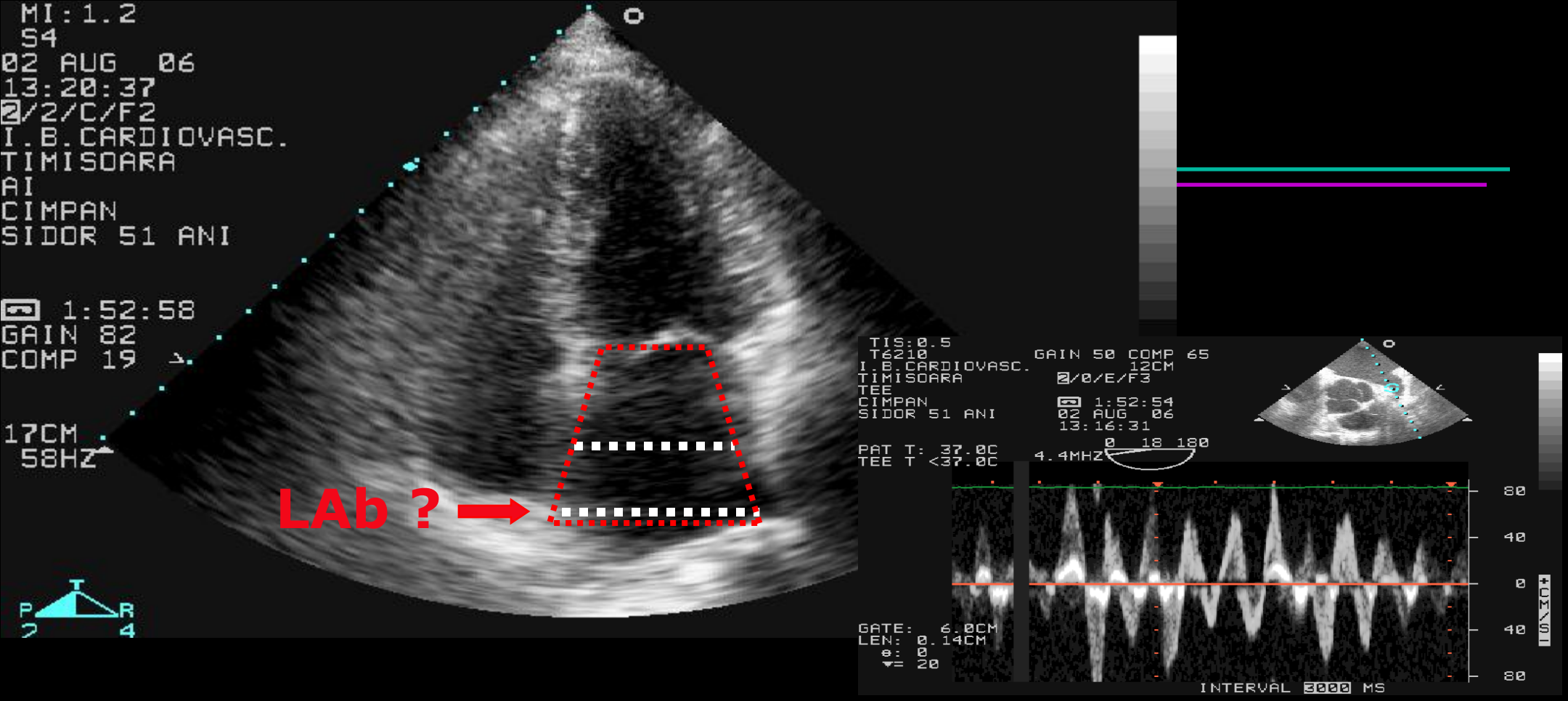
58HZ
D. Cozma et al , Eur J Echocard 2004 (abstr)



LA size-shape & vulnerability to AF

D. Cozma, B.A. Popescu et al

PACE 2007

WHEN IS LA IMPORTANT?

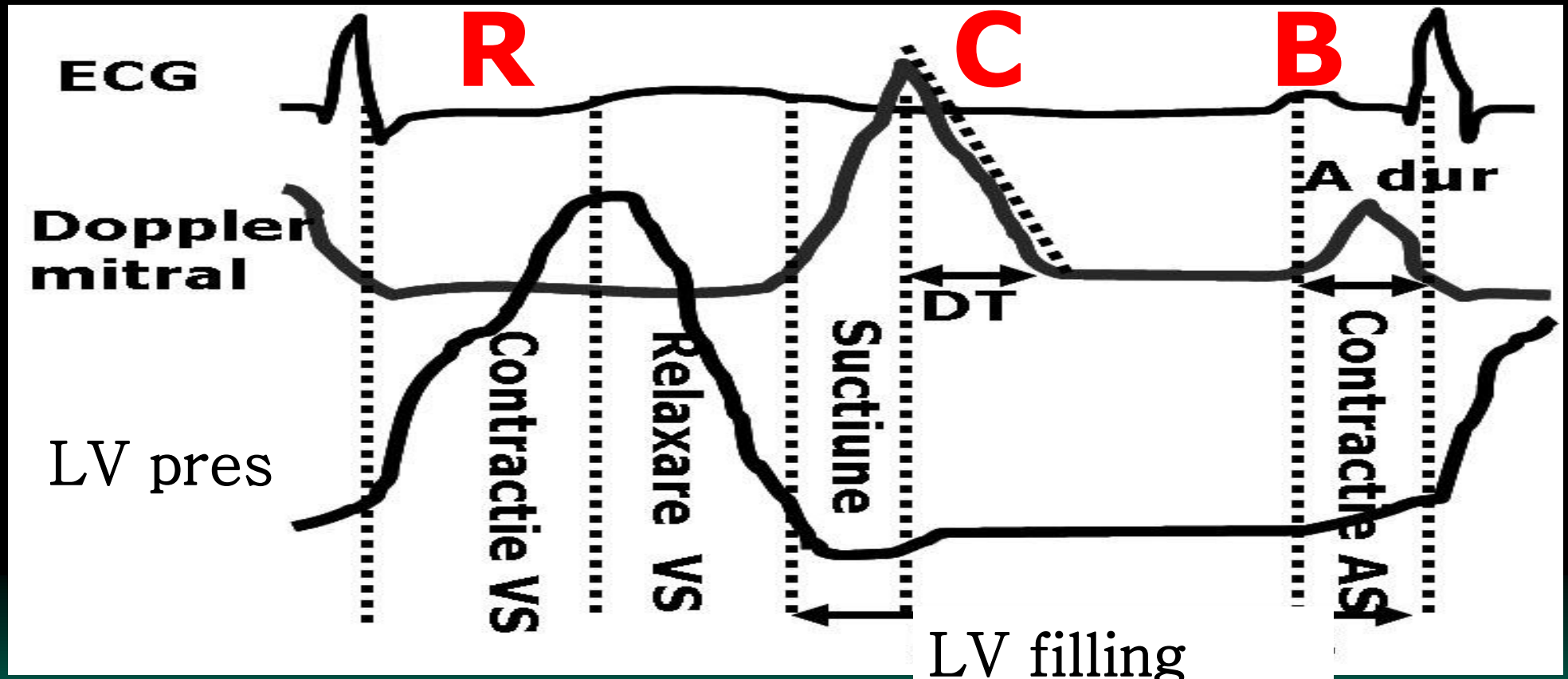
- **in the presence of a normal LV, impairment of LA contraction has little effect on cardiac output, because conduit function compensates for atrial and ventricular filling.**

