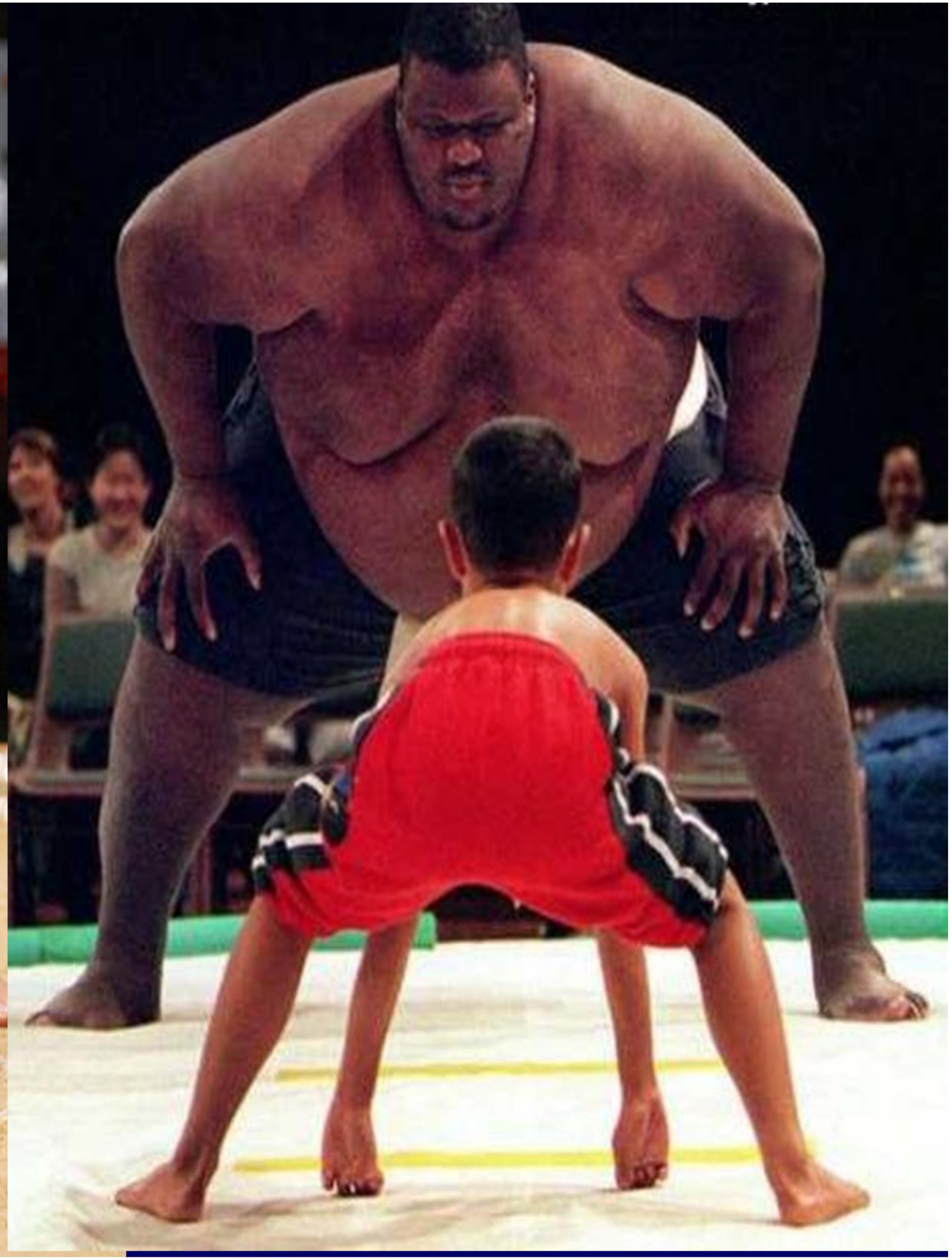
15th APCDE 2011

Application of Strain Imaging : Other Than Left Ventricle

Kye Hun Kim

Chonnam National University Hospital, Korea

Strain and Strain Rate

- Strain (S, %)

