2011 APCDE

Assessment of Left Atrial Size and Function

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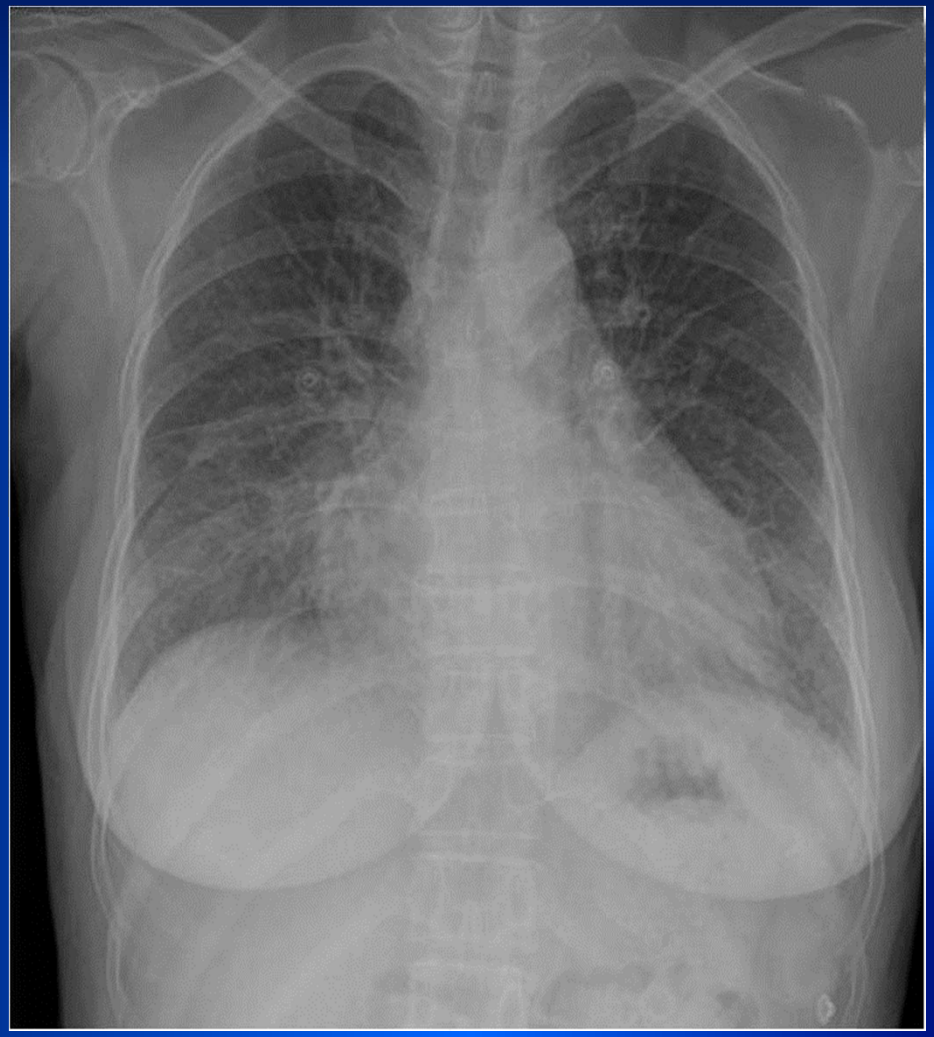
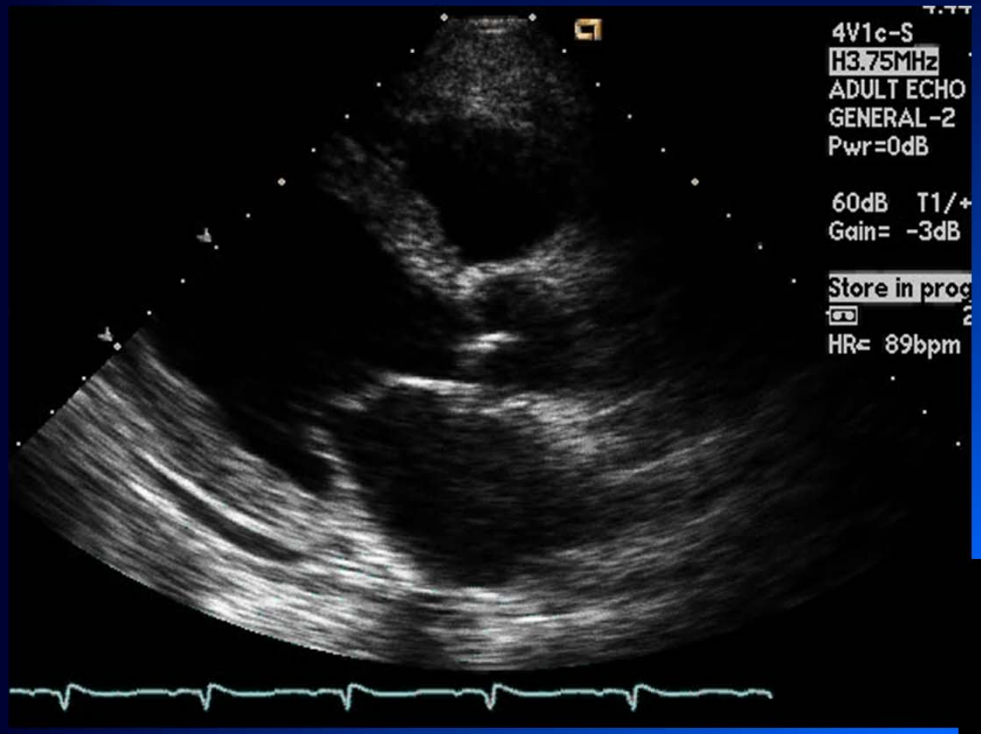
F/73

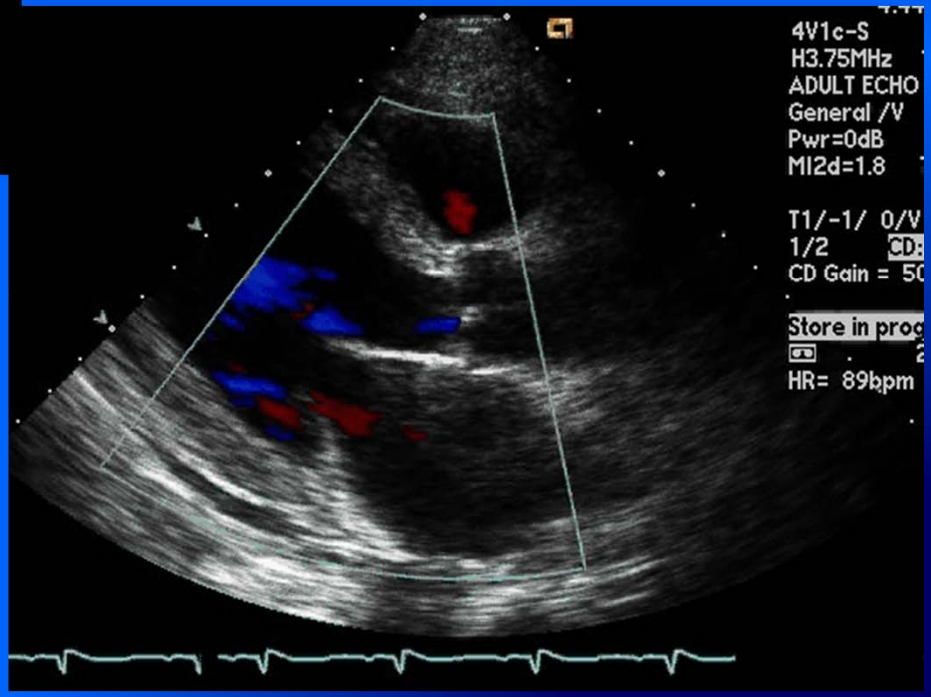
- C/C: Dyspnea aggravation for 2 days

- P/I: Known DM, HTN, Visited ED dept via LMC
  Easy fatigue(+), DOE(+), Orthopnea(+), PND(+)
- PMHx: DM for 10years, HTN for 5 years
- Physical Exam
  - Both neck vein distension (+)
  - Lung sound : rale(+)
  - Heart sound : systolic murmur at Apex (G III/VI)
  - Both leg pitting edema(+)
- NT-proBNP : 2919pq/ml

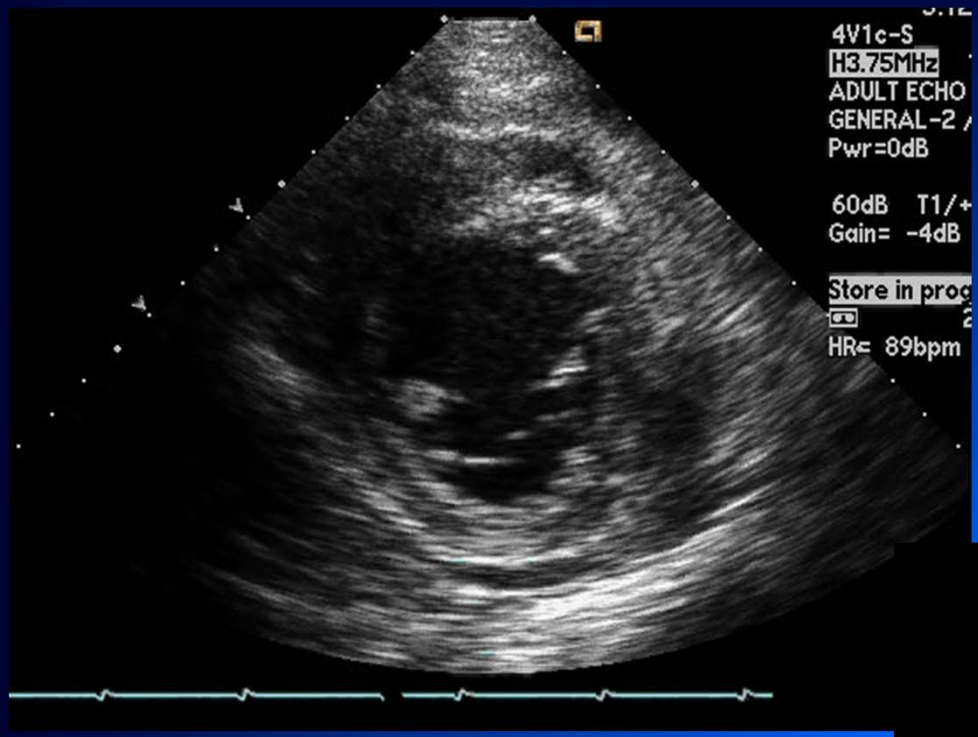
Chest PA







LVEDD : 55 mm
LVESD : 38 mm
EF : 50 %
LA volume index : 36mm^3/m^2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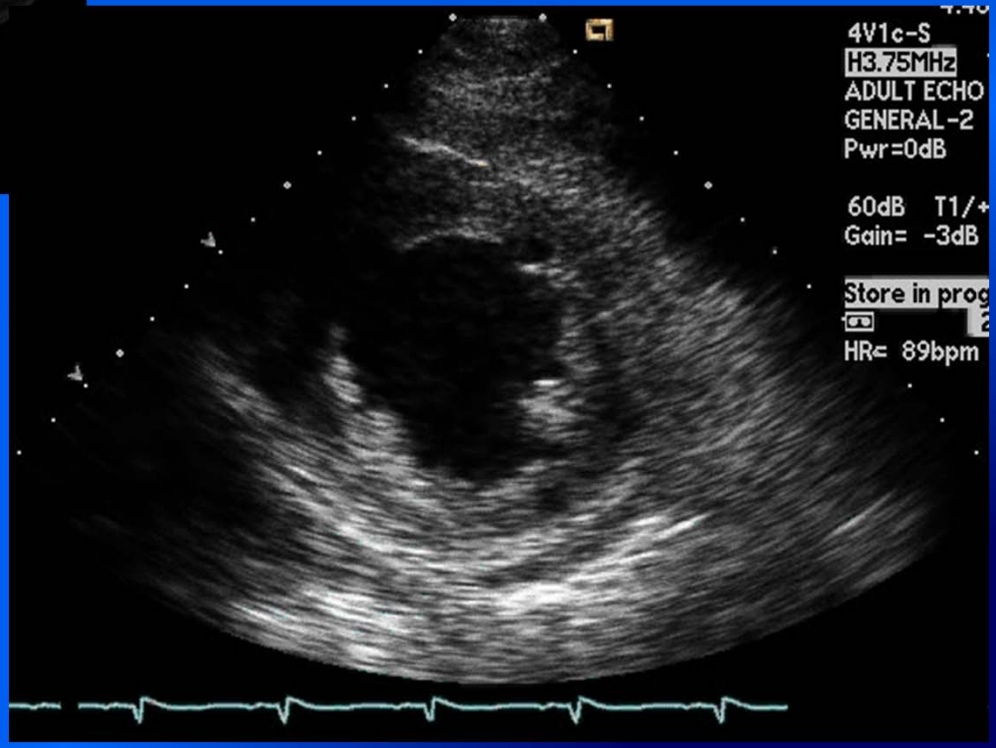
60dB T1/+
Gain= -4dB
Store in prog
HR= 89bpm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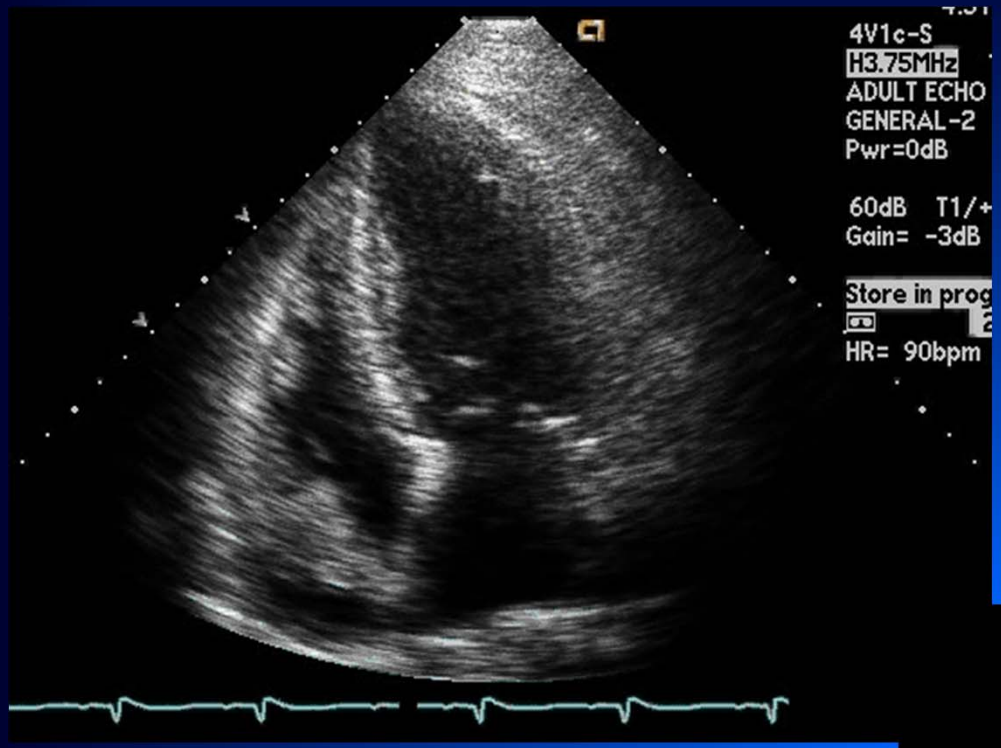
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ADULT ECHO
GENERAL-2
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60dB T1/+
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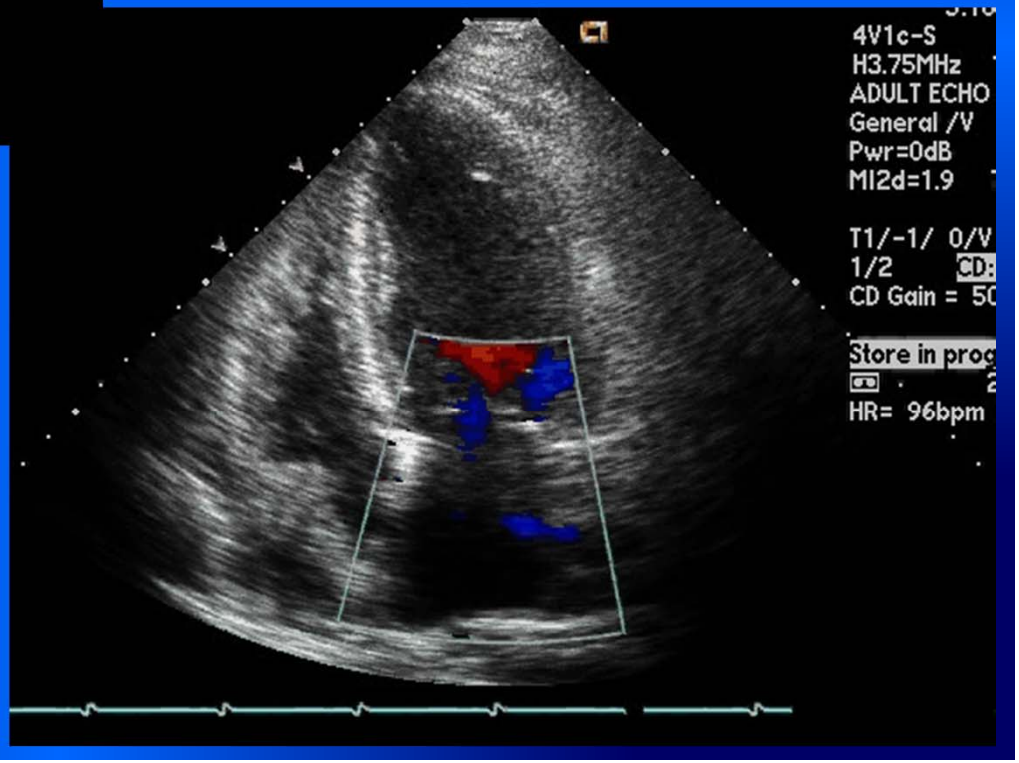
HR= 90bpm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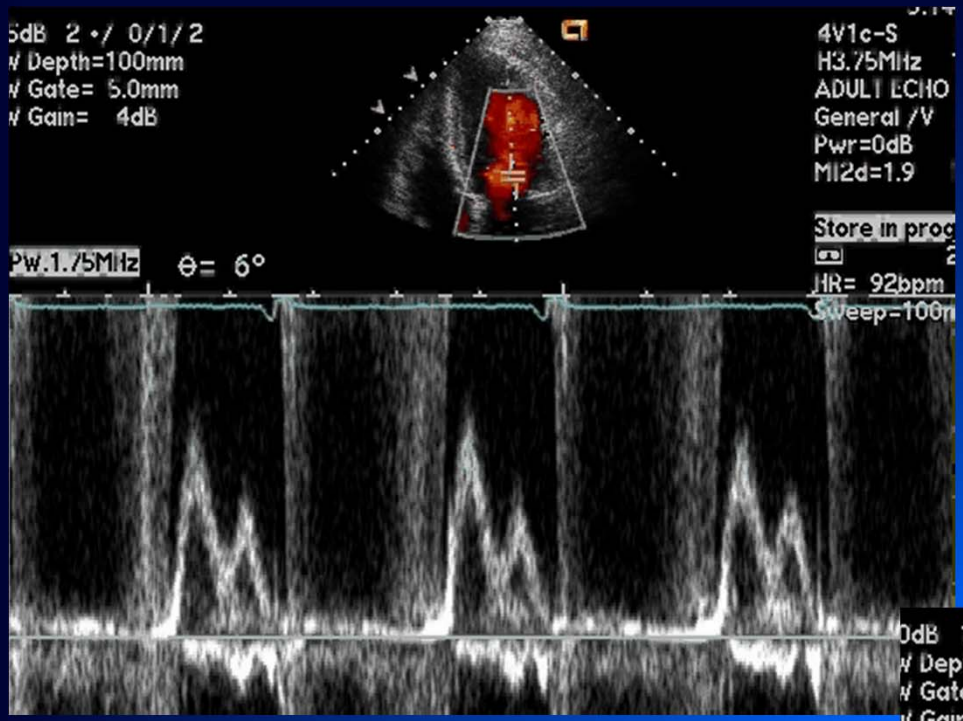