In contrast,

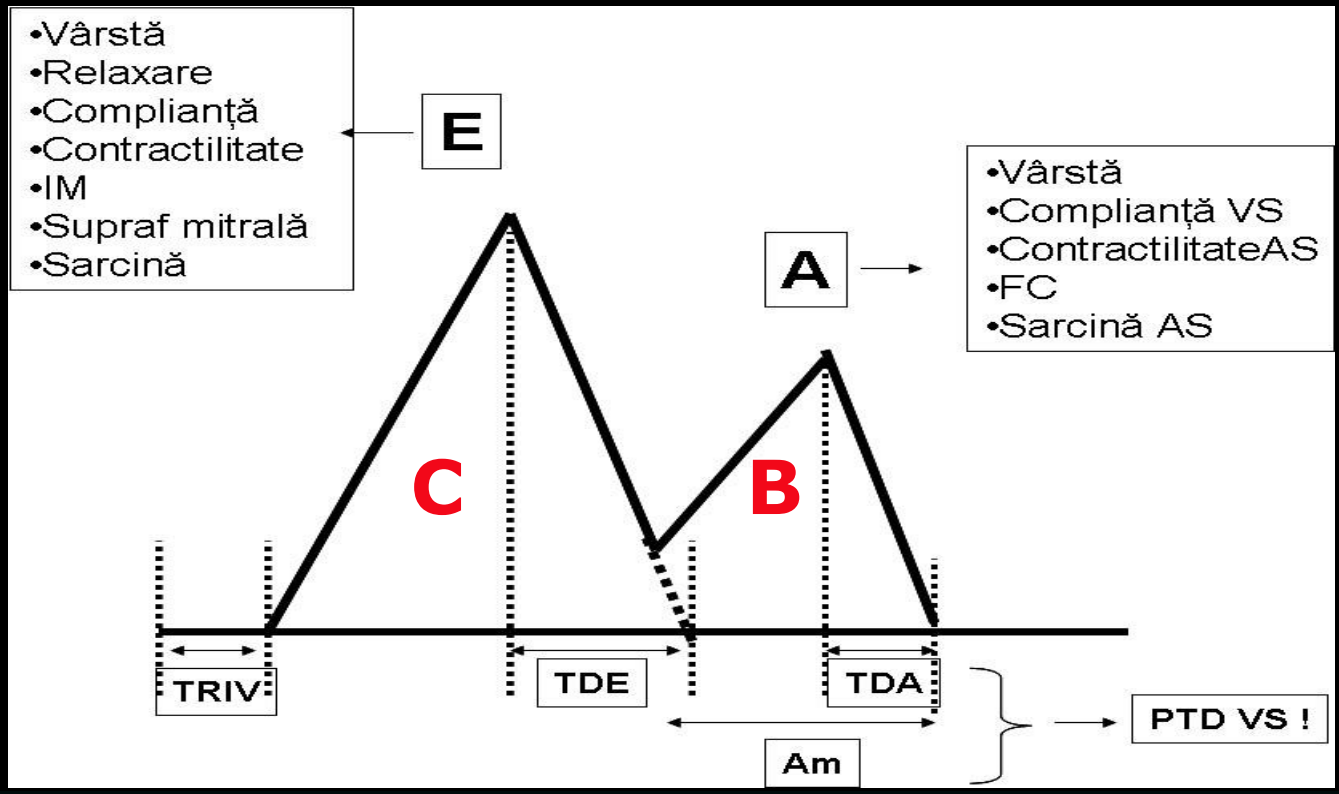
- **in the presence of early LV dysfunction, when atrial booster pump and reservoir functions are increased, impairment of atrial contraction causes a decrease in cardiac output because atrial conduit function is unable to provide compensatory atrial and ventricular filling.**

HOW TO EVALUATE LA FUNCTION ?

CONVENTIONAL MITRAL Doppler



CONVENTIONAL MITRAL Doppler

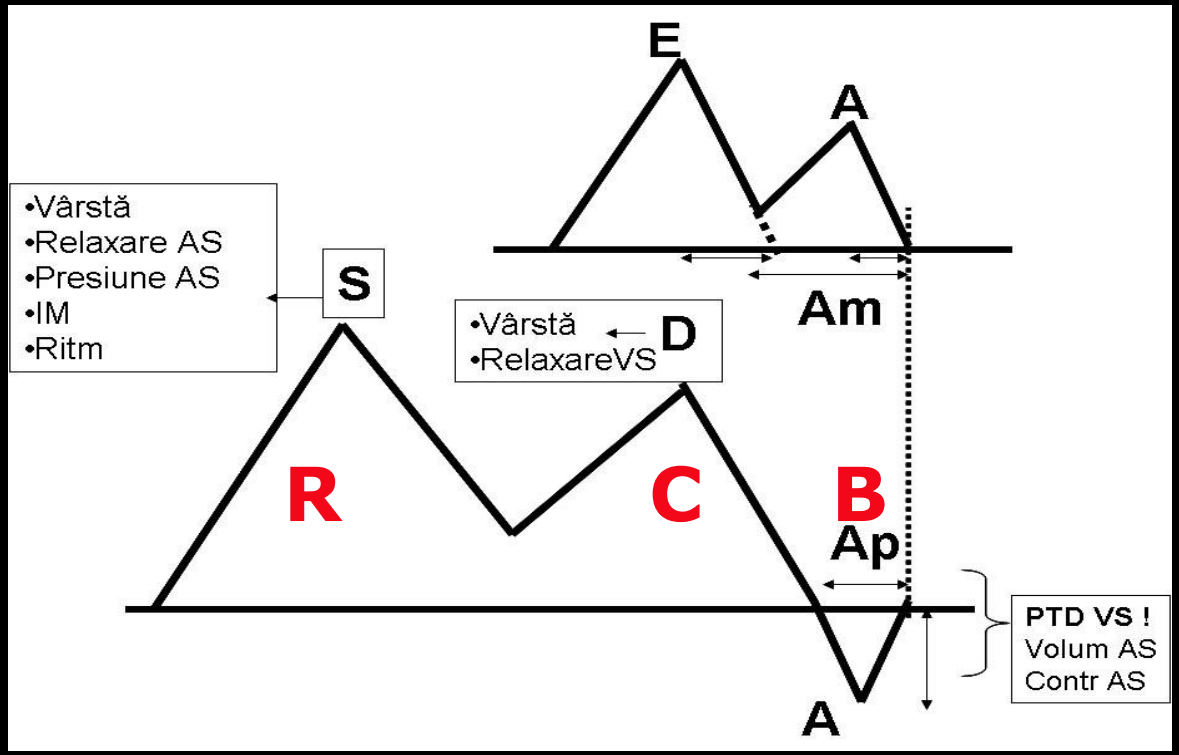


- **Ratio E/A (N. V. 1-2)**
- **VTI mitral / VTI A**
- **A wave Deceleration Time (N.V. 60-100ms) LV EDP >18 mmHg if A DT wave < 60ms; (sens: 89% - spec: 100%)**
- **Duration mitral A wave (Am)**