  : Measure of deformation

  : Lengthening or shortening

  : Strain = (L – L0)/(L0)

- Strain rate (1/sec)

  : Rate of changes of the deformation

Strain and Strain Rate Echocardiography

- How to measure?
  - : M-mode
  - : Tissue Doppler based measurements
  - : 2D speckle tracking methods

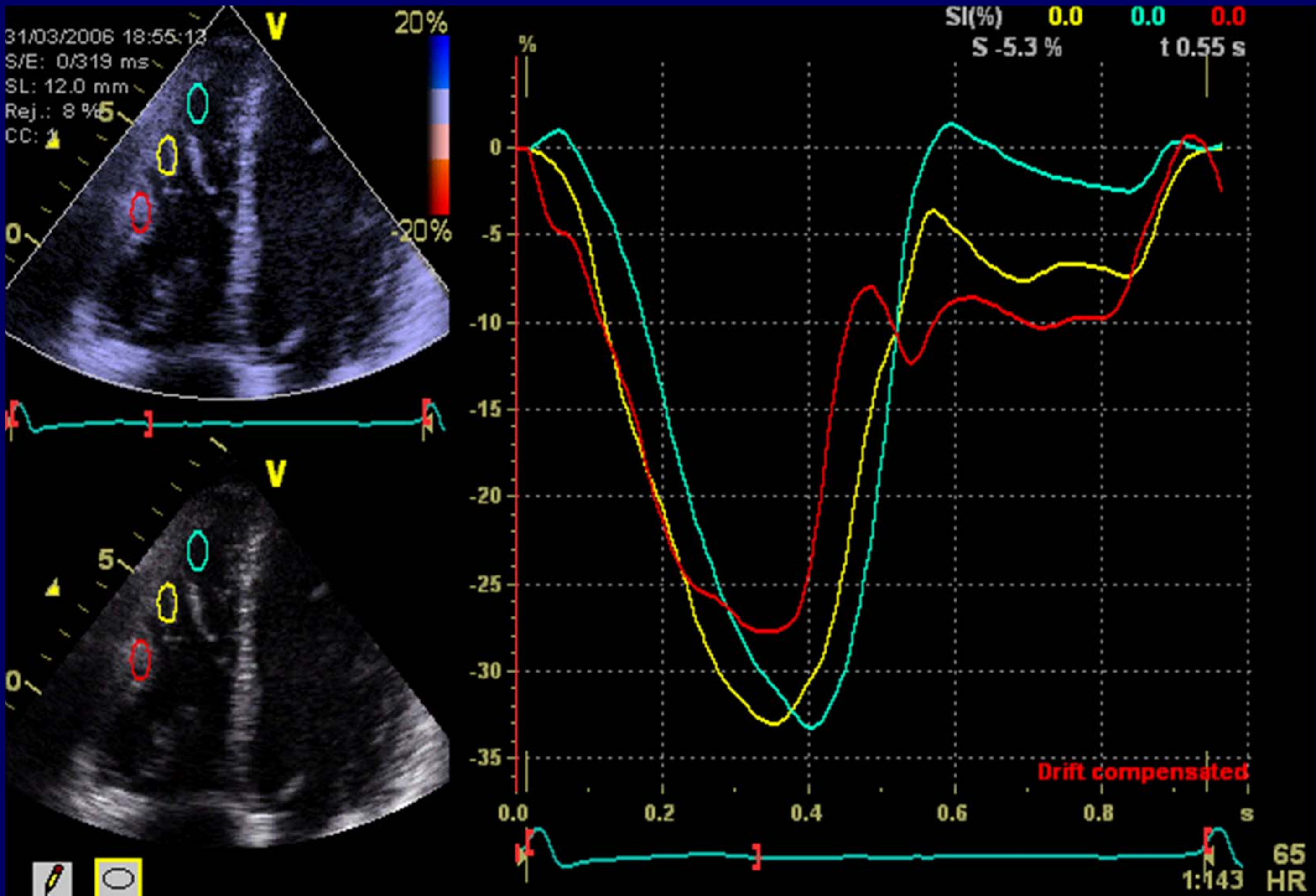
- Allow the measurement of regional myocardial deformation to assess specific local and global function