E vel: 1.29m/s, A vel: 0.82m/s
E/A ratio: 1.5
DT: 102 msec
E' vel: 0.065 m/sec
E/E' : 23

Patient with Shortness breath in the cath lab

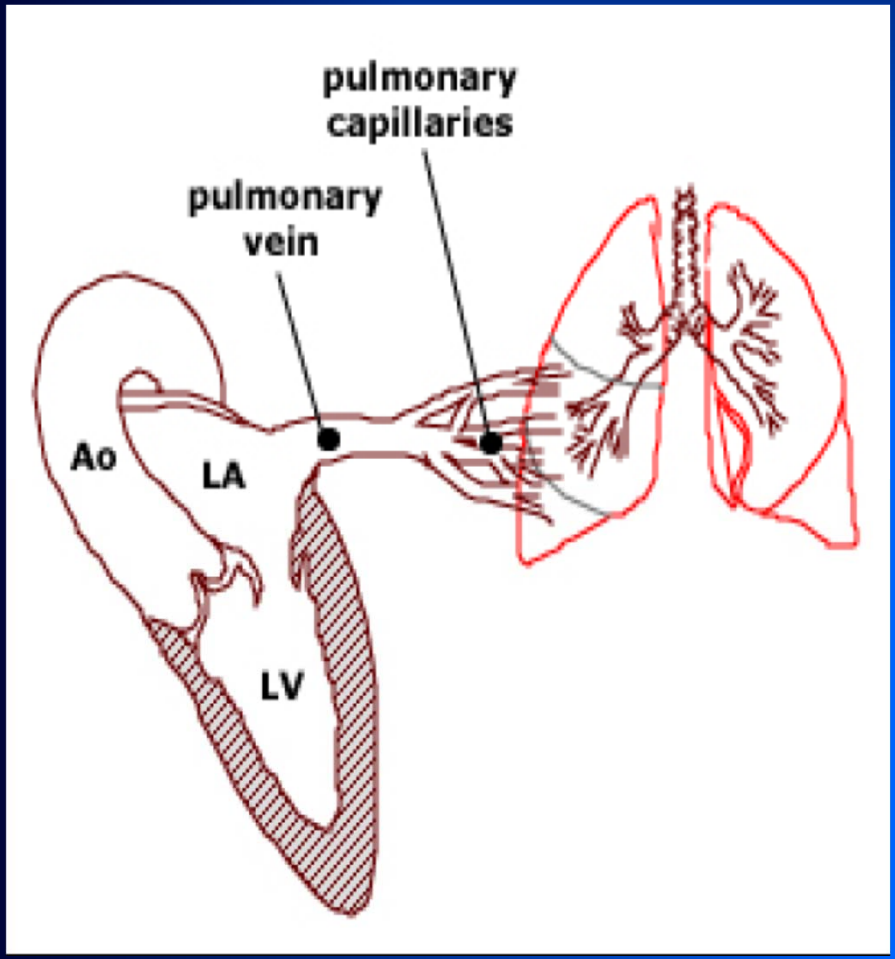
- Normal coronary arteries
- LVEDP : 31mm/Hg
- PCWP 25mmHg
- PA 50/30 mean 30mmHg

  RV 50/15/ RA 10

Final diagnosis

- Diastolic Heart Failure
- Diabetic cardiomyopathy
- Mitral regurgitation

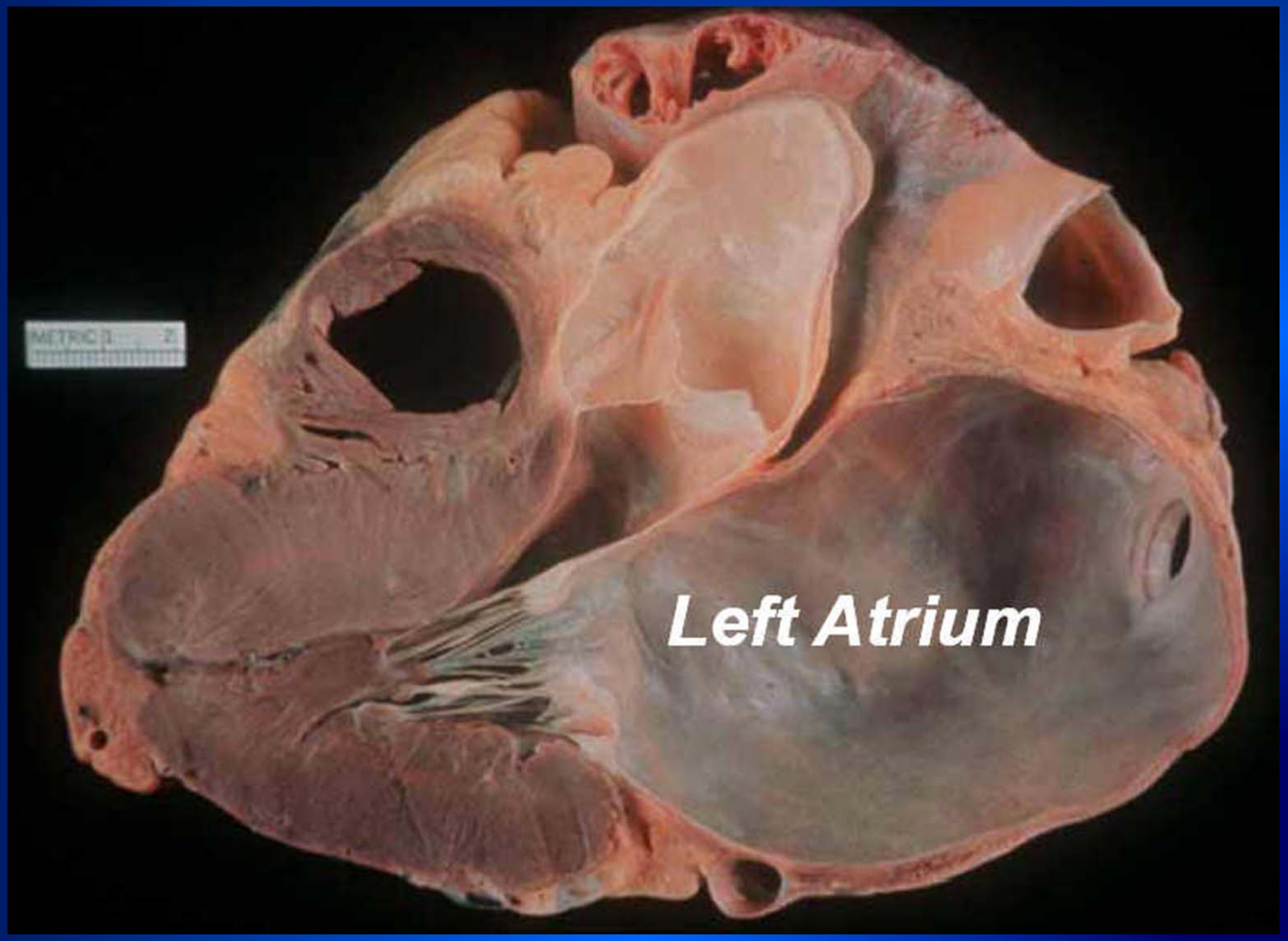
Mechanism of Heart Failure



Under these circumstances, a relatively small increase in central blood volume or an increase in venous tone, arterial stiffness, or both can cause a substantial increase in LA and pulmonary venous pressures and may result in acute pulmonary edema.

NEJM 2004;351:1097-1105

LA Size and Function



Left Atrium

The left atrium (LA) serves multiple functions

- Reservoir during left ventricular (LV) systole
- Conduit for blood transiting from the pulmonary veins to LV during early diastole
- Active contractile chamber that augments LV ventricular filling in late diastole
- Suction source that refills itself in early systole

Left Atrial Volume

- During diastole, when the mitral valve is open, the left atrium is exposed to the loading pressure within the left ventricle
- Over time, exposure of LA to increased filling pressure will result in its remodeling and increased volume
- Left atrial size is a useful marker for chronicity of diastolic dysfunction

JACC 2003;41:1036-1043

LA Volume

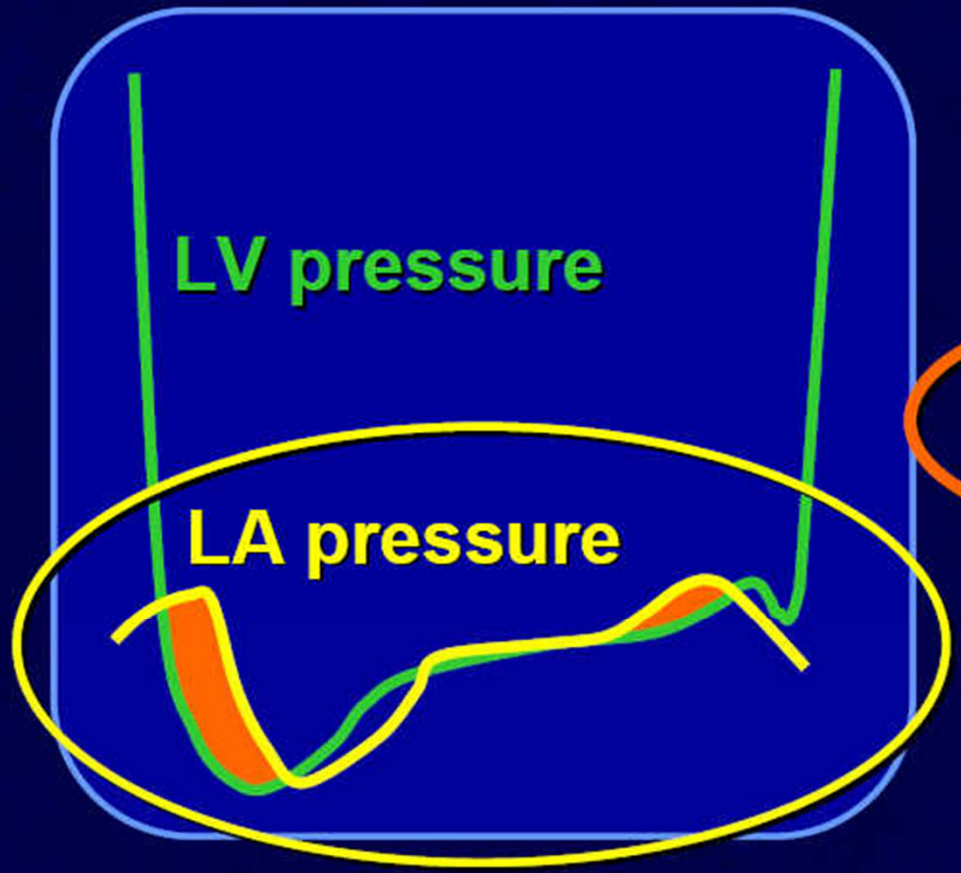
Helps assess and predict

- LV diastolic function –filling pressure
- Risk new onset A-fib and CHF
- Future risk of TIA / Stroke
- CV morbidity - mortality

LV Diastolic Filling

Elastic recoil

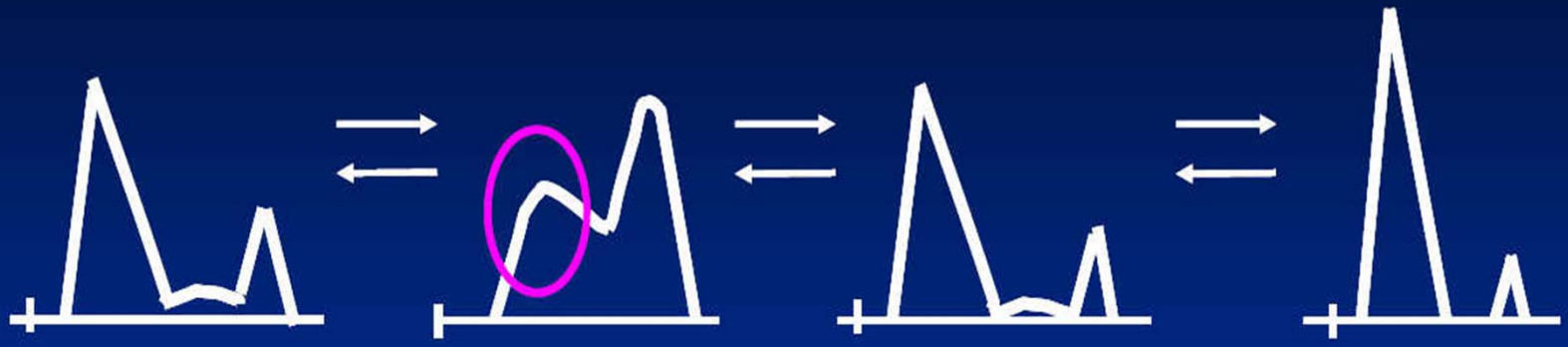
Compliance



Relaxation

LA pressure

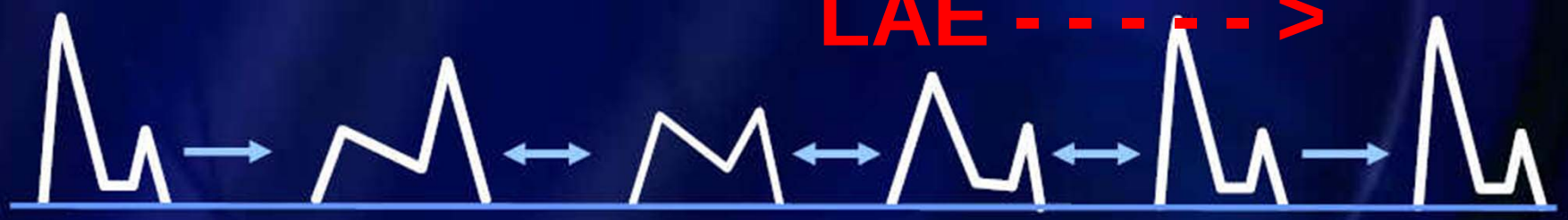
Mitral Flow Velocity



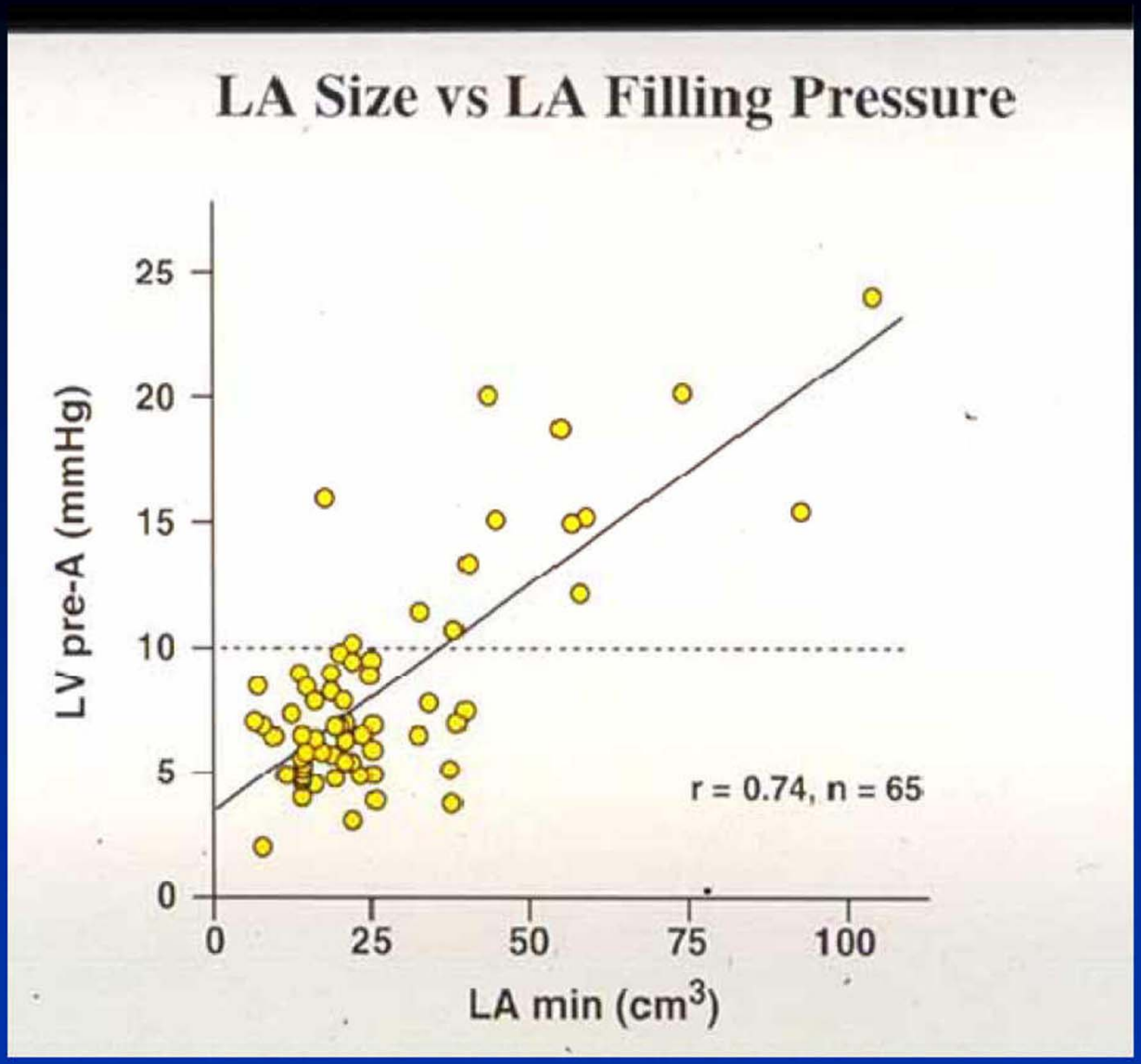
Normal	Abnormal relaxation	Abnormal relaxation	Abnormal relaxation
	+	+	+
Only if E wave appropriately reduced	normal / low LA pressure	↑ LAP ↑ LV RFW	↑ LAP ↑ LV RFW