Tenenbaum A, J Am Coll Cardiol. 1996

PULMONARY VEINS FLOW

- S/D ratio
- (normal >1)

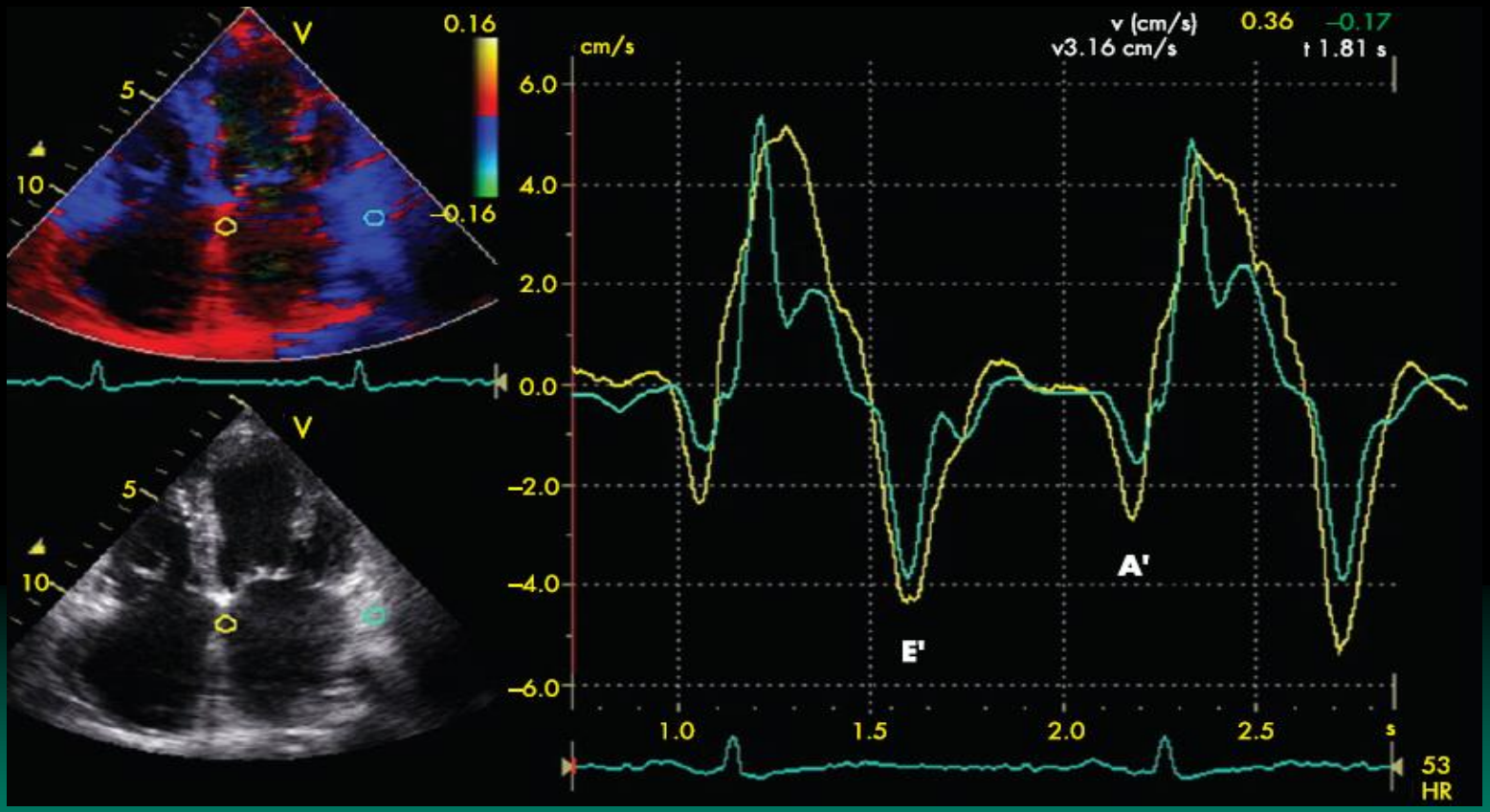


- PV A wave (normal < 35 cm/s)
- Duration A wave PV flow (normal Ap < Am)
- Ap > Am coresponds to LV EDP>15 mmHg sens 85%, spec 79%

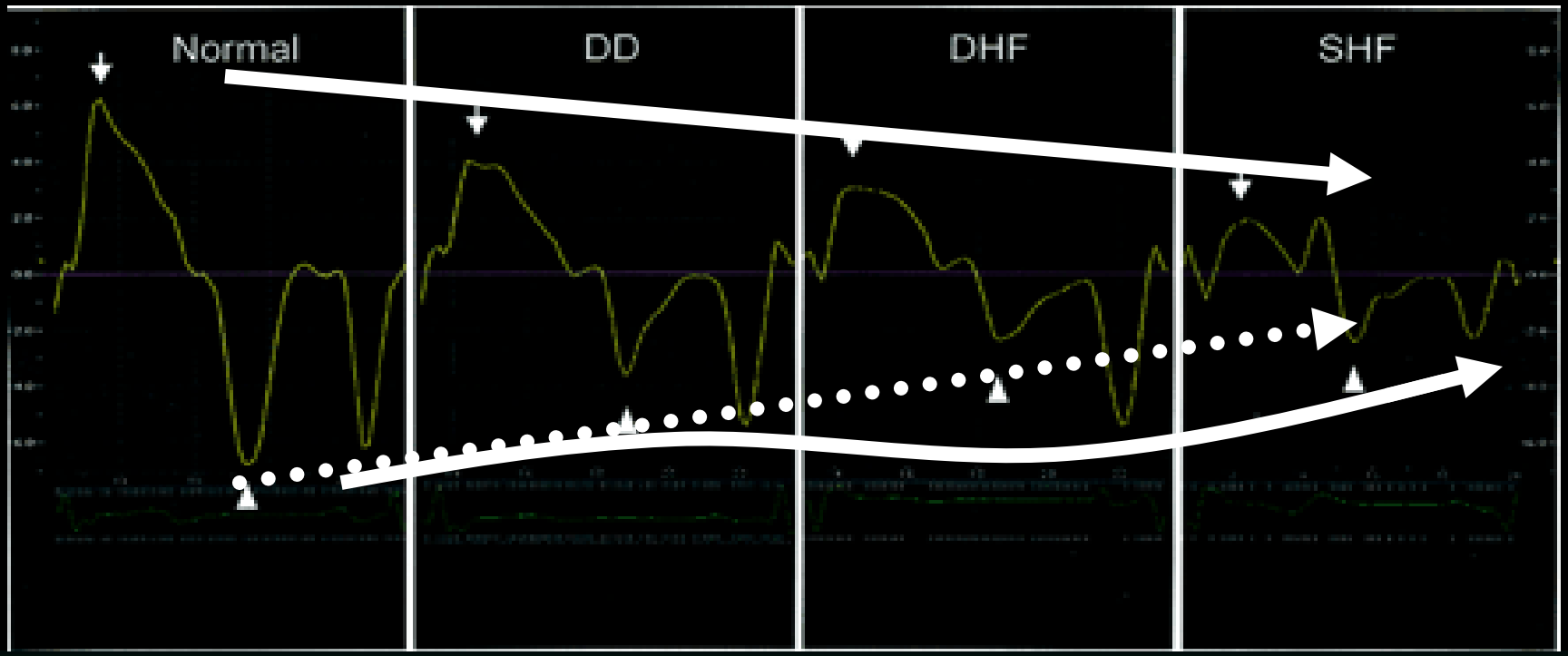
Rossvoll O, Hatle LK J Am Coll Cardiol. 1993