- Widely studied to evaluate LV function, dyssynchrony, and its relation to prognosis, and to identify subclinical risks

Strain Imaging Other Than Left Ventricle

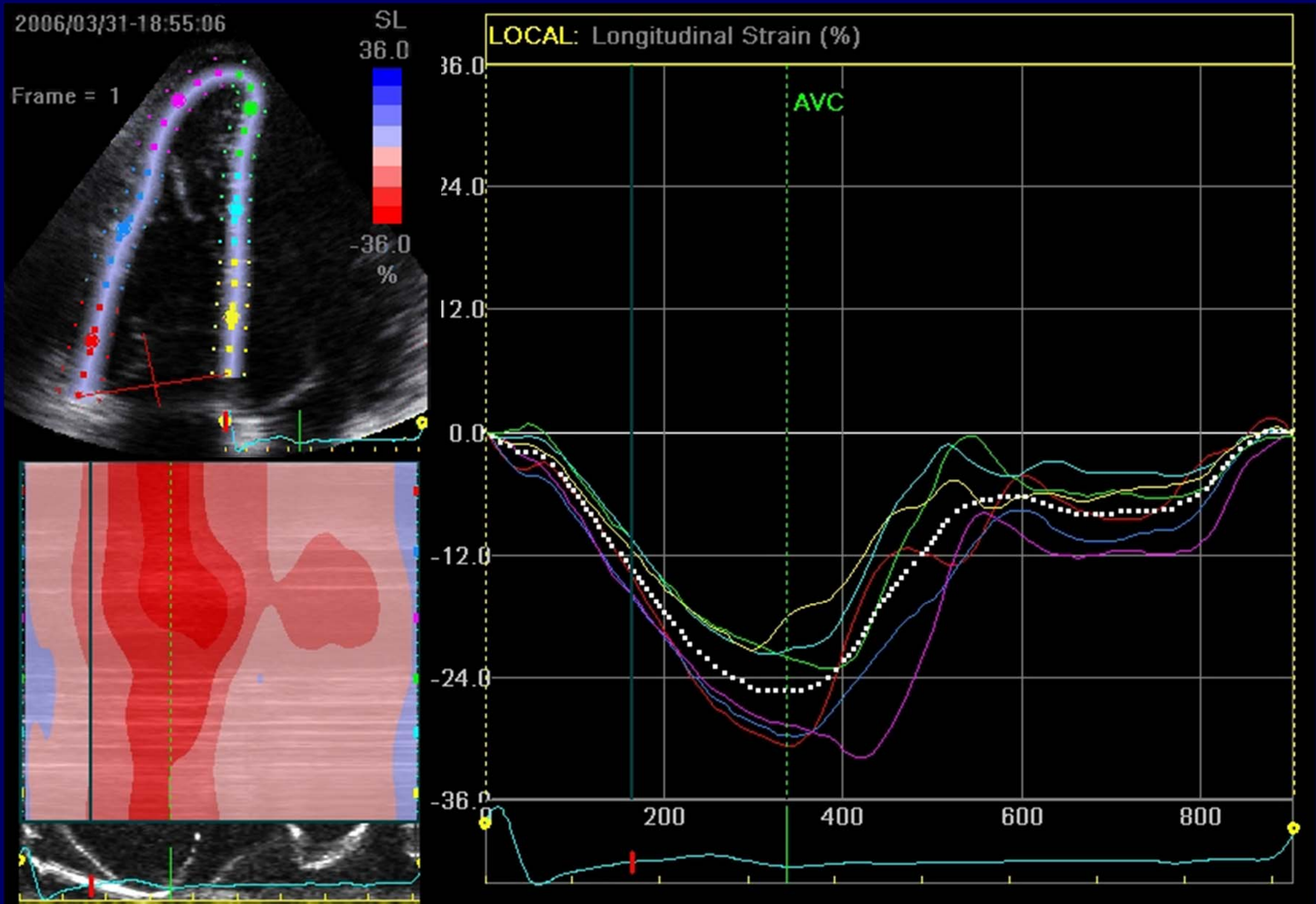
- Right Ventricle
- Left atrium
- Right atrium
- Blood vessels
  : Aorta
  : Carotid artery