Diastolic Function

Normal	AR		PN	Restrictive	
	I		II	III	(IV)



No single number or algorithm can differentiate

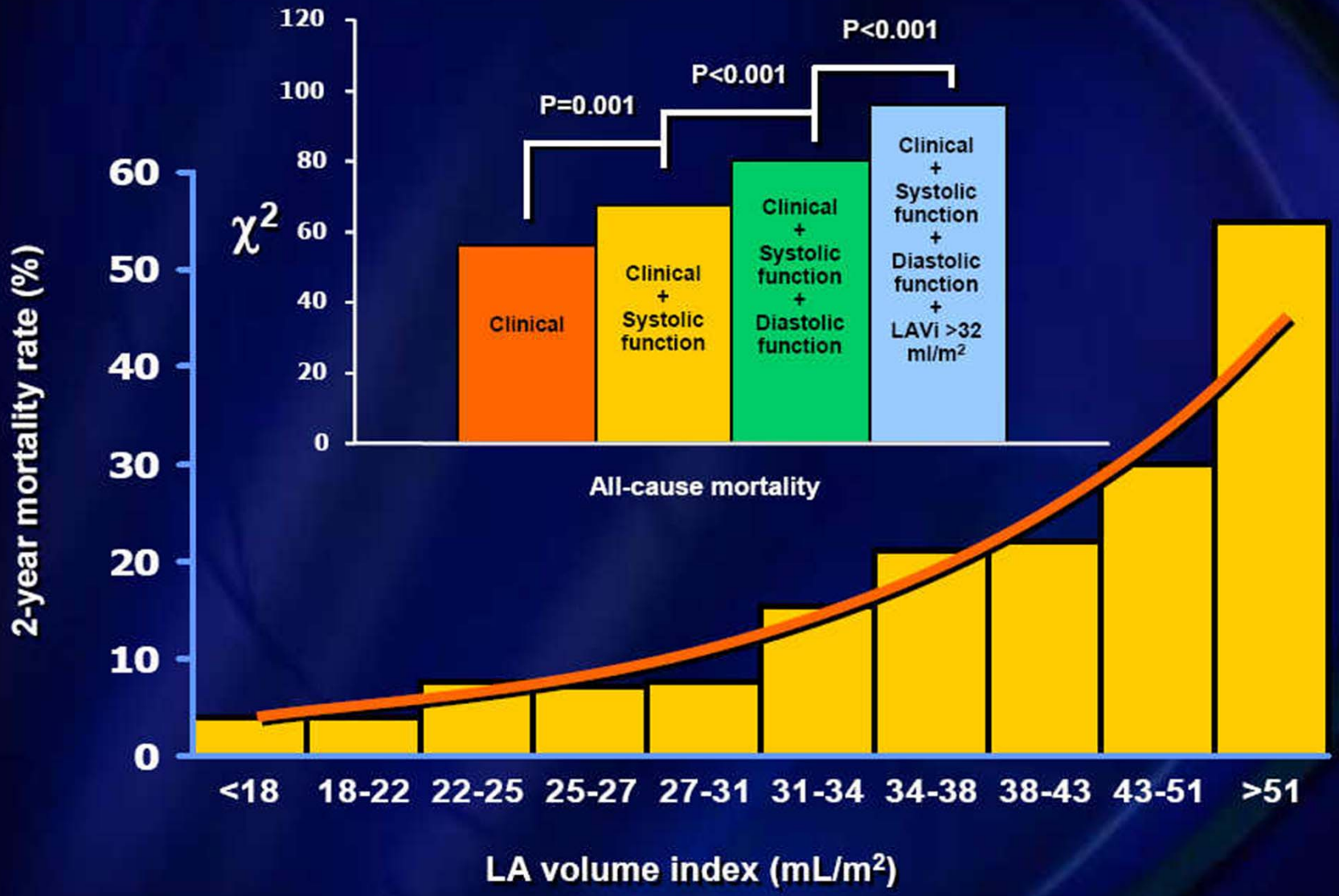


Appleton CP et al JACC 1993

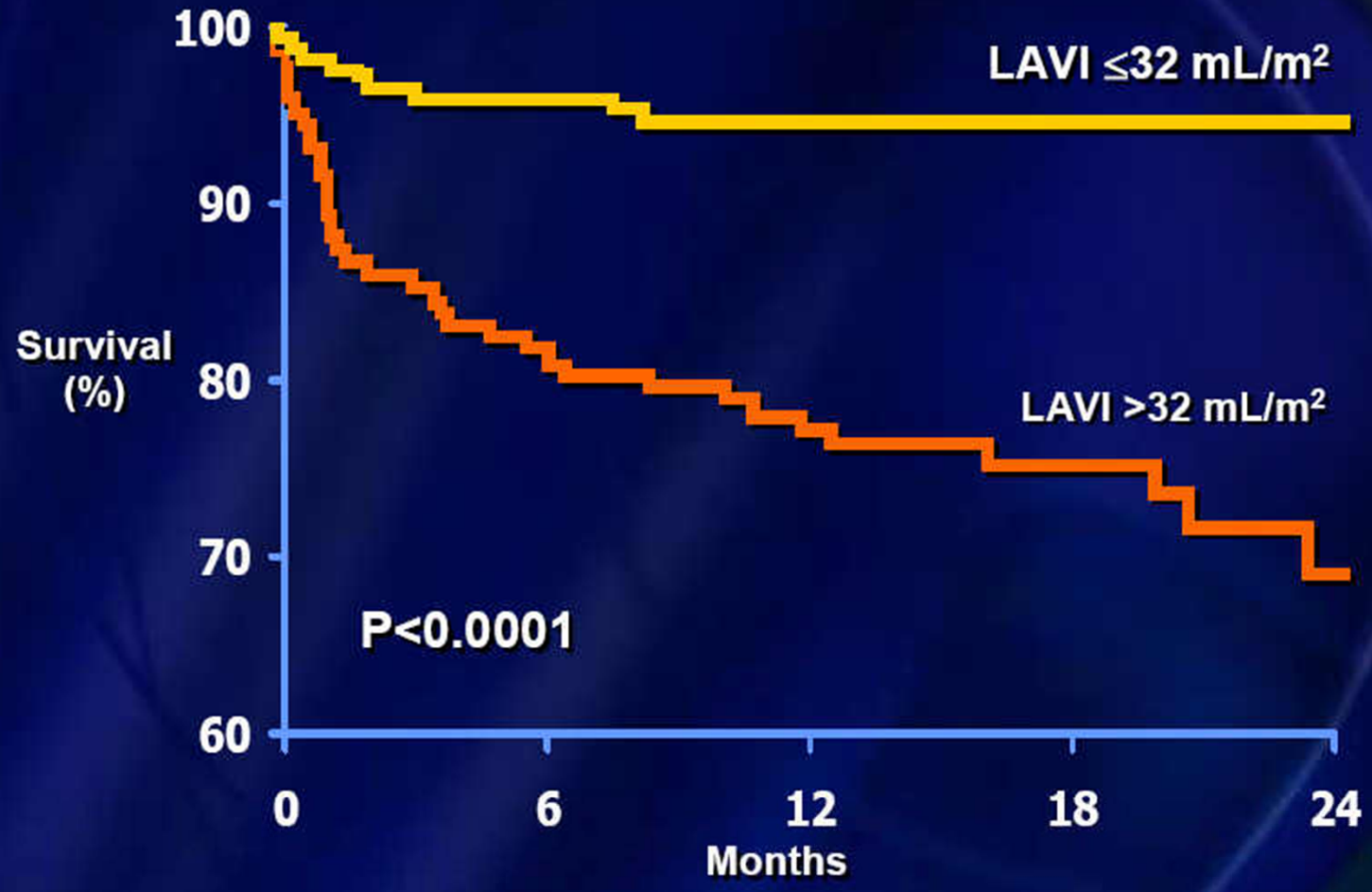
Left Atrial Size

Why Should LA Volume be Measured?

LA VOLUME INDEX AND SURVIVAL



LA VOLUME INDEX AND SURVIVAL



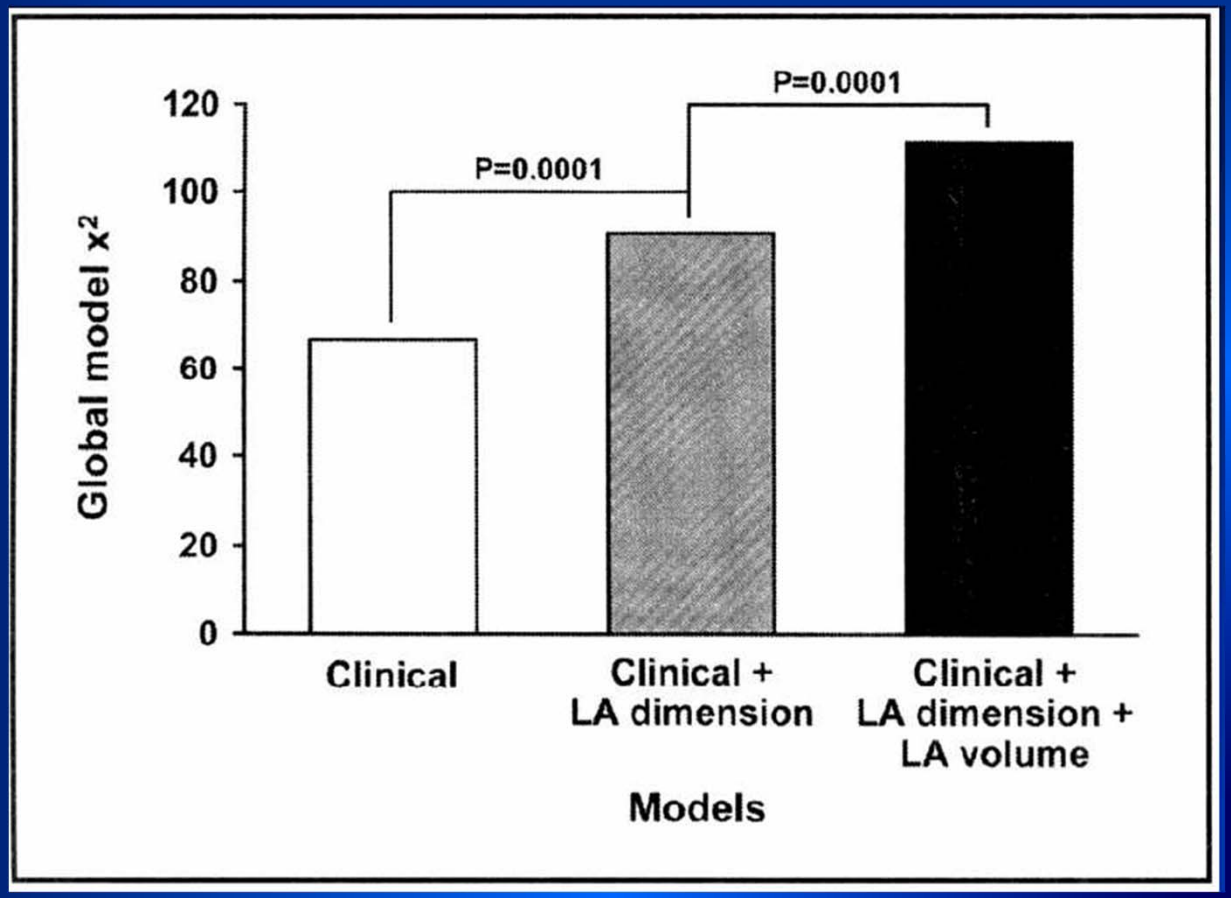
Number at risk					
LAVI ≤32 mL/m²	172	165	113	53	15
LAVI >32 mL/m²	142	116	91	53	19

LA Volume

Importantly, observational studies including 6,657 patients without baseline histories of atrial fibrillation and significant valvular heart disease have shown that

LA volume index ≥ 34 mL/m^2 is an independent predictor of death, heart failure, atrial fibrillation, and ischemic stroke.