TDI mitral anulus / LA walls

N. V. E'> A'



LV DYSFUNCTION PROGRESSION

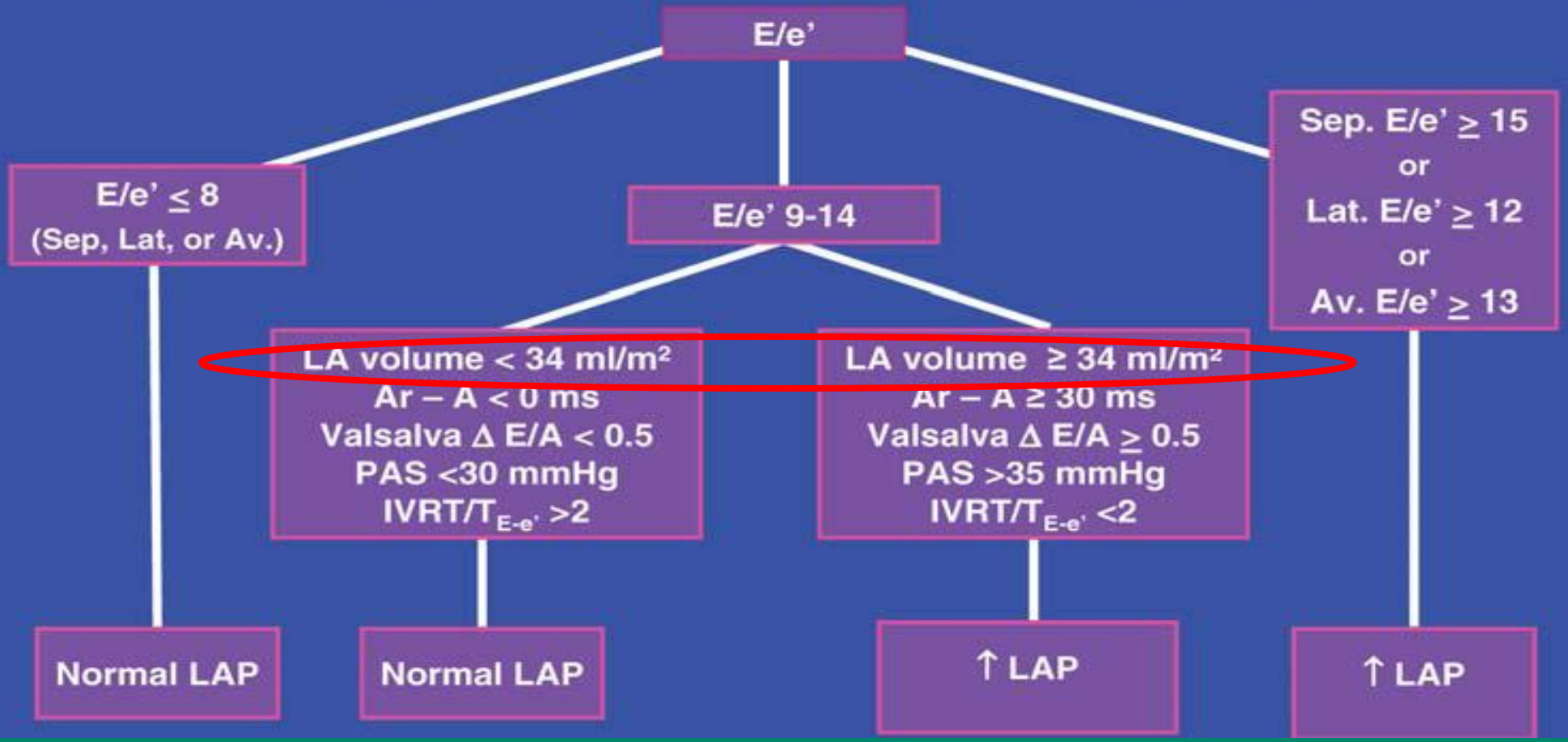


Cheuk-Man Yu Progression of Systolic Abnormalities in Patients With "Isolated" Diastolic Heart Failure and Diastolic Dysfunction **Circulation. 2002**

European Journal of Echocardiography (2009) 10, 165–193
doi:10.1093/ejechocard/jep007