Right Ventricle: TDI Based Strain Measurement

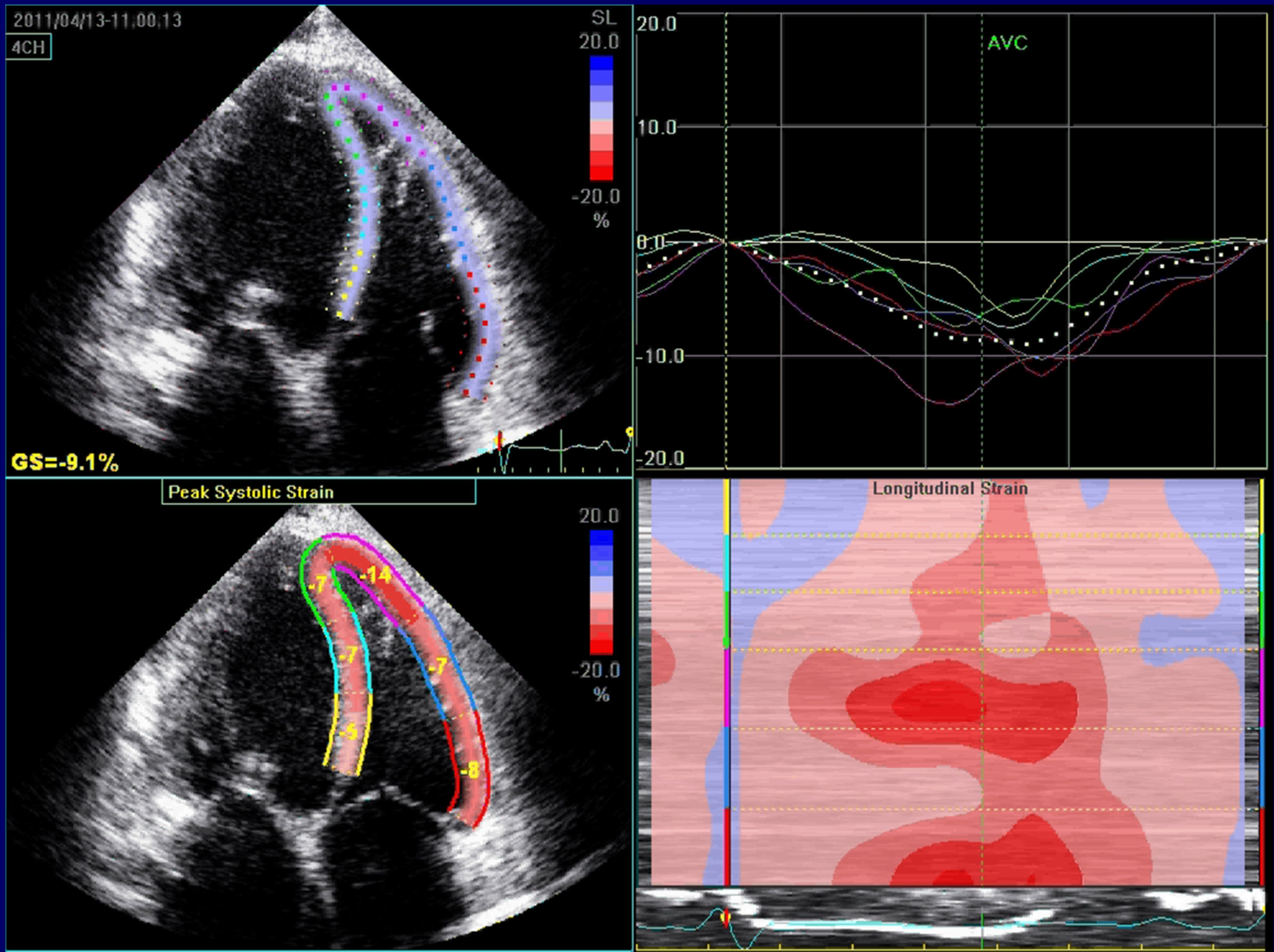


- Limitation of angle dependency
- High frame rates (≥ 150 frames/s)