Prognostic Value of LA size for Predicting New Onset A-fib

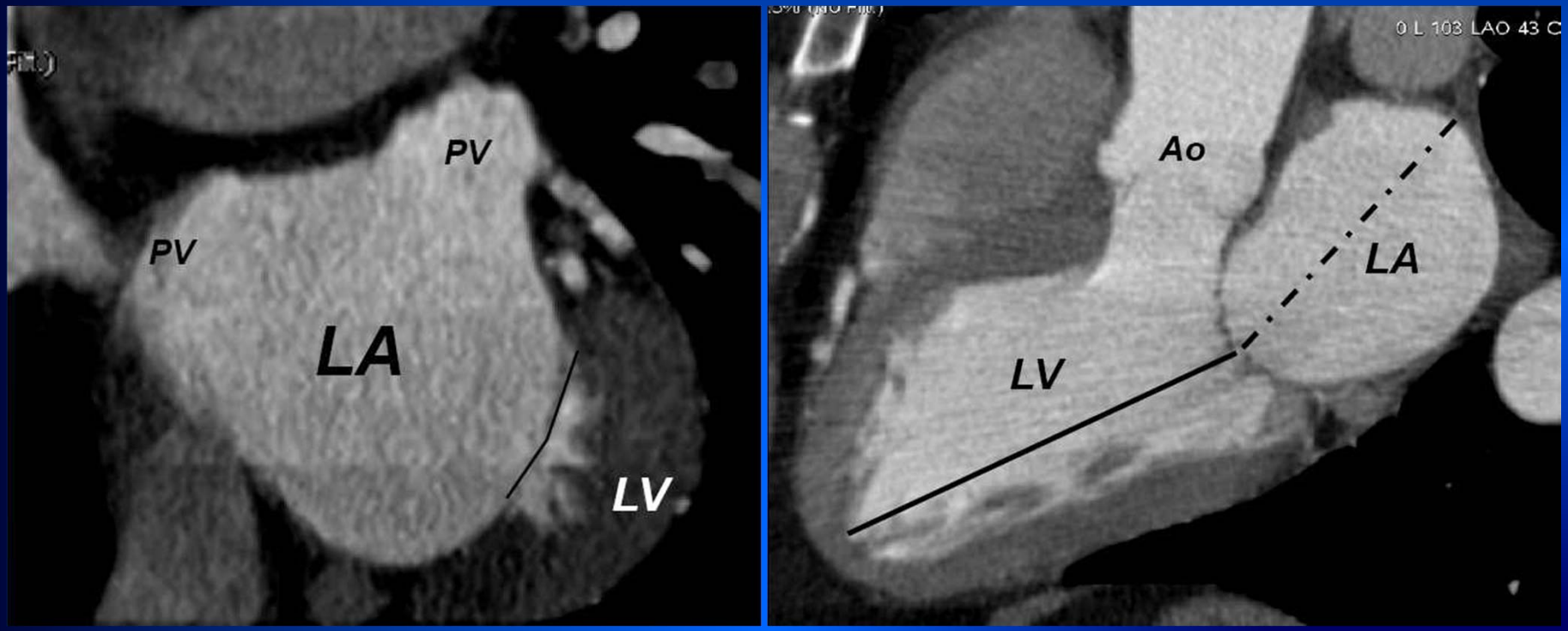


Tsang et al Mayo Clin Proc 2001

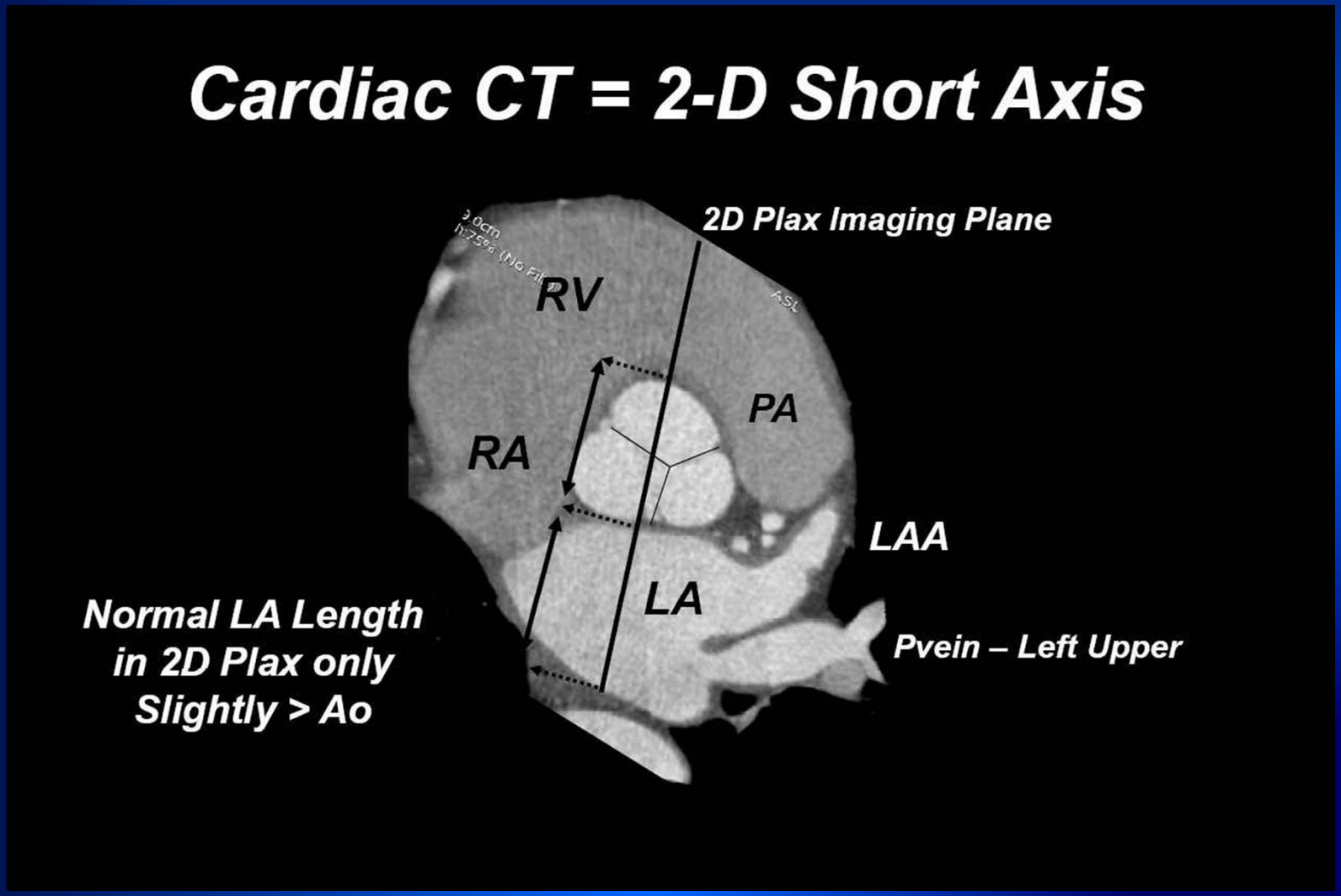
Left Atrial Volume

"The HbA1C of diastolic function"

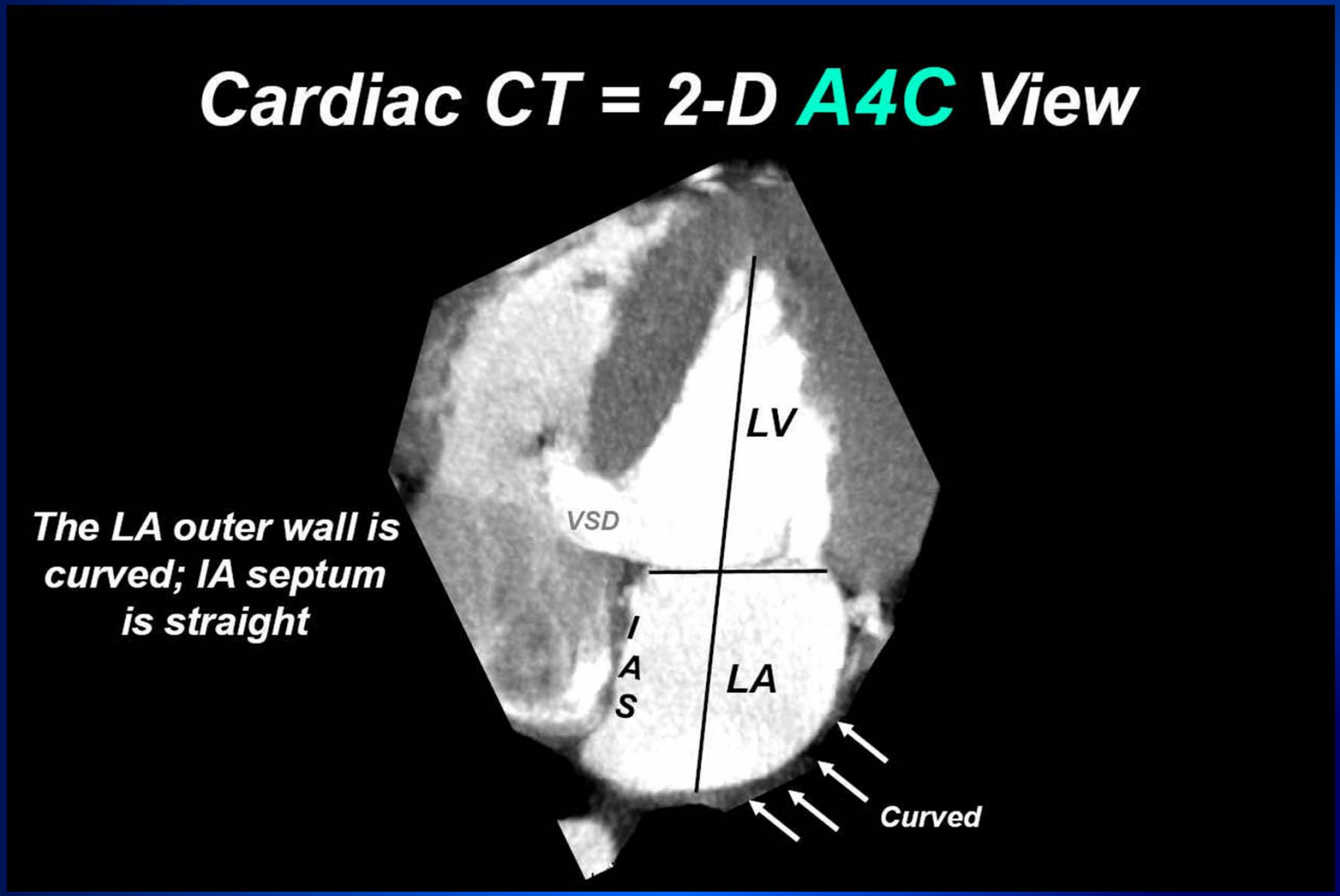
Left Atrial Anatomy



Left Atrial Anatomy



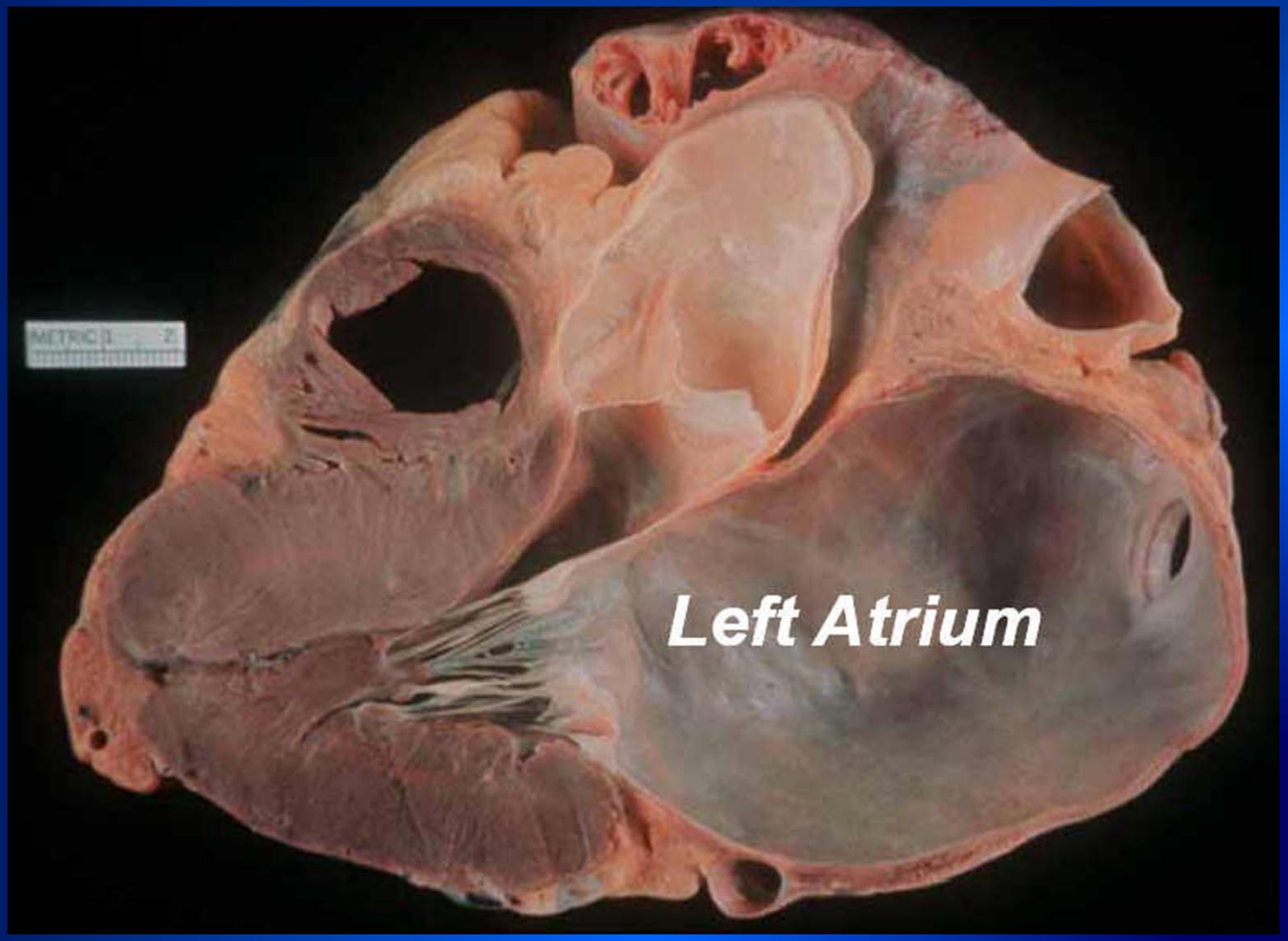
Left Atrial Anatomy



Left Atrial Anatomy

- LA has complex shape
- Long axis 35 – 45° more vertical than LV
- 2-D A4C – A2C ≠ exact 90 °

Measuring LA Volume



Evaluation of LA size

- MRI (gold standard)
- Cardiac CT
- 2-D Echo methods
  - M-mode
  - Prolate-ellipsoid
  - Biplane Area-Length
  - Biplane Simpson's
  - 3D Echo

Left Atrial Size
- Physiologic correlates -

- Body size, gender
- Age
- Need normal reference value

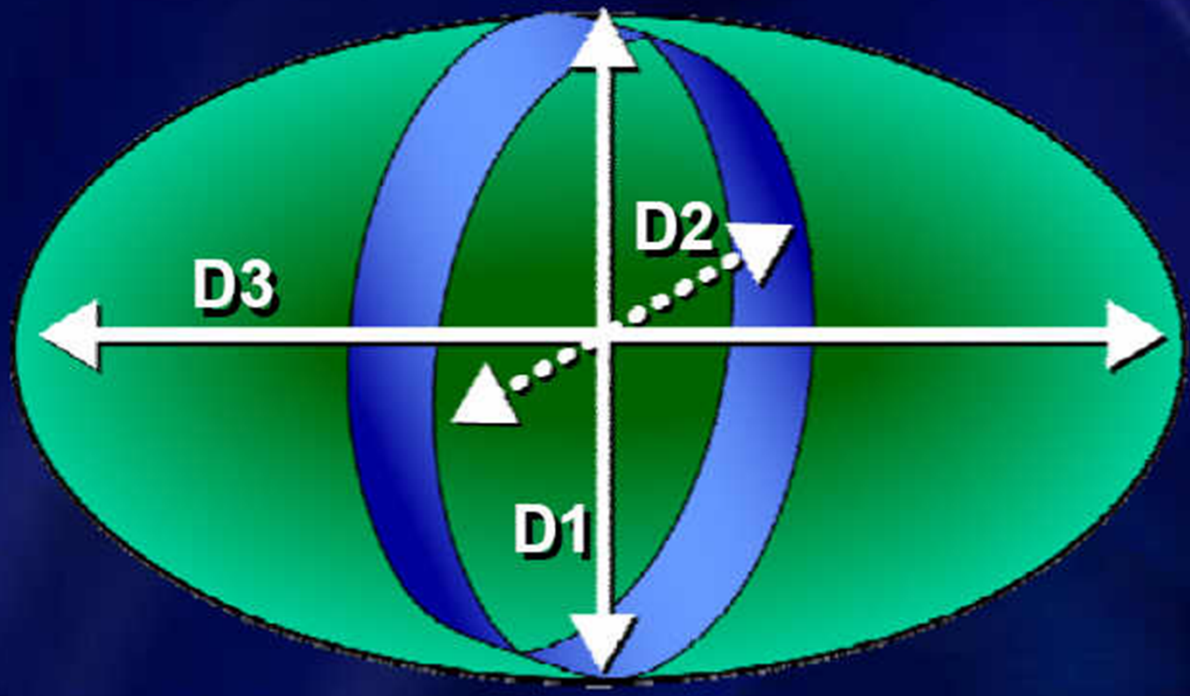
Left Atrial Size
- Estimating Volume -

What Method to be Used?

- **Easy**
- **Accuracy**
- **Reproducibility**

Left Atrial Volume

Prolate Ellipse Method

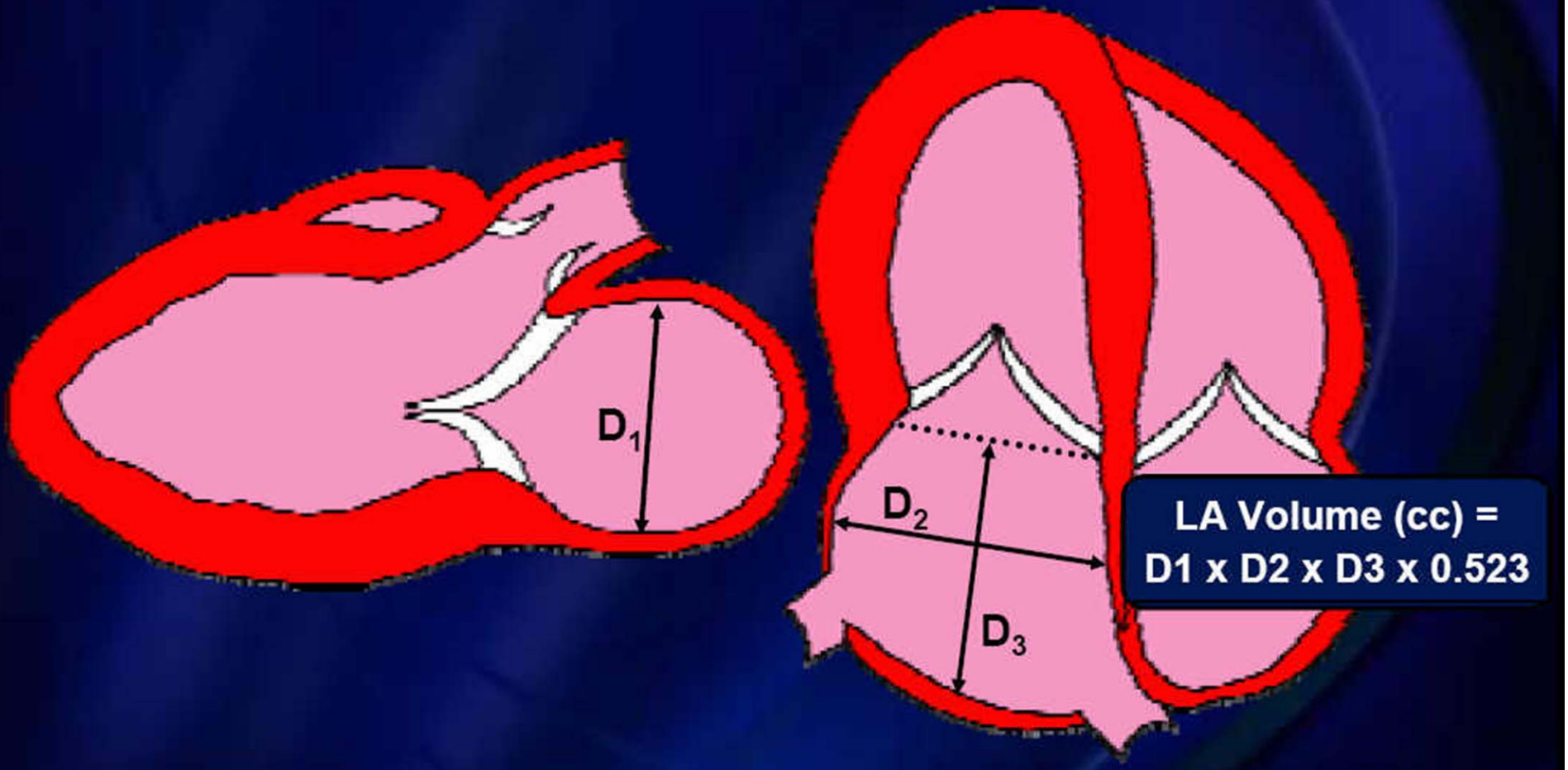


$$LAV = \frac{4}{3}\pi \times \frac{D1}{2} \times \frac{D2}{2} \times \frac{D3}{2}$$