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography 2009

Estimation of Filling Pressures in Patients with Normal EF



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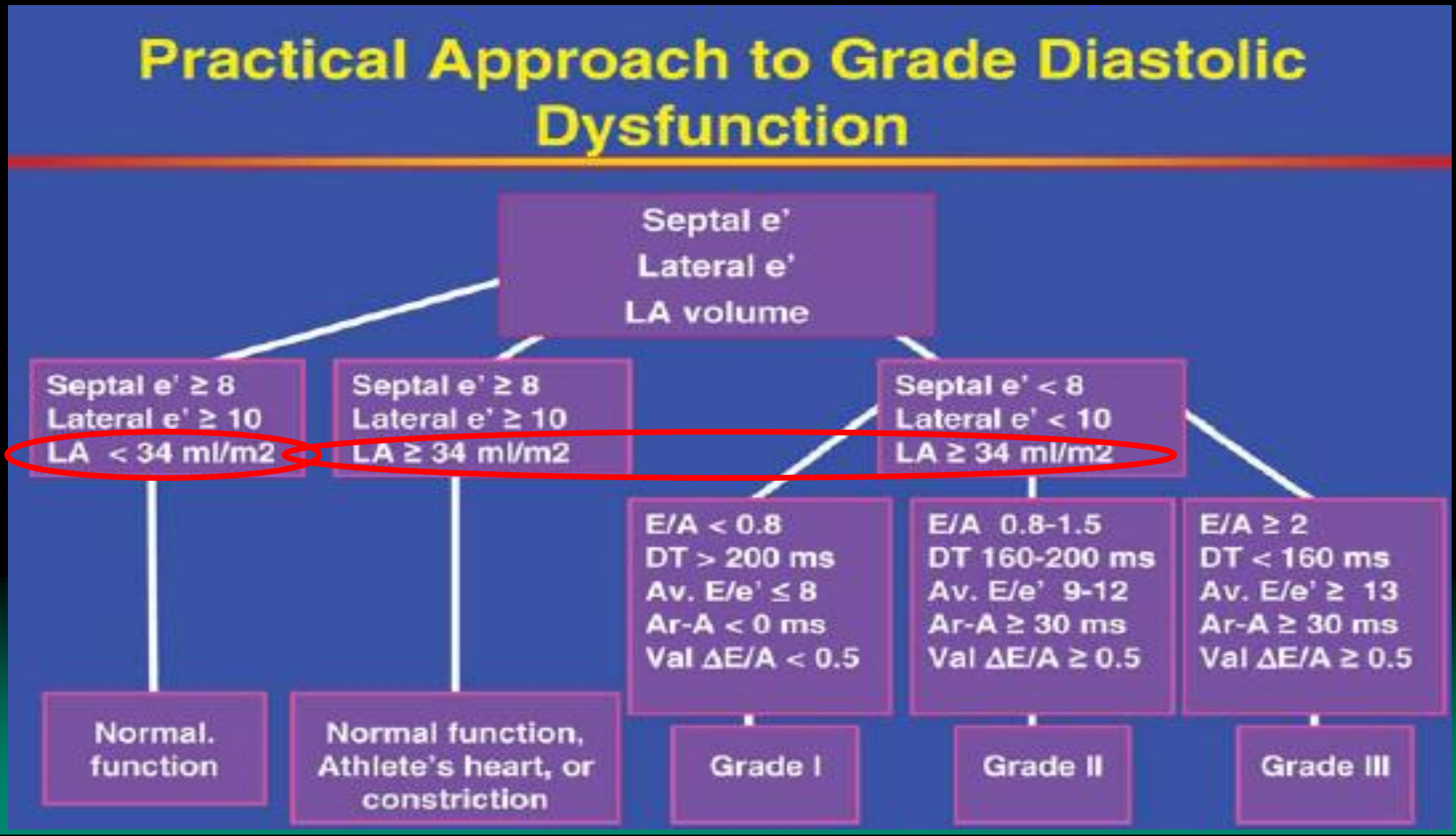
doi:10.1093/ejechocard/jep007

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography 2009



DOPPLER LIMITATIONS

currently Doppler ecocardiography is used for LA function definition

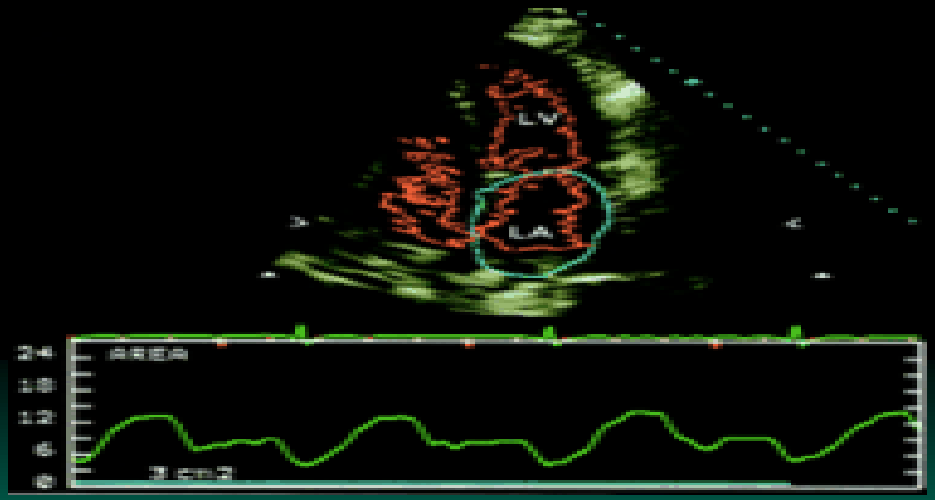
But there are significant limitations concerning the relation between LA dilation and booster pomp

R / C / B phases descriptions are incomplete

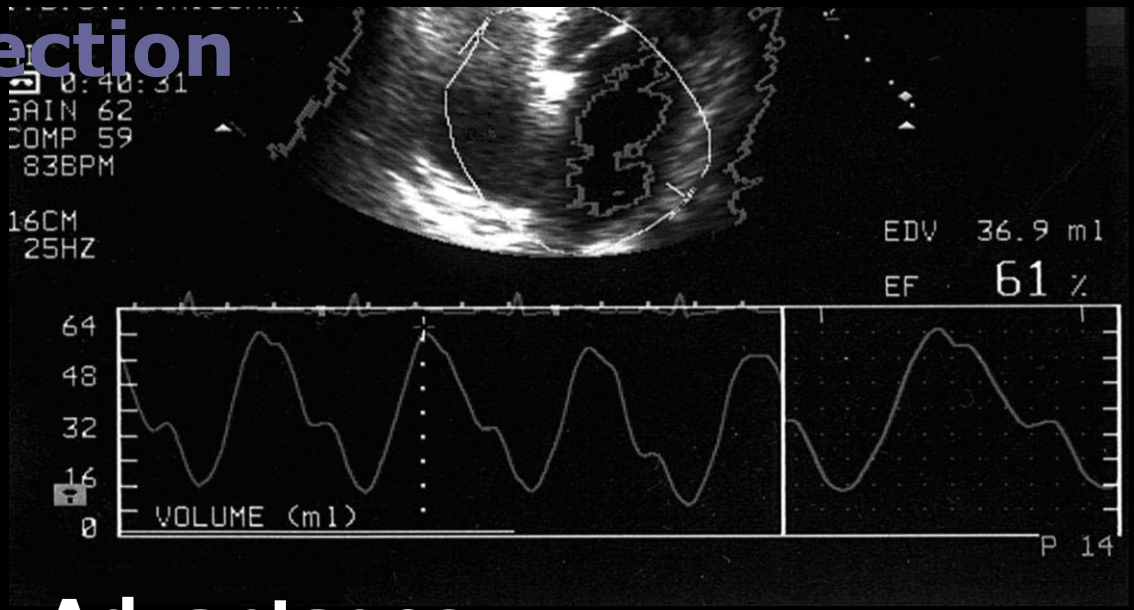
LA VOLUME VARIATION - ABD

Automatic Border Detection

Limitations: accuracy of LA borders.