Right Ventricle: 2D Strain Measurement



Right Ventricle: 2D Strain Measurement



Right Ventricle: Strain Imaging Echocardiography

- RV longitudinal strain in apical view
  - : Feasible in clinical setting
  - : Have been studied in a number of conditions affecting the right heart, including arrhythmogenic RV dysplasia, pulmonary embolism, PH, systemic right ventricle, and amyloidosis

- Acute increase in RV afterload
  - : Increase in RV myocardial strain rate
  - : Decrease in peak systolic strain, indicating a decrease in SV

RV Strain Measurement: Clinical Significances

- Associate with major adverse events in chronic heart failure

  (Donal et al. Eur J Echocardiography 2007)

- Determine RV dysfunction in COPD

  : Complementary to conventional echocardiographic findings

  : Correlated with pulmonary HT and respiratory function tests

  (Vitarelli et al. Eur Respir J 2006)

- Predicts future right heart failure, clinical deterioration, and mortality in patients with PAH

  (Sachdev et al. Chest 2010)

RV Strain Measurement: Clinical Significances

- Predicts RV dysfunction after surgical correction of congenital heart disease

  (Eyskens B et al. Cardiol Young 2004)

- Detect cardiac involvement in patients with infiltrative CMP

  (Lindqvist P et al. Eur J Echocardiogr 2006)

- Useful in the evaluation of RV function in APE

  (Hsiao SH et al. J Am Soc Echocardiogr 2006)

Right Ventricle: Strain Imaging Echocardiography

Variable	Studies	n	LRV (95% CI)	Mean (95% CI)	URV (95% CI)
2D peak strain rate at the base (s^{-1})	1	61	0.70 (0.50-0.90)	1.62 (1.50-1.74)	2.54 (2.34-2.74)
2D peak strain rate at the mid cavity (s^{-1})	2	80	0.85 (0.66-1.04)	1.54 (1.46-1.62)	2.23 (2.04-2.42)
2D peak strain rate at the apex (s^{-1})	2	80	0.86 (0.46-1.25)	1.62 (1.46-1.79)	2.39 (1.99-2.78)
2D peak strain at the base (%)	5	183	18 (14-22)	28 (25-32)	39 (35-43)
2D peak strain at the mid cavity (%)	4	125	20 (15-24)	29 (25-33)	38 (34-43)
2D peak strain at the apex (%)	4	145	19 (15-22)	29 (26-32)	39 (36-43)
Doppler peak strain rate at the base (s^{-1})	7	261	1.00 (0.63-1.38)	1.83 (1.50-2.15)	2.66 (2.28-3.03)
Doppler peak strain rate at the mid cavity (s^{-1})	5	187	0.98 (0.68-1.28)	1.88 (1.73-2.03)	2.79 (2.49-3.09)
Doppler peak strain rate at the apex (s^{-1})	5	204	1.14 (0.60-1.69)	2.04 (1.57-2.51)	2.93 (2.39-3.48)
Doppler peak strain at the apex (%)	7	290	17 (12-21)	30 (27-34)	44 (39-48)
Doppler peak strain at the base (%)	11	385	13 (9-17)	29 (27-31)	45 (41-49)
Doppler peak strain at the mid cavity (%)	7	269	13 (9-18)	31 (29-32)	48 (44-52)