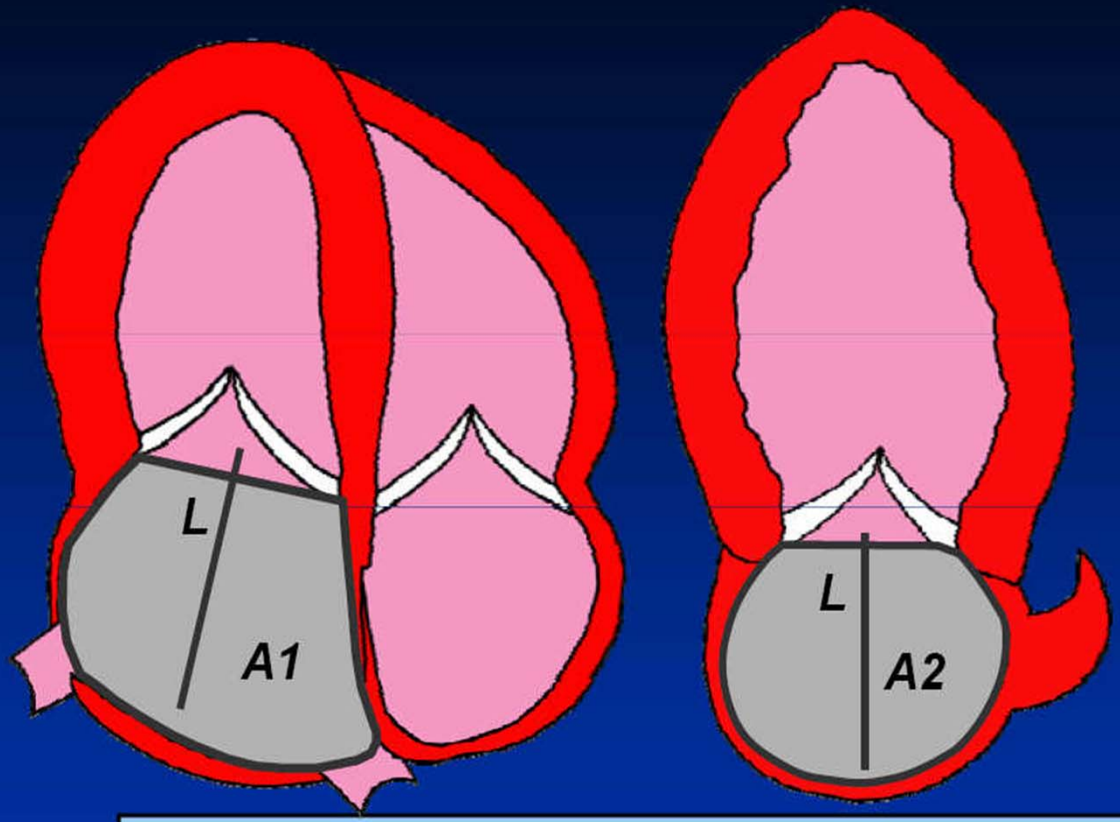
LEFT ATRIAL VOLUME = D1 x D2 x D3 x 0.523

Left Atrial Volume

Prolate Ellipse Method



Biplane Area-Length Method



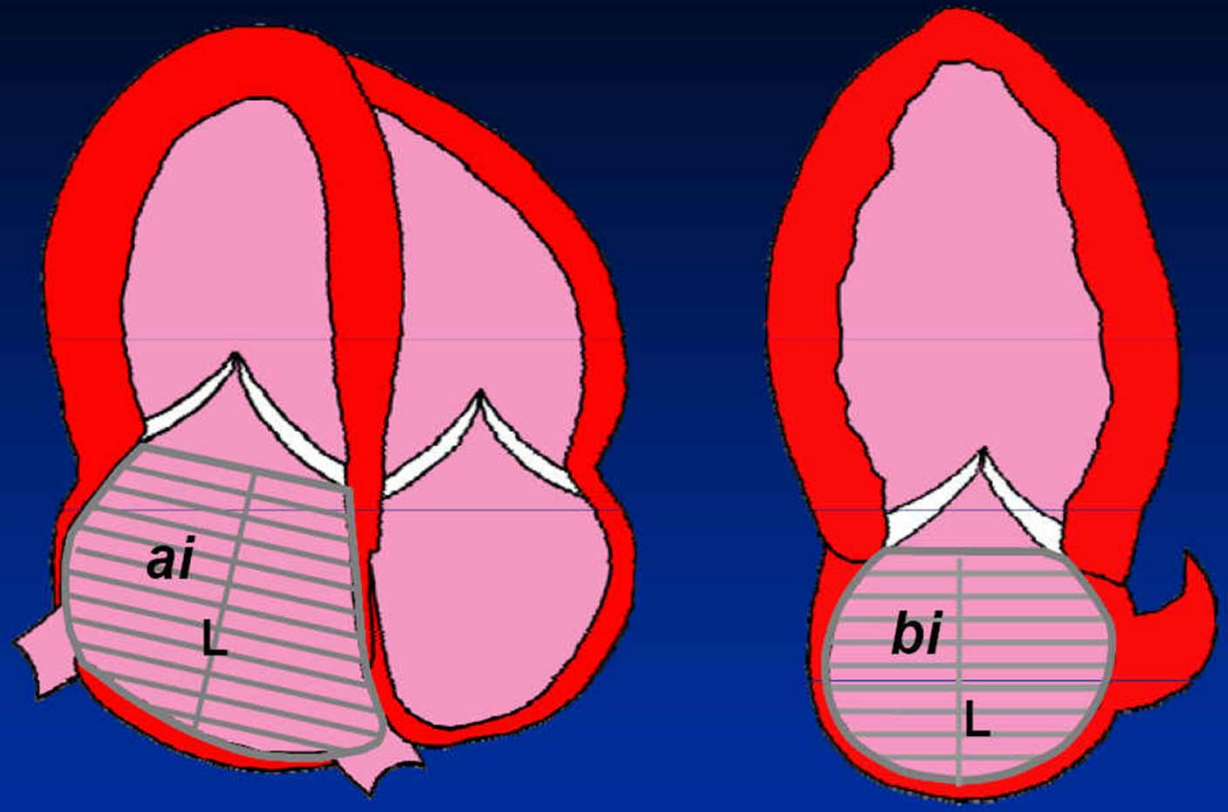
A1 = LA area, A-4C

A2 = LA area, A-2C

L = LA length

$$\text{LA volume} = \frac{(0.85)x(A1)x(A2)}{L}$$

Biplane Simpson's Method



$$\text{LA Volume} = \frac{\pi}{4} \sum_{i=1}^{20} a_i \times b_i \times L$$

2-D Echo Method for Assessment of LA Volume

Method	*Volume (mean ± SD) (mL)*
Biplane AL	73.2 ± 26.4
Simpson's	67.4 ± 24.8
Prolate	56.6 ± 20.4

Ujino K & Tsang TS et al AJC 2006

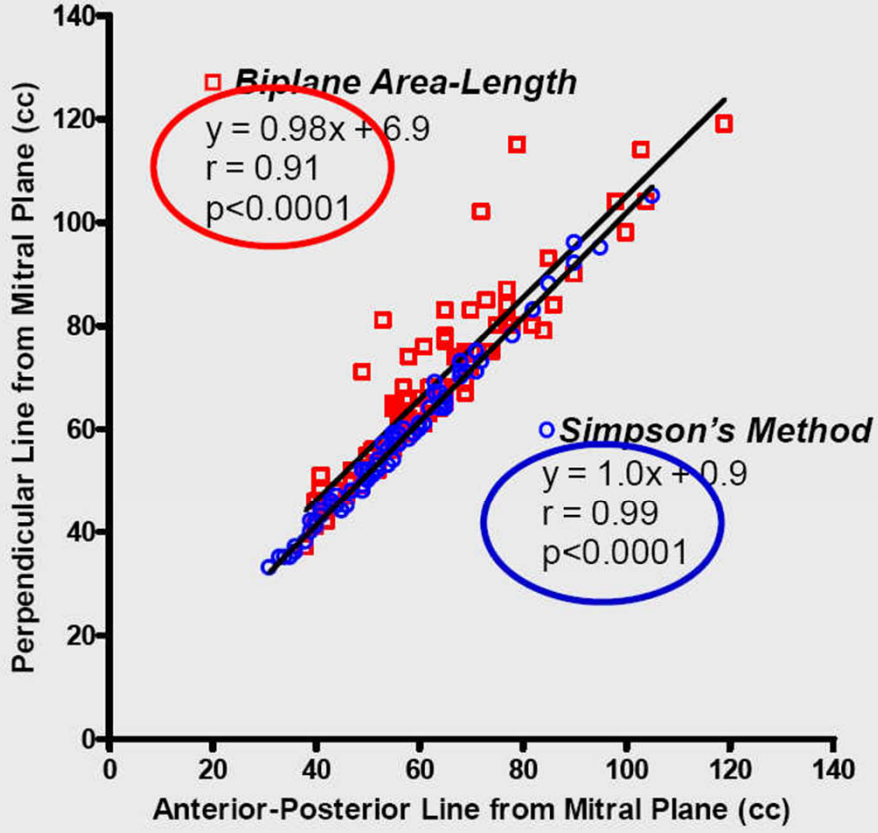
Comparison of LA Vol Methods

Method	r =	Distribution of Differences, ml (mean ± SD)
Biplane AL versus Simpson's	0.98	5.7 ± 4.9
Biplane AL versus Prolate	0.85	16.5 ± 12.7
Simpson's versus Prolate	0.86	10.8 ±13.9

Ujino K & Tsang TS et al AJC 2006

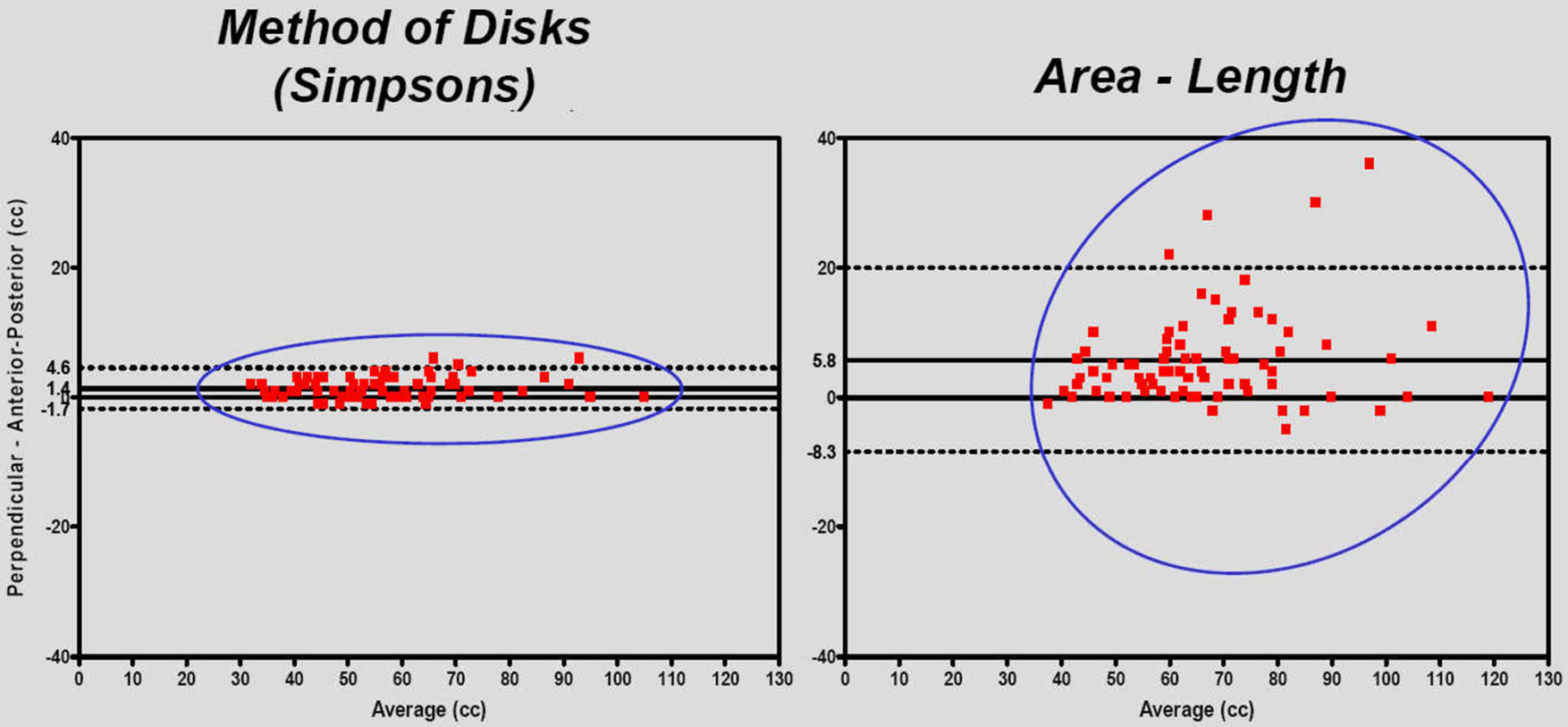
Bi-Plane LA Volume in Normal Subjects

Perpendicular vs Longest L from Mitral Annulus



n =80; from Vianna

Bland-Altman Plots – Bi-Plane LA Volume: NI Subjects – ⊥ to Mitral Annulus



n =80; from Vianna RP

LA Volume
Normal Values (ml/m^2)

Either biplane AL or Simpson's Methods

Normal	Mild Increase	Mod Increase	Severe Increase
22 ± 6 ml / m^2	29 - 33	34 - 39	> 40

Lang R et al, JASE 2005;18:1440

LA Volume
Suggested Grading (ml/m^2)

Either biplane AL or Simpson's Methods

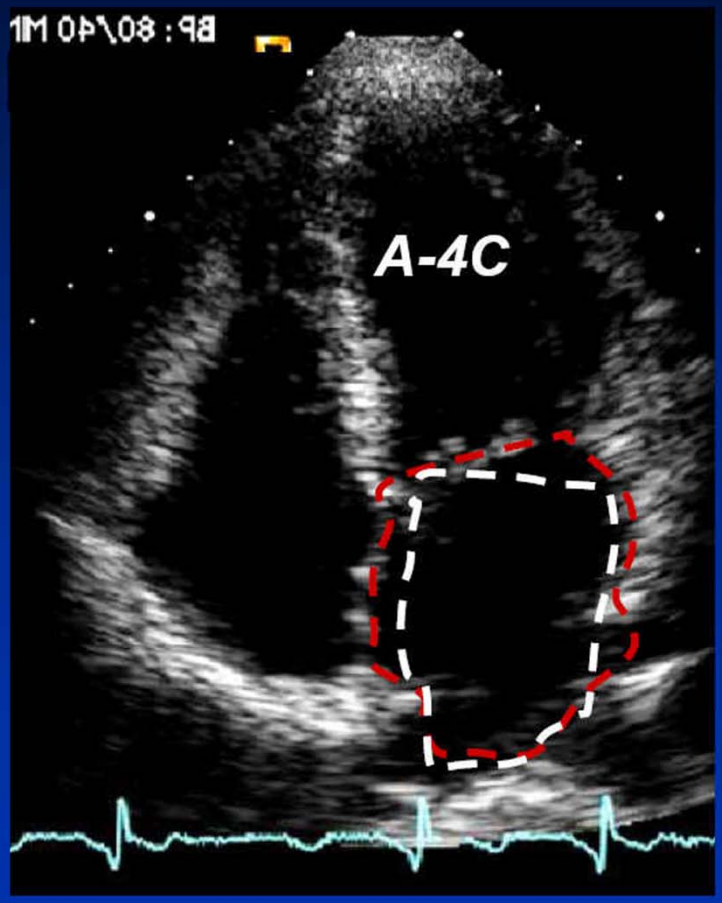
Normal	Bord Abn	Mild LAE	Mod LAE	Severe LAE
22 ± 6 ml / m^2	29-33	34-39	40-46	>46

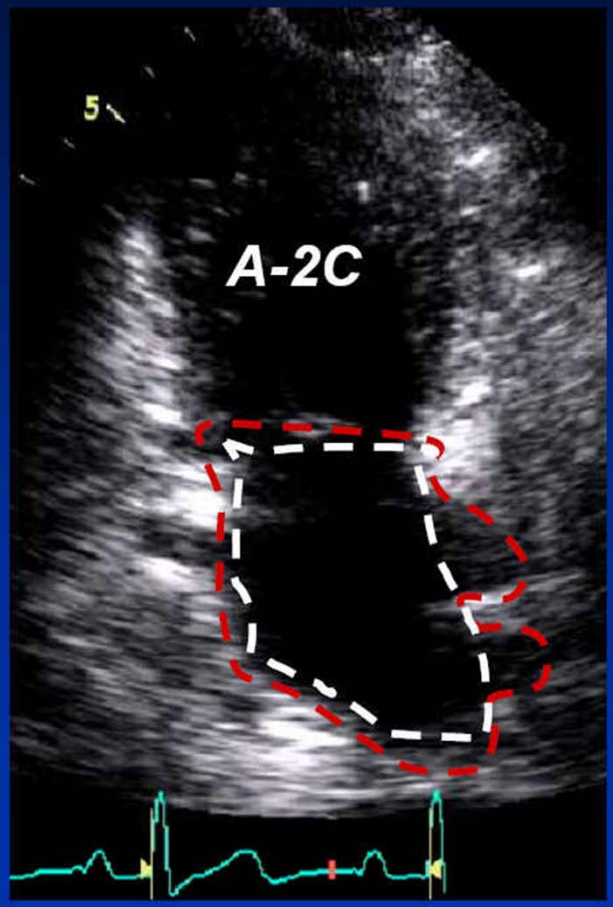
LA Volume Measurement: Pitfalls

- Errors of imaging planes
  - Foreshortening
  - Failure to use landmarks
- LA tracing errors
- A-L method: perpendicular to mitral annulus not always longest length