K T Spencer et al *Heart* 2001

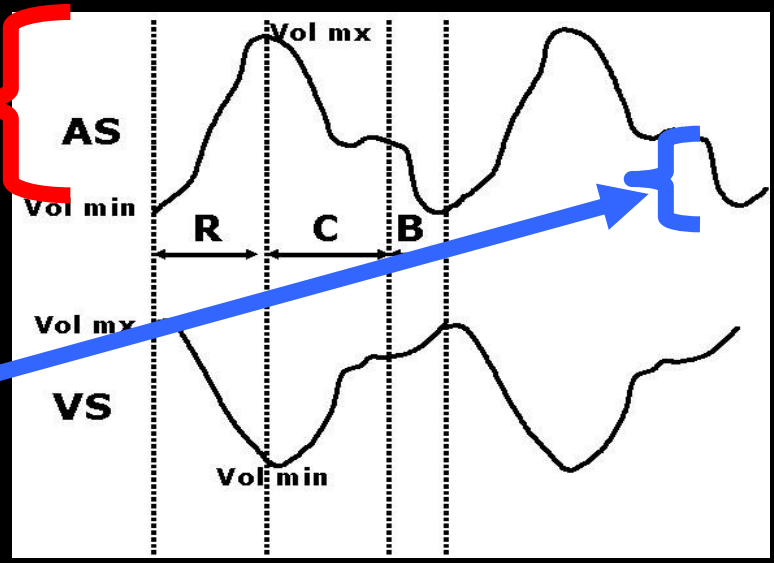


Advantages:

- **LA vol variation curves (complete evaluation R C B)**
- **Good temporal resolution (better than manual measurement which is time consuming)**

LA VOL VARIATION derived parameters :

Total LA EF
(max vol – min vol / max vol),

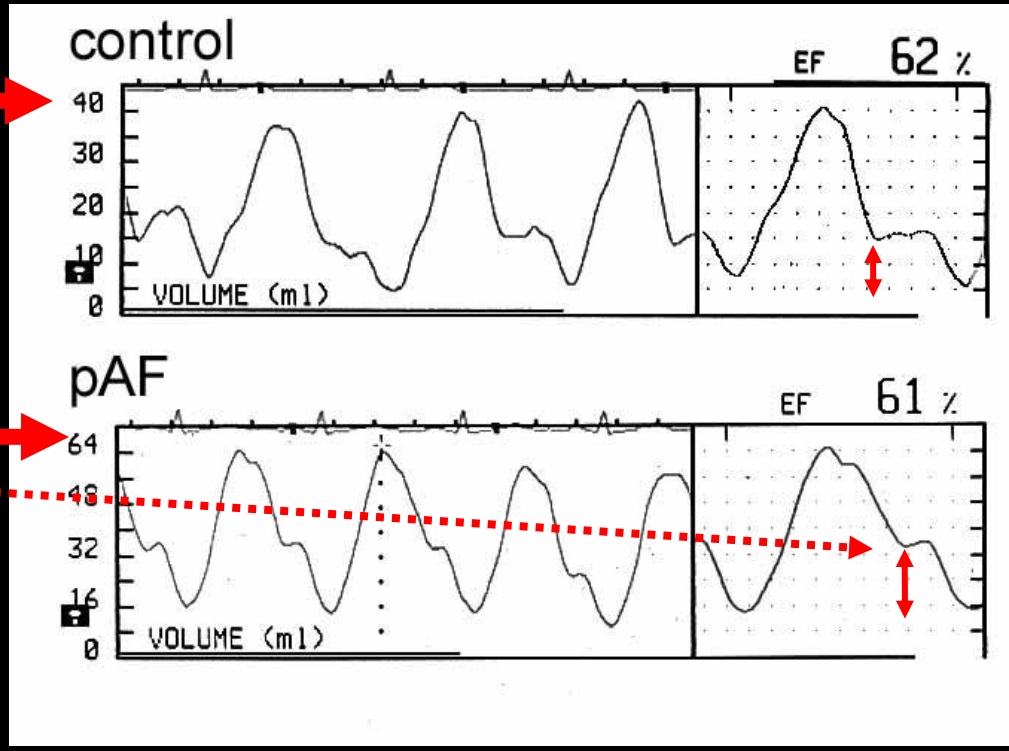


Active LA EF
(atrial presystolic vol – min vol /atrial presystolic vol).

MAX VOL - MIN VOL = reservoir
MAX VOL – PRESYST VOL = conduit
Active LA EF – informations concerning LA contractility
66% LA emptying is passive / 34% active

LA VOL VARIATION

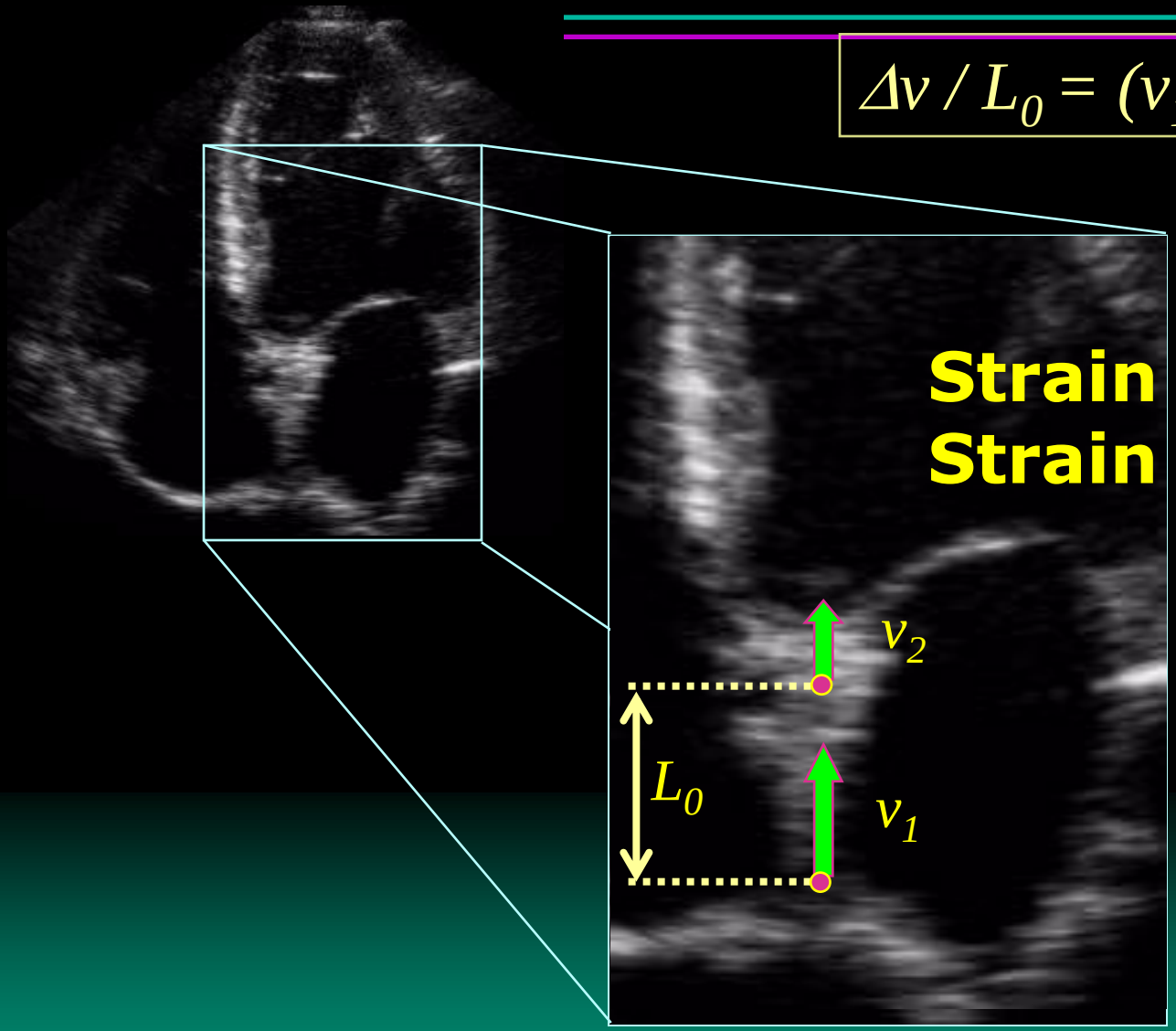
Parox AF pts : increased LA active contractile function, with upward shift of the volume variation curves suggesting pseudonormal mitral pattern