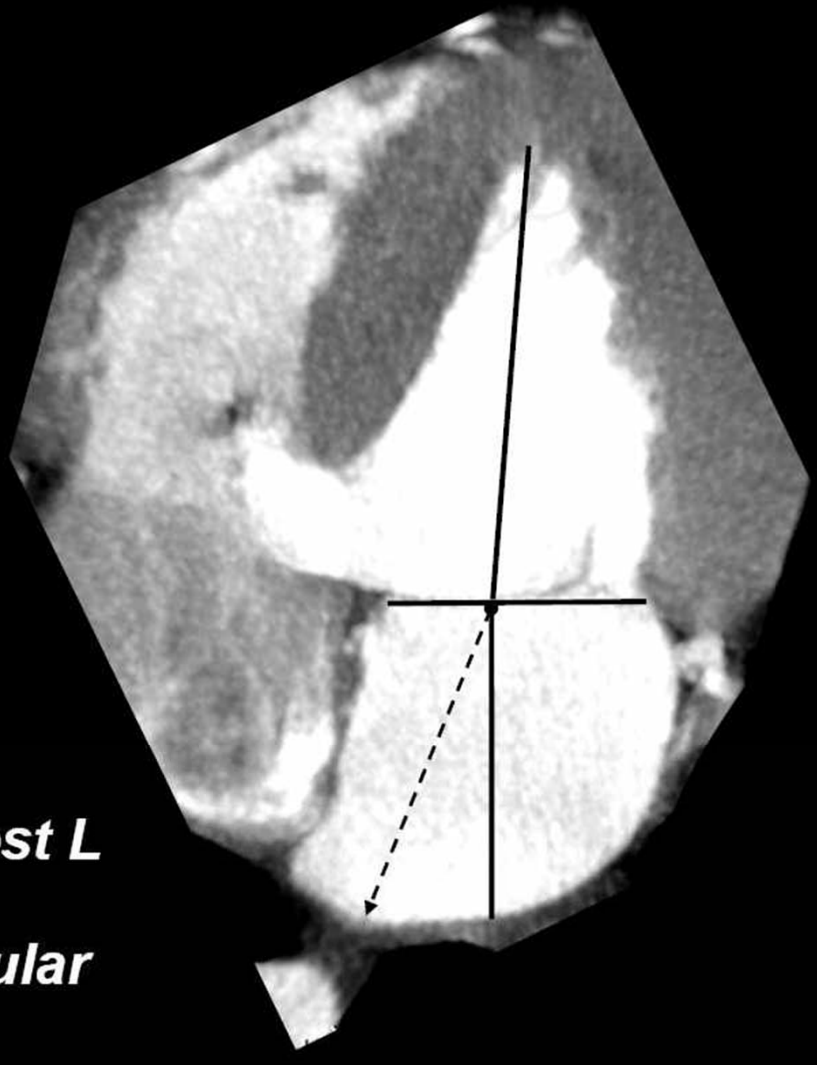
LA Volume Measurement: Pitfalls

Too Large Drawing





Cardiac CT 2-D A4C



- - is longest L
vs
perpendicular

LA Volume Measurement: Pitfalls

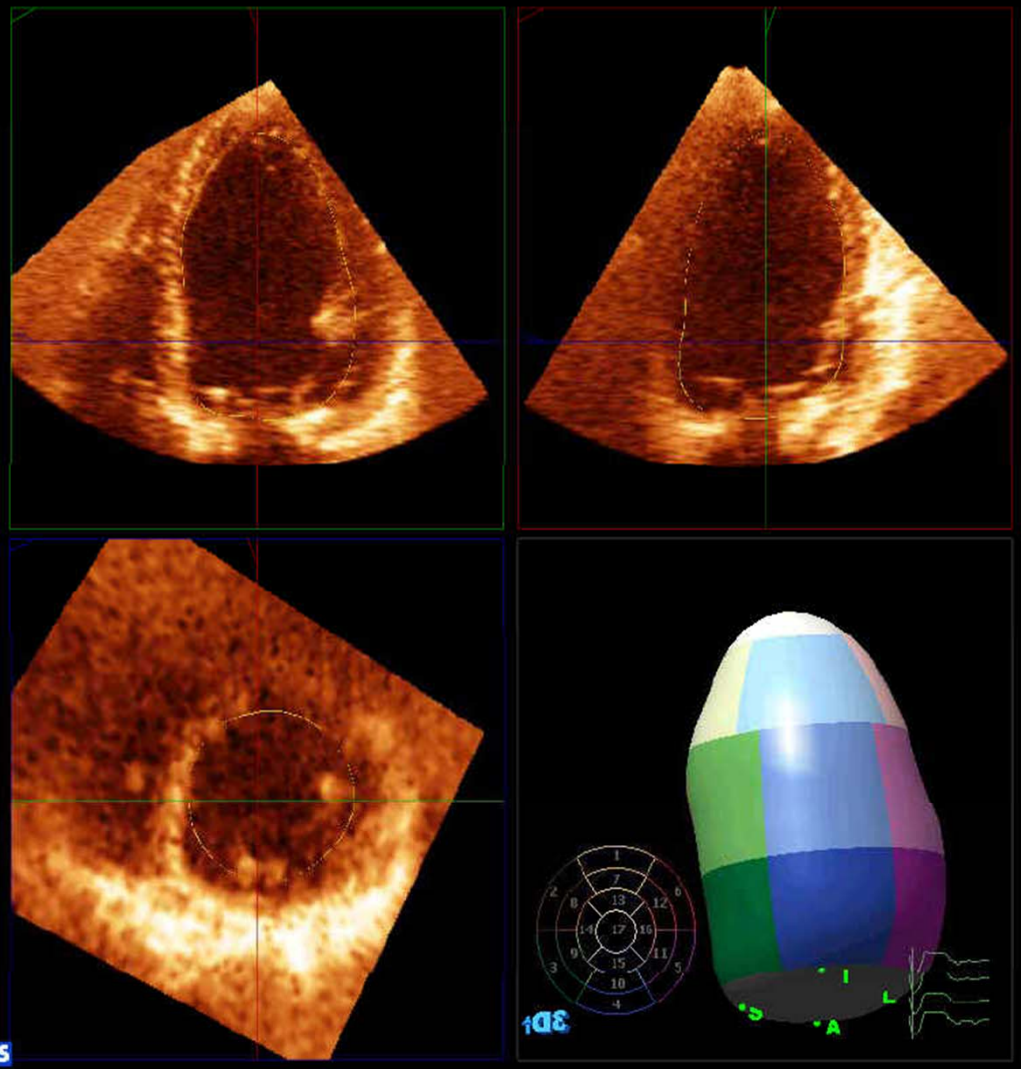
- High output state
  - Anemia, fever, sepsis, ESRD, athletes..
- Bradycardia
- Paroxysmal atrial fibrillation / flutter
- Significant mitral valve disease
- Obesity

Left Atrial Volume Meausurement

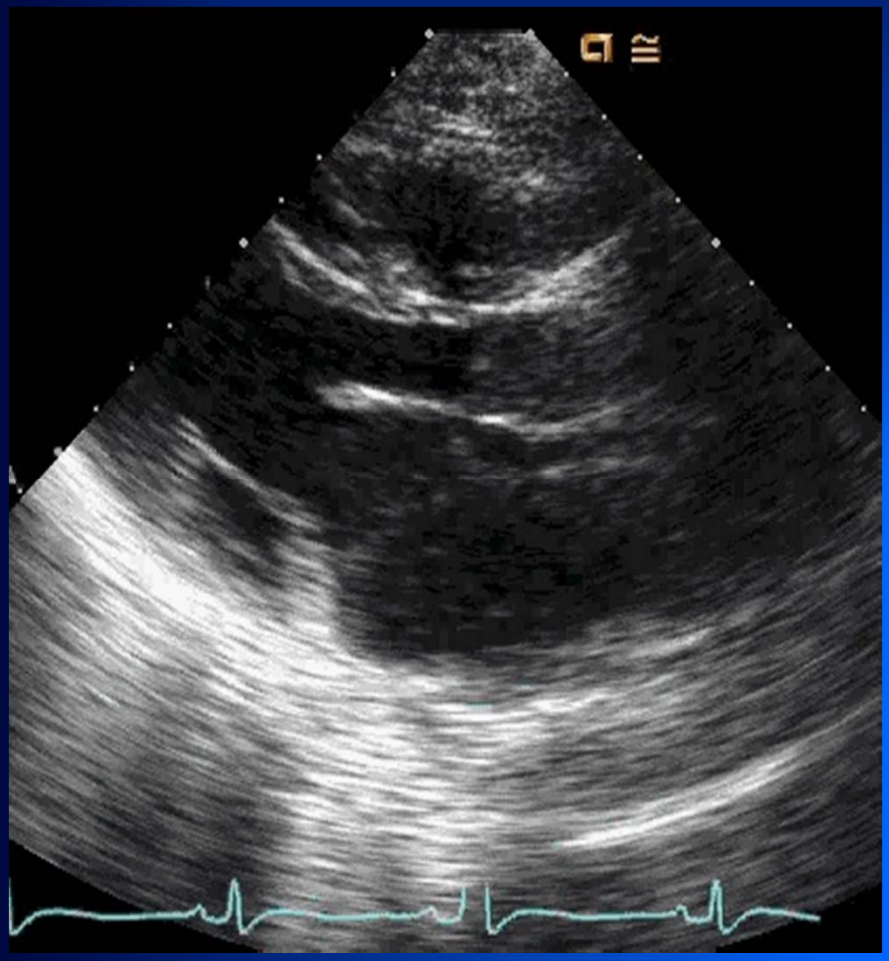
3-Dimensional Echo

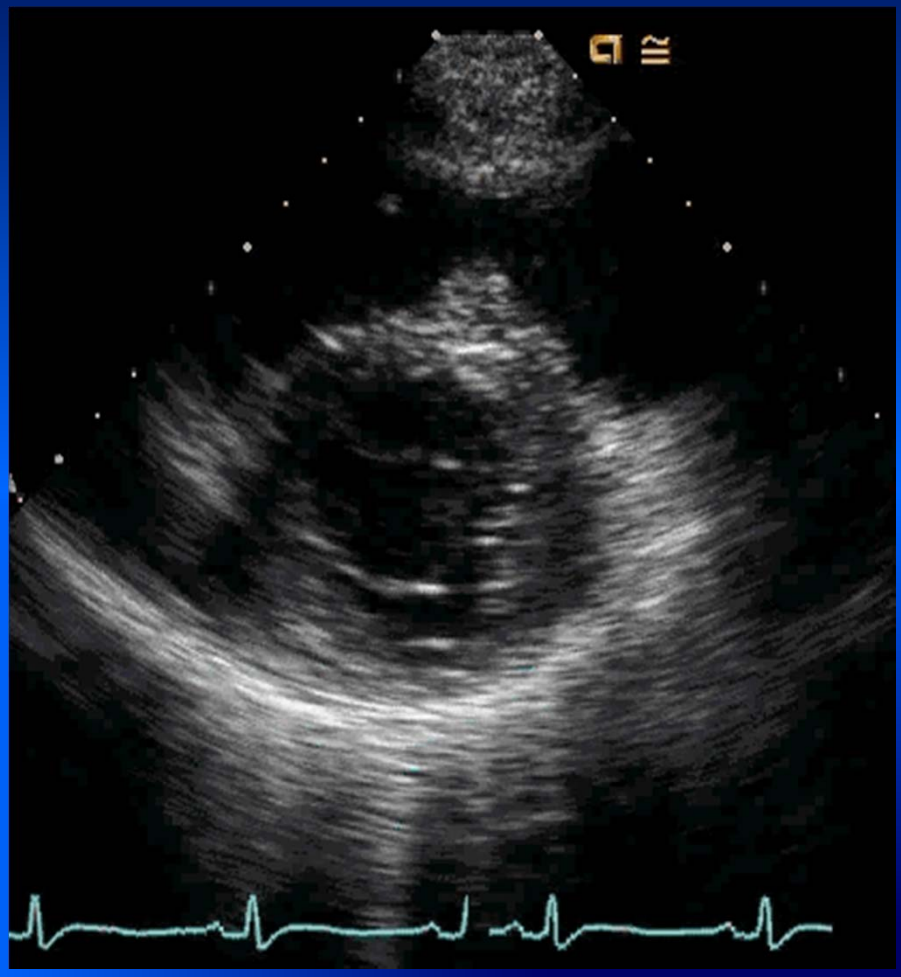
- Values closest to MRI
- Greater accuracy absolute value
- Better reproducibility
- Need good image quality and intensive labor

Cardiac 3-D LV to LA

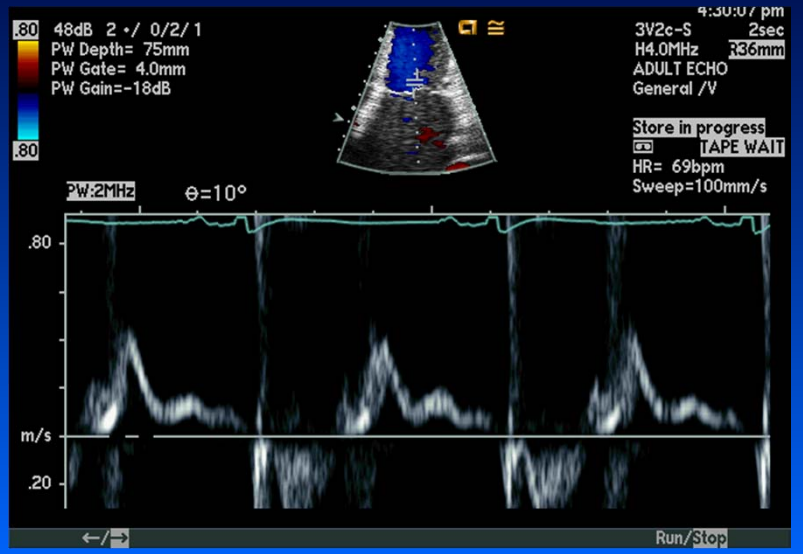


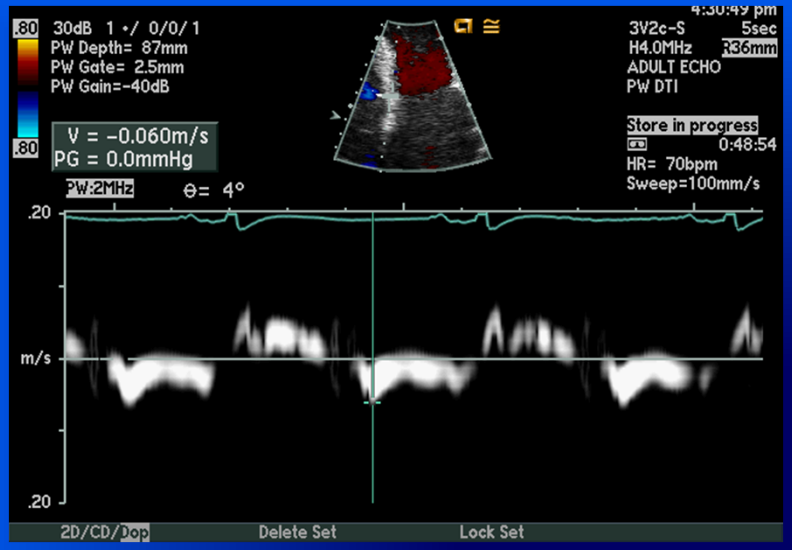
37 year old woman with dyspnea





LVEDD : 40mm LA dia : 50mm LVEF : 55%

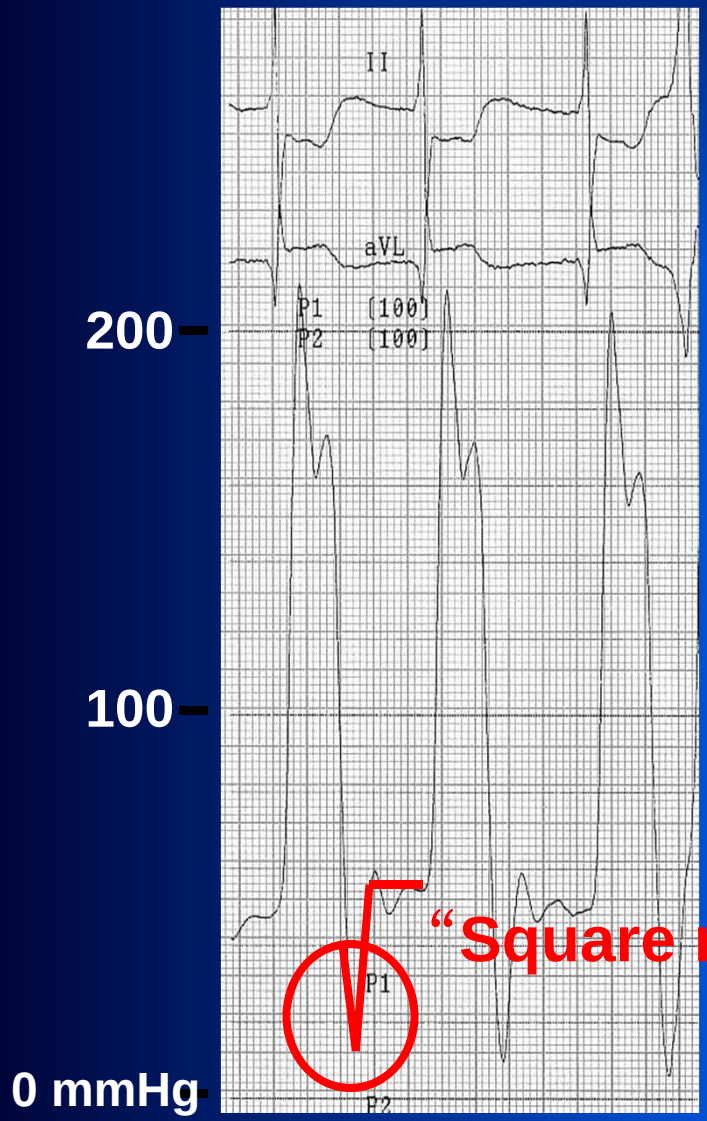

.80
48dB 2 •/ 0/2/1
PW Depth= 75mm
PW Gate= 4.0mm
PW Gain=-18dB
.80
3V2c-S 2sec
H4.0MHz R36mm
ADULT ECHO
General /V
Store in progress
TAPE WAIT
HR= 69bpm
Sweep=100mm/s
PW:2MHz
θ=10°
.80
m/s
.20
←/→
Run/Stop

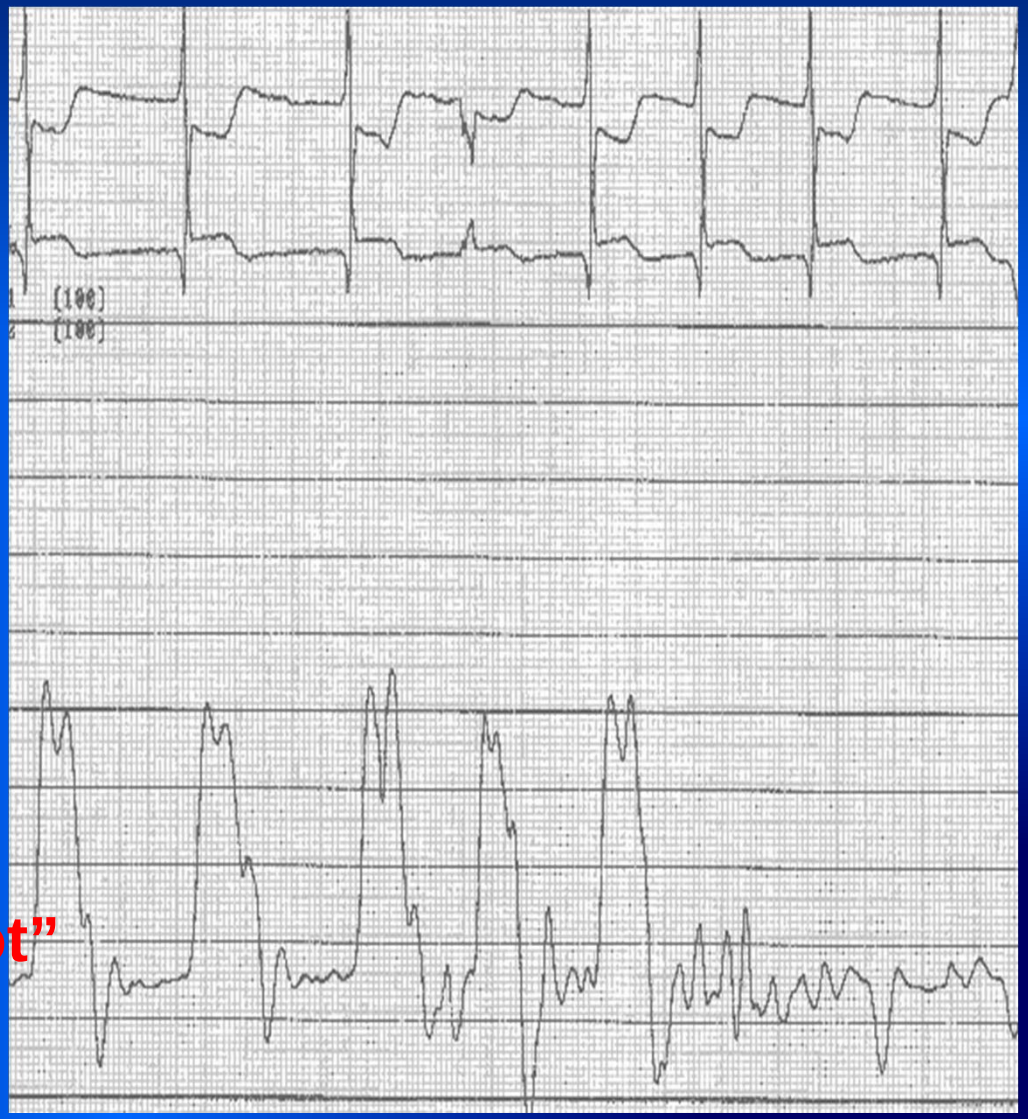

.80
30dB 1 •/ 0/0/1
PW Depth= 87mm
PW Gate= 2.5mm
PW Gain=-40dB
.80
V = -0.060m/s
PG = 0.0mmHg
3V2c-S 5sec
H4.0MHz R36mm
ADULT ECHO
PW DTI
Store in progress
0:48:54
HR= 70bpm
Sweep=100mm/s
PW:2MHz
θ= 4°
.20
m/s
.20
2D/CD/Dop
Delete Set
Lock Set

Cardiac catheterization

Left side cath.

Right side cath.





Measurement of LA size by Echo Doppler

→ *the main tool for detecting diastolic dysfunction patients. However…*

1) LA enlargement is final consequence of diastolic dysfunction

2) Less reliable in predicting symptoms and variable among patients

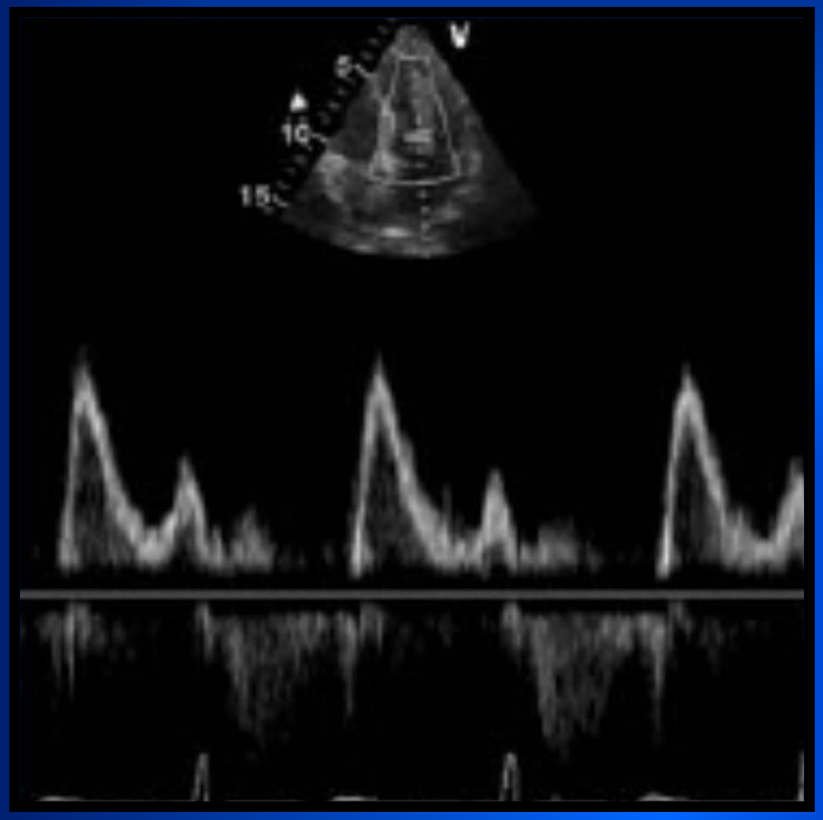
Need more precise hemodynamic monitoring for early detection of LA dysfunction and decision of treatment strategy

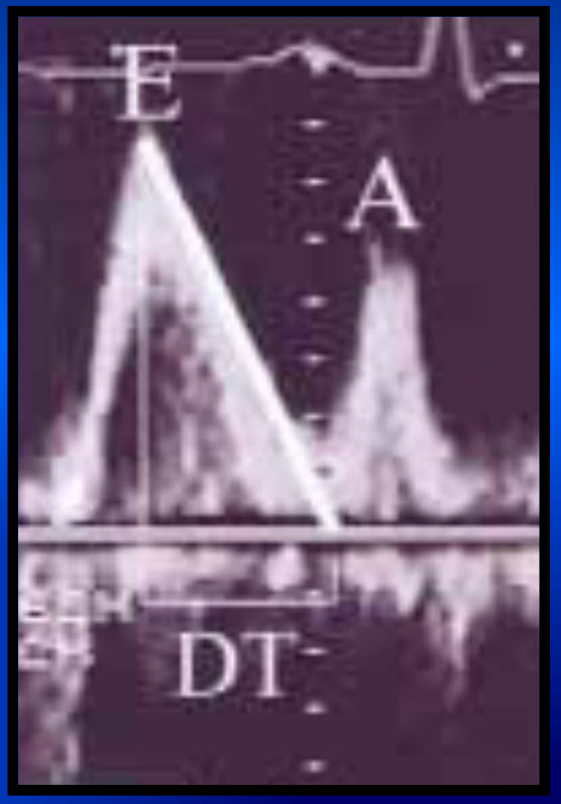
Assessment of LA Function

- **Mitral inflow velocity**
  - Peak A wave velocity
  - TVI, atrial fraction
- **Atrial ejection force**
- **Tissue Doppler Imaging**
  - Atrial strain & strain rate
- **LA flow dynamics**

Assessment of LA Function

Mitral Inflow Velocity





Assessment of LA Function

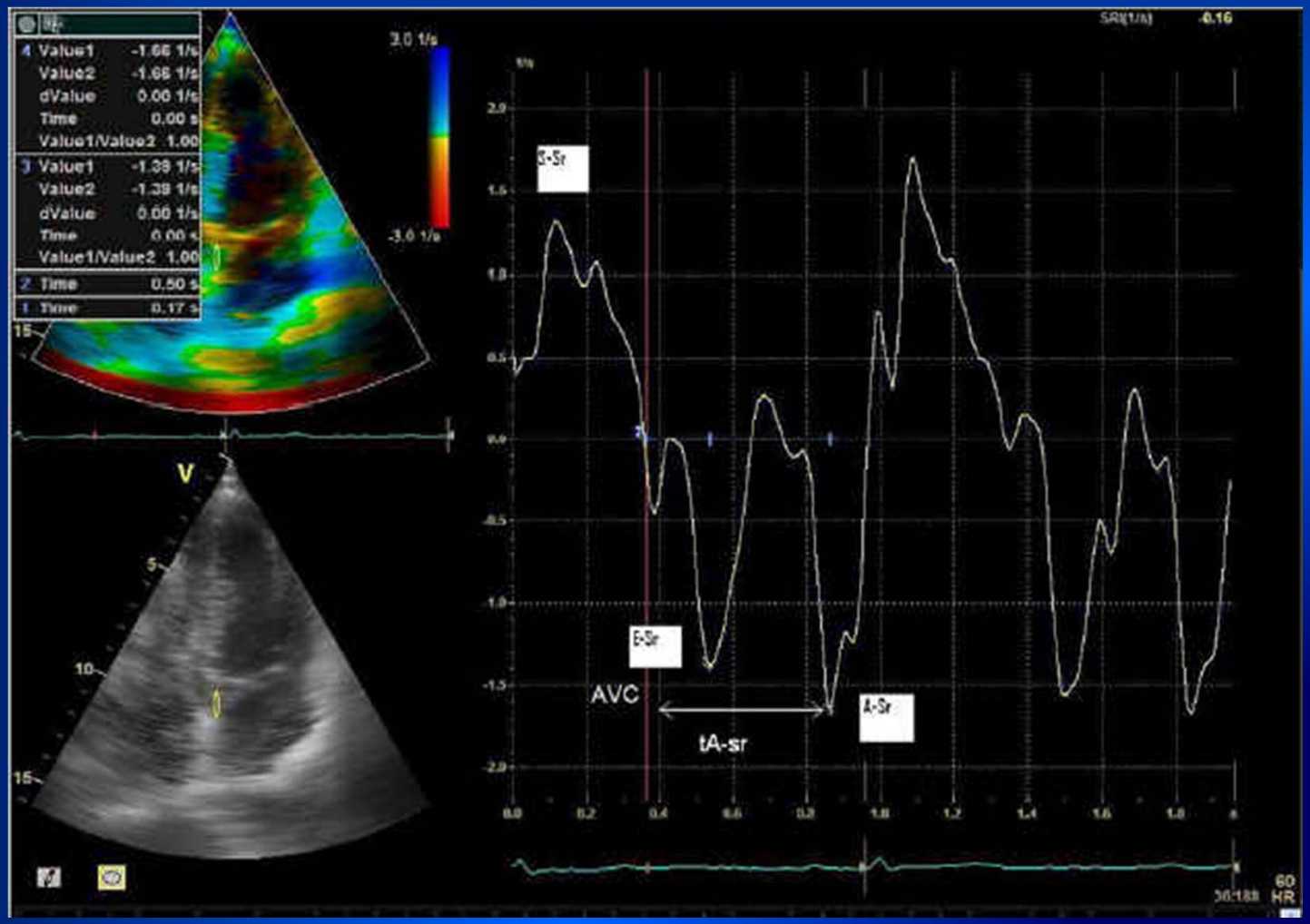
Atrial Ejection Force

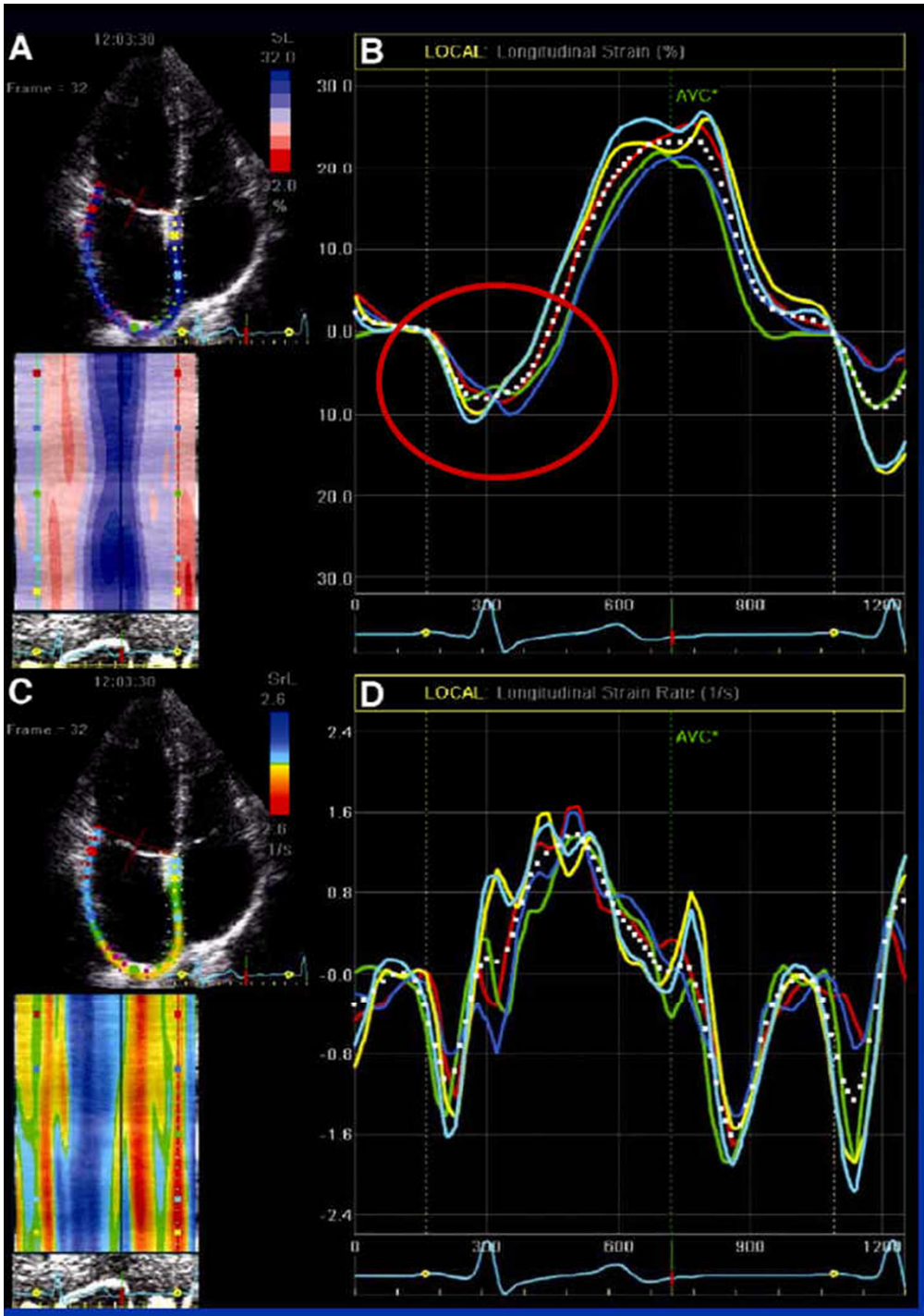
- Force exerted by the LA to propel blood across the mitral valve into the left ventricle during atrial systole
- Calculated as the product of the mass and acceleration of blood from the LA during atrial systole

  Atrial ejection force = 0.5 x 1.06g/cm^3 x mitral annulus area (peak A velocity)
- Used as a marker of recovery of atrial mechanical function after successful cardioversion
- In the Strong Heart Study, greater atrial ejection force was an independent predictor of subsequent cardiovascular events.