D. Cozma et al , Eur J Echocard 2004 (abstr)

STRAIN –*is the mean relative deformation*

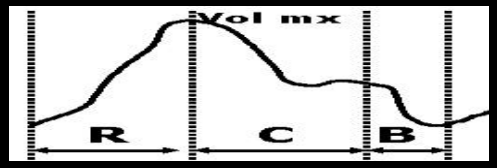
$$\Delta v / L_0 = (v_1 - v_2) / L_0$$



Strain - = shortening
Strain + = lenghtening

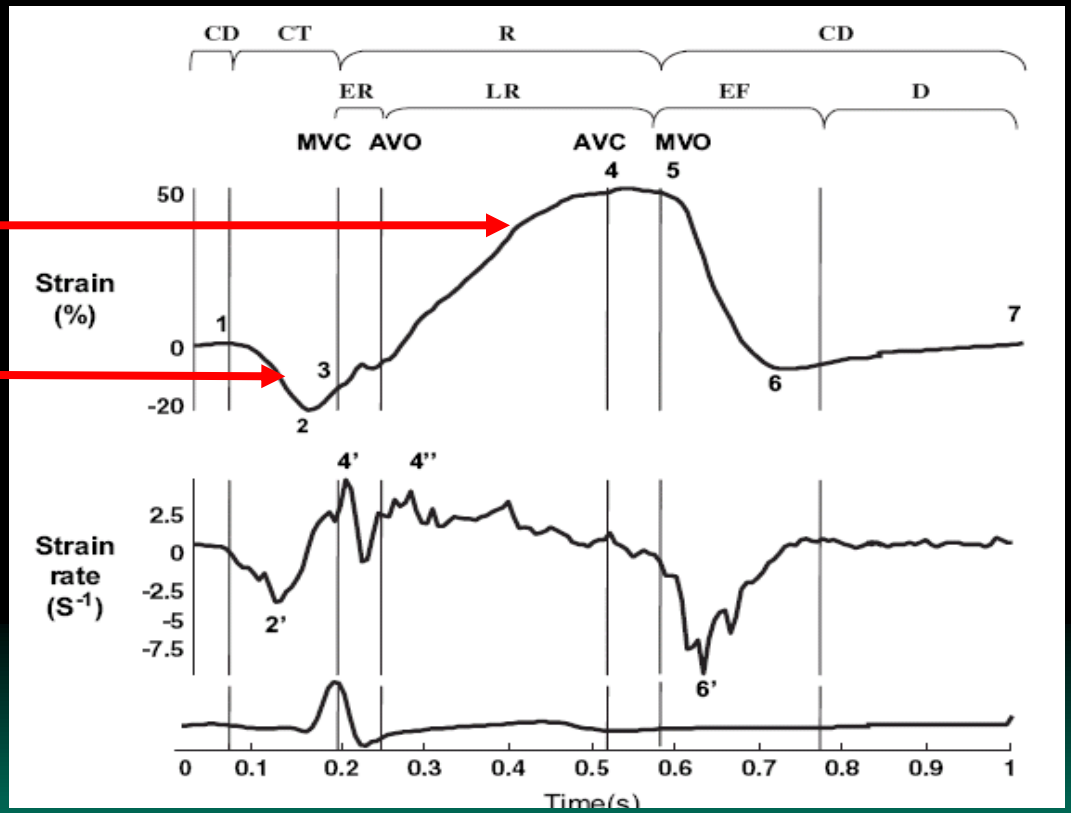
strain rate = speed at which deformation - strain occurs