Assessment of LA Function

Tissue Doppler Imaging



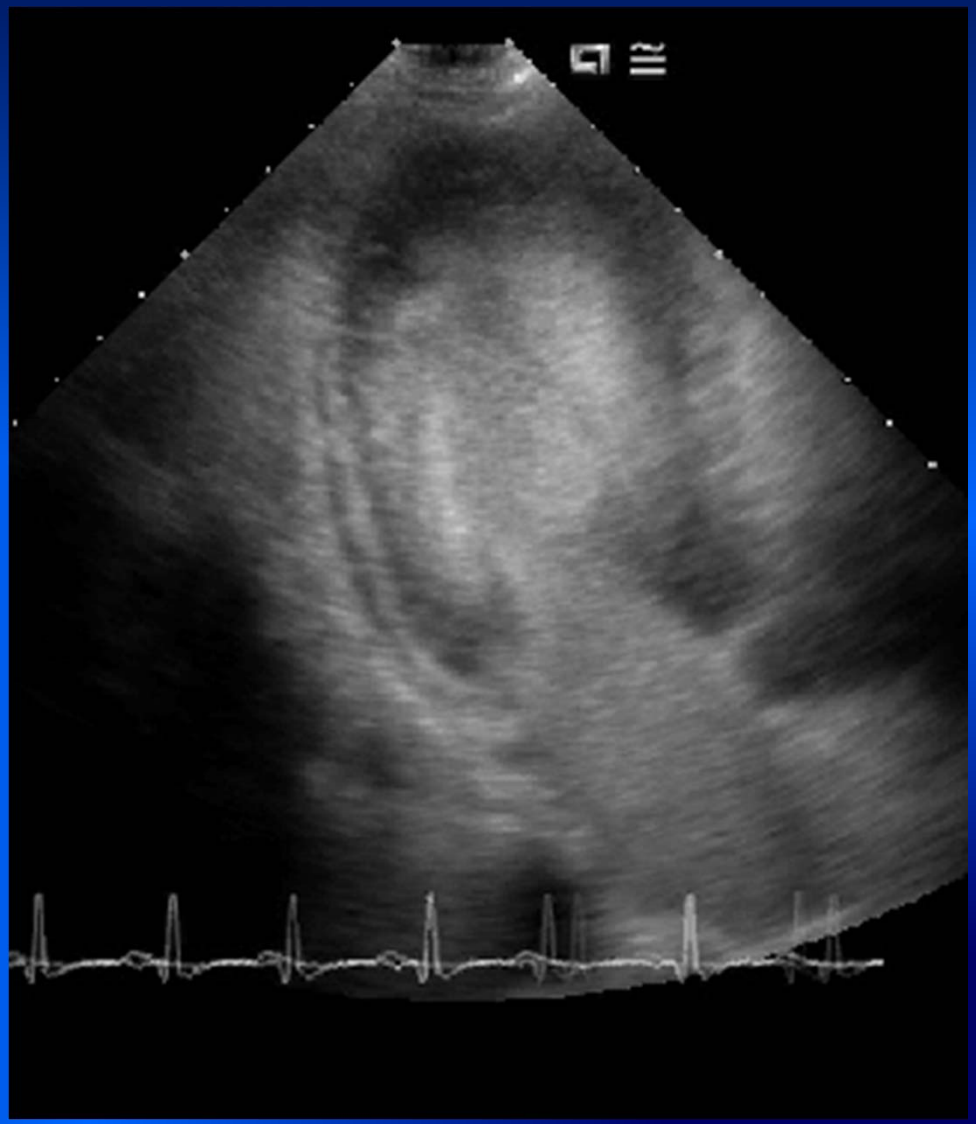


LA Strain

LA Strain Rate

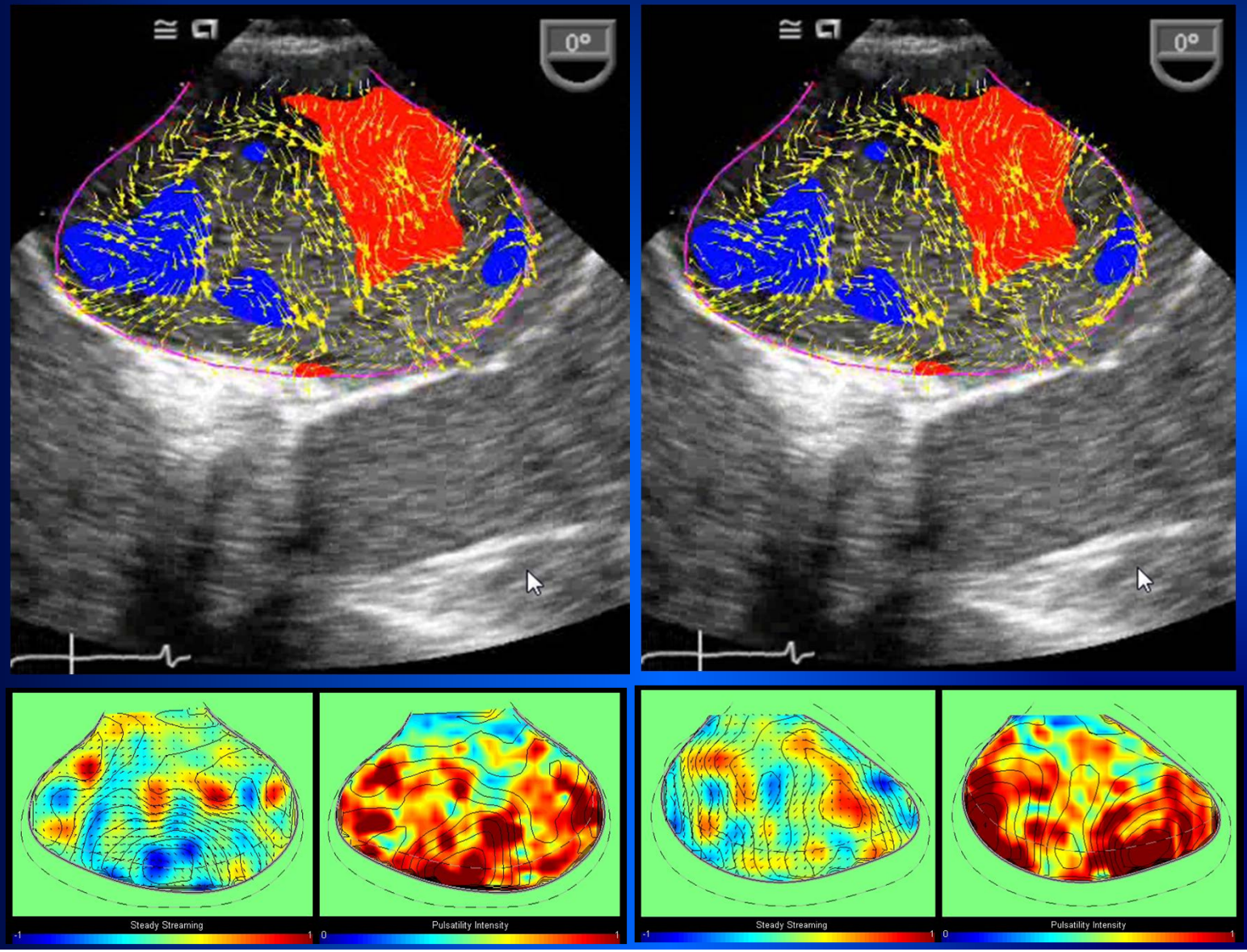
Vianna R, Appleton C JASE 2010

Vortex...



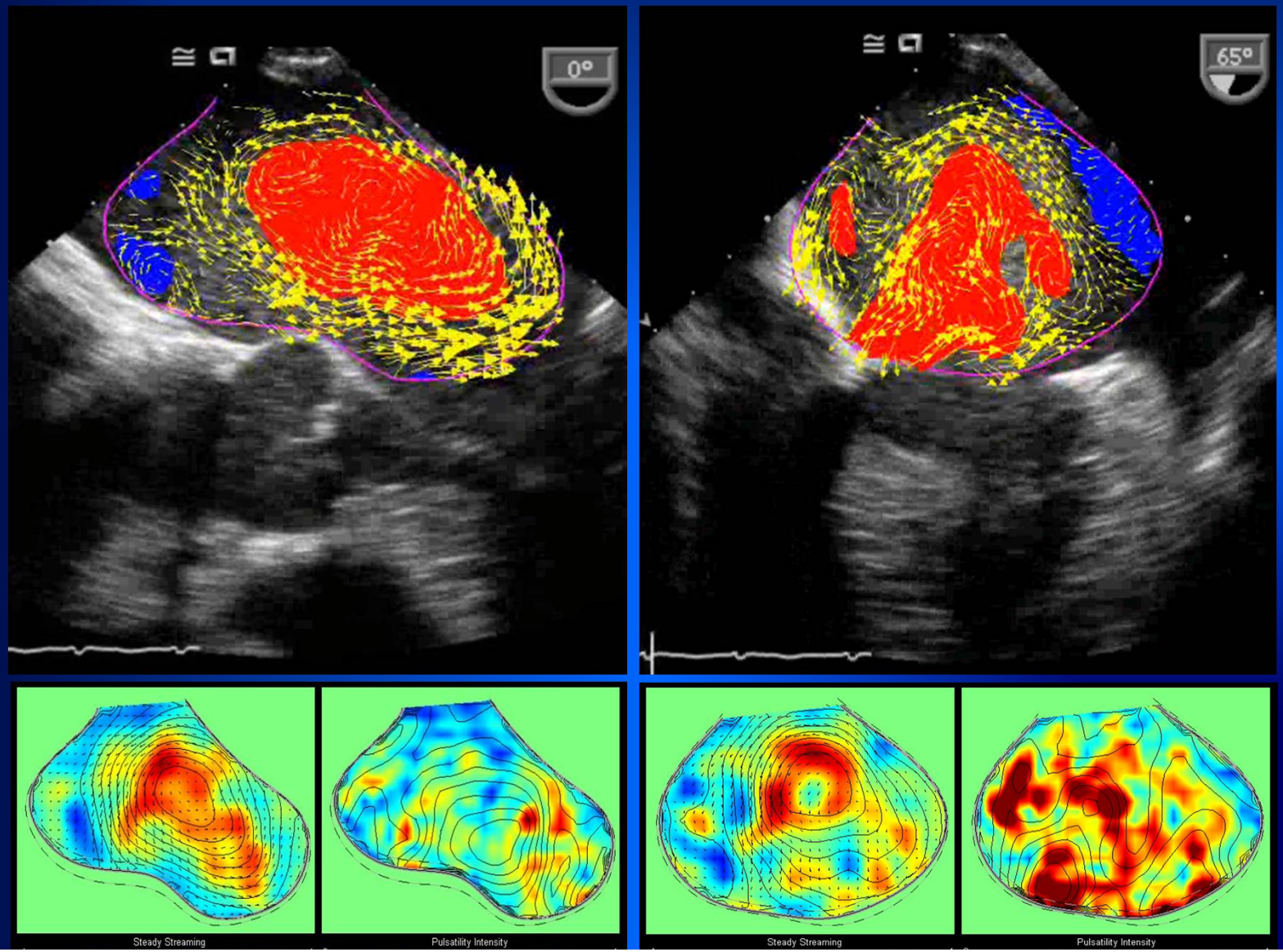
LA Vortex Flow Analysis

LA vortex flow in normal



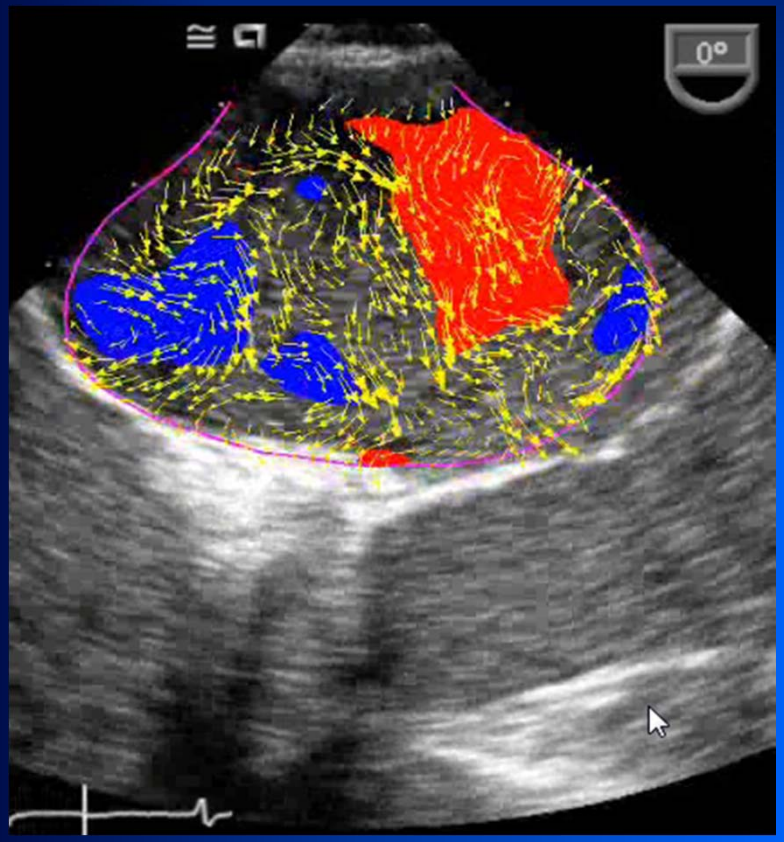
LA Vortex Flow Analysis

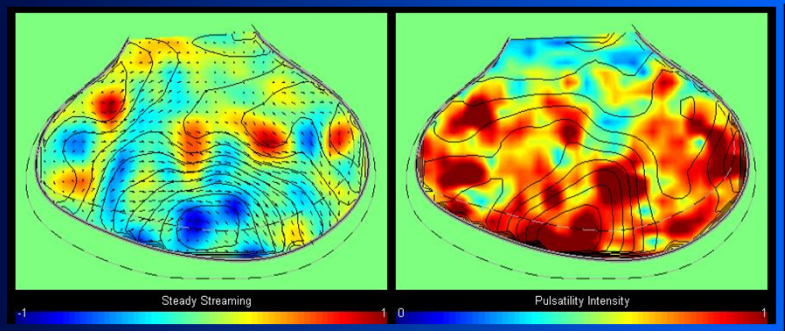
LA vortex flow in patient with Af



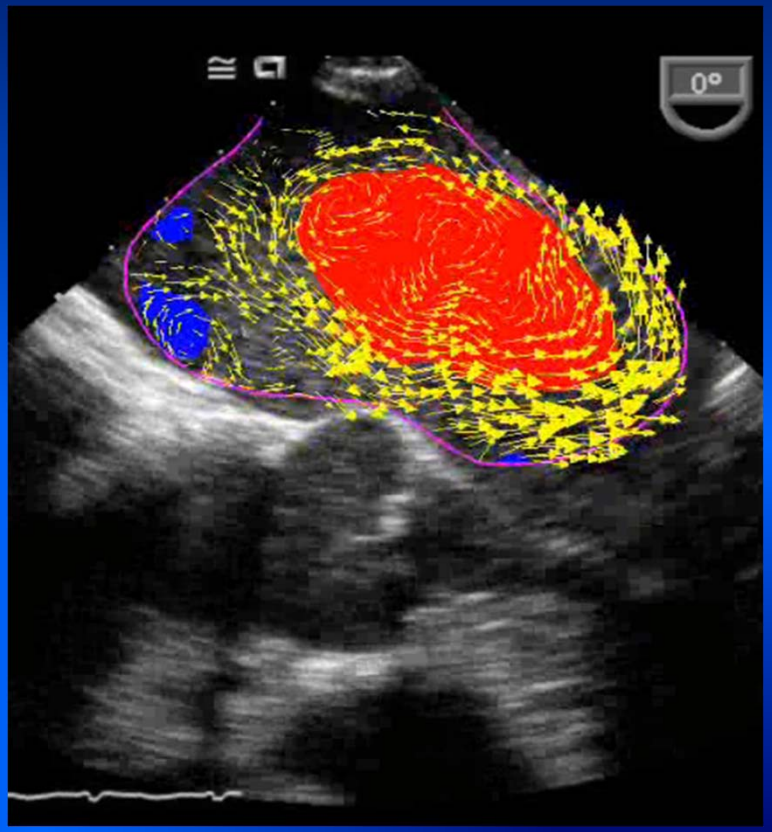
LA Vortex Flow Analysis

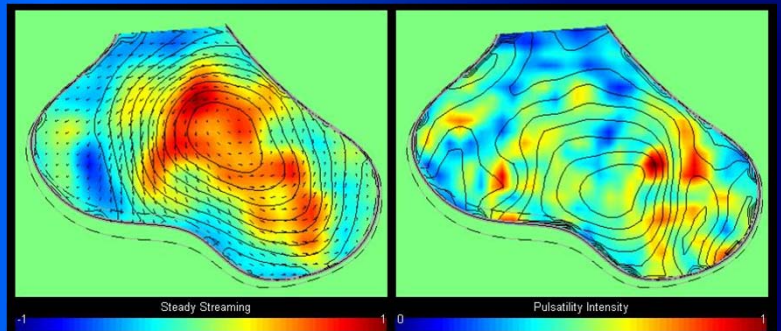
Normal





Af





Prediction of Recurrence of Atrial Fibrillation after Radiofrequency Ablation by Analysis of Left Atrial Vortex Flow in Patient with Atrial Fibrillation

- There were no significantly different in baseline characteristics and conventional echocardiographic parameters
- In LA vortex flow analysis, vortex length (VL), vortex width (VW), and vortex relative strength (VRS) at long cardiac view were significantly higher in recurrence group than non-recurrence
- Relative strength was not significantly different between two groups but tended to be lower in recurrence group

2011 ASE abstract

Take Home Messages

- LA size and function provide insights into and are prognostic markers in a wide range of pathological conditions
- LA size should be measured as a biplane LA volume and indexed to BSA to make comparisons between groups meaningful.
- The newer parameters of atrial function including tissue Doppler Imaging, flow analysis may afford to incremental information
- Routine, thorough evaluation of atrial size and function may assist in the early detection of “subclinical disease,” provide useful adjunctive information during cardiac evaluation

Thank you for Your attention