LA STRAIN / STRAIN RATE & R/C/B



Strain + = lenghtening

Strain - = shortening



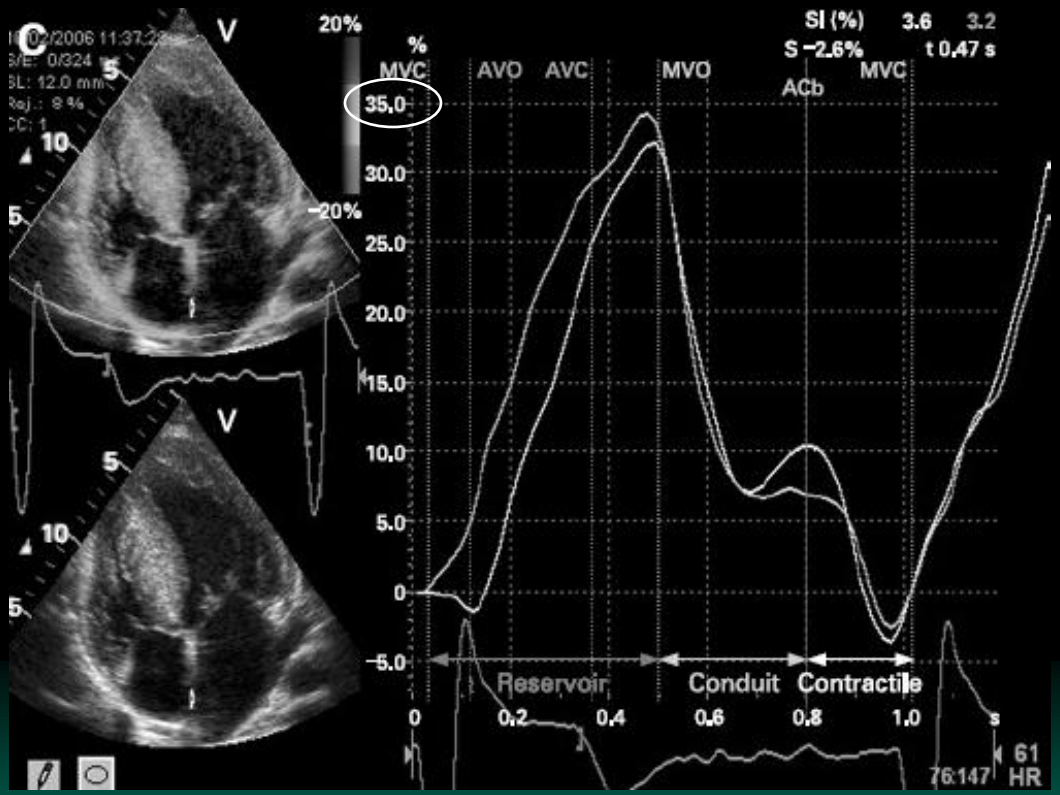
C. Sirbu

Eur J Echocardiography (2006)

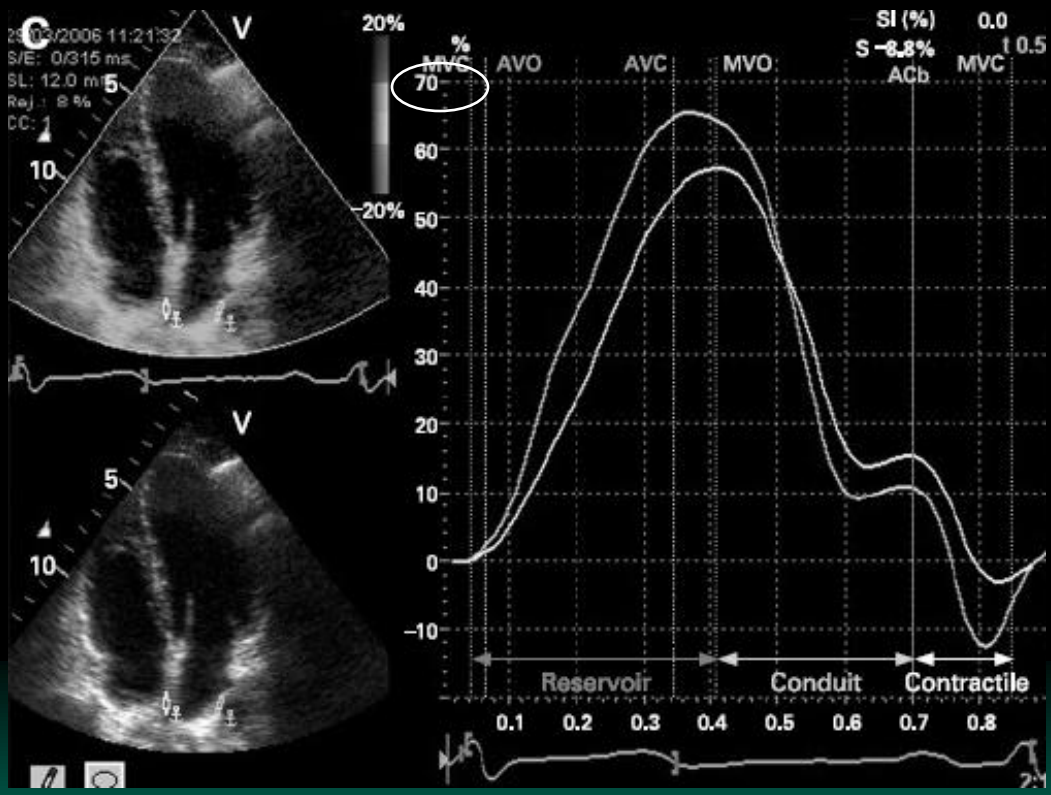
because of its thin wall, strain rate imaging in the atria is extra prone to artifacts due to low lateral resolution

LA STRAIN & R/C/B

left atrial longitudinal strain is reduced in HCM patients



HCM



normal

I A Paraskevaidis, et al Heart 2009

R & LA Function vs AF

Reduced LA reservoir function markedly increases the propensity for first AF episode, independent of LA volume, left ventricular function, and clinical risk factors.

Abhayaratna WP, **Am J Cardiol. 2008**

LA PROGNOSTIC ROLE

Stroke & LA vol

85% of strokes occur in SR!!

American Heart Association. Heart Disease and Stroke Statistics–2005 Update

LA vol – predictor of first ischemic stroke

Barnes ME, et al Mayo Clin Proc. 2004

LA and HF

Increased LA size is associated with the new development of HF in old subjects without valvular heart disease and normal ejection fraction

Gottdiener JS, et al Am J Cardiol 2006

LA & heart surgery

LA dilation is predictor of postoperative mortality

- **after mitral valvular replacement in symptomatic pts with mitral regurgitation**

Reed D, et al Circulation 1991

- **LA size has predictive value for outcome in pts with Ao stenosis**

Rossi A et al Am J Cardiol 2000

LA in patients with low EF

Pts EF ≤ 35%,

LA dilation = independent predictor of mortality of any cause

and has prognostic value additional to demographic, clinical, and conventional ecocardiographic data

Giannuzzi P, et al J Am Coll Cardiol 1996

LA size & DCM /AMI

Restrictive and Dilated CM - prognostic value for survival

Rossi A, et al J Am Coll Cardiol 2002

Ammash NMet al Circulation 2000

Increased left atrial volume is a powerful predictor of mortality after acute myocardial infarction and provides prognostic information incremental to clinical data and conventional measures of LV systolic and diastolic function.

Beinart Ret al J Am Coll Cardiol 2004.

CONCLUSIONS

- **Single measurement of LA parasternal dimension is not acceptable to assess LA dilation**
- **It is generally recommended to measure LA volume**
- **LA function may be assessed using conventional mitral Doppler/ TDI / strain / volume variation**
- **LA has prognostic value and correlates to LV dysfunction**

CONCLUSIONS

"LA size represents the integration of LV diastolic performance over time"

"Drawing a parallel to two of the most commonly used diagnostic tests in diabetes is nearly irresistible. Just as serum glucose is used to assess transient diabetic control, LV filling pressure is used to assess transient loading conditions. In turn, the diastolic function corollary of measurement of hemoglobin A1C (a long-term biomarker of average metabolic state) is LA size (a long-term biomarker of average LV diastolic pressure, and hence, when increased, of diastolic dysfunction)."

Pamela S. Douglas
The left atrium: A biomarker of chronic diastolic dysfunction and cardiovascular disease risk *J. Am. Coll. Cardiol.* 2003