Rudski LG et al. J Am Soc Echocardiogr 2010

RV Strain Measurement: Current Recommendations

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

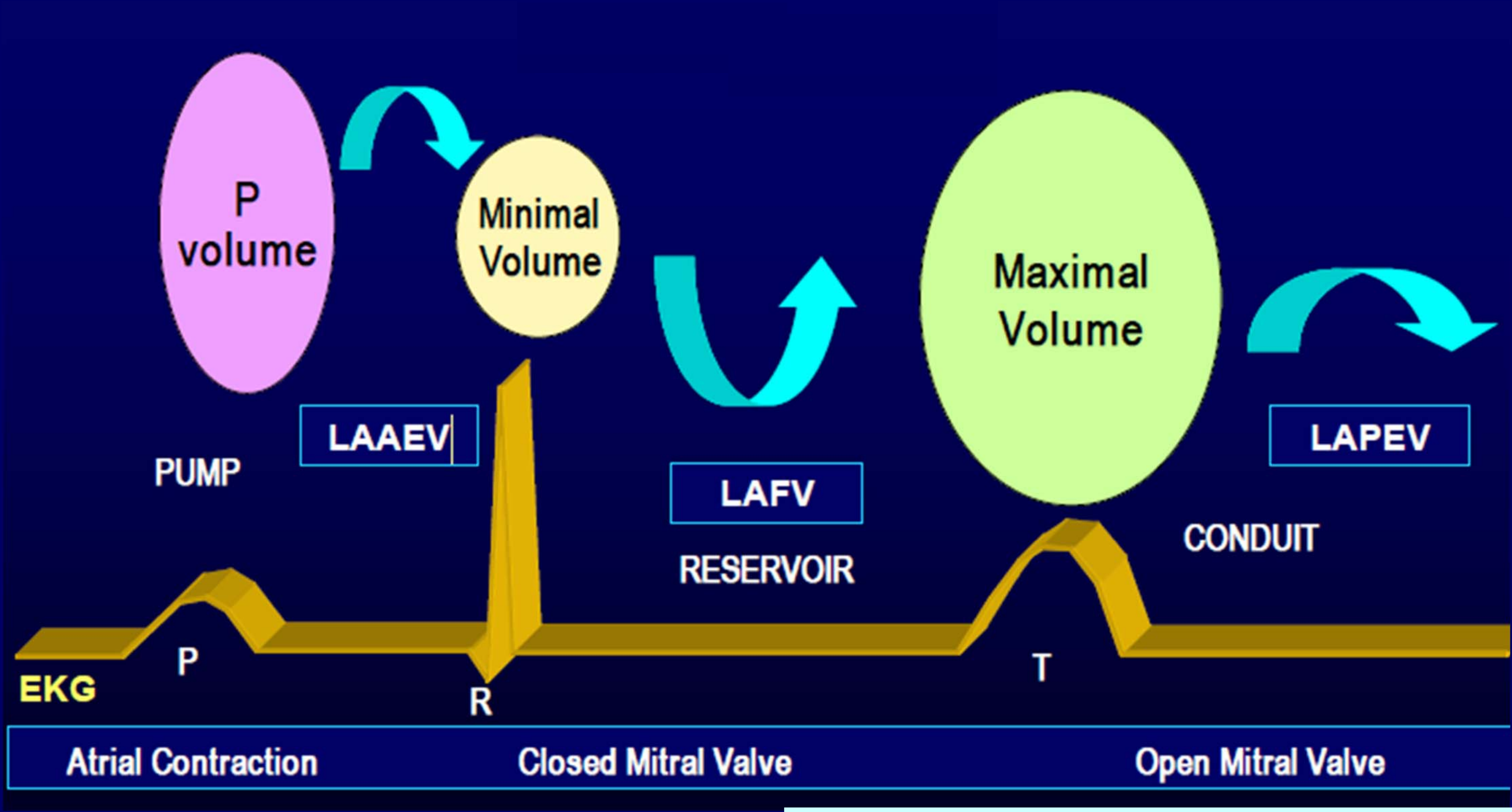
Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, *Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California*

(J Am Soc Echocardiogr 2010;23:685-713.)

Recommendations: The significant disadvantages listed above limit the clinical use of regional RV strain. Reference limits cannot be recommended, because of very wide confidence intervals both around the mean values and around the reference limits. Strain and strain rate remain research tools in experienced labs until their limitations can be overcome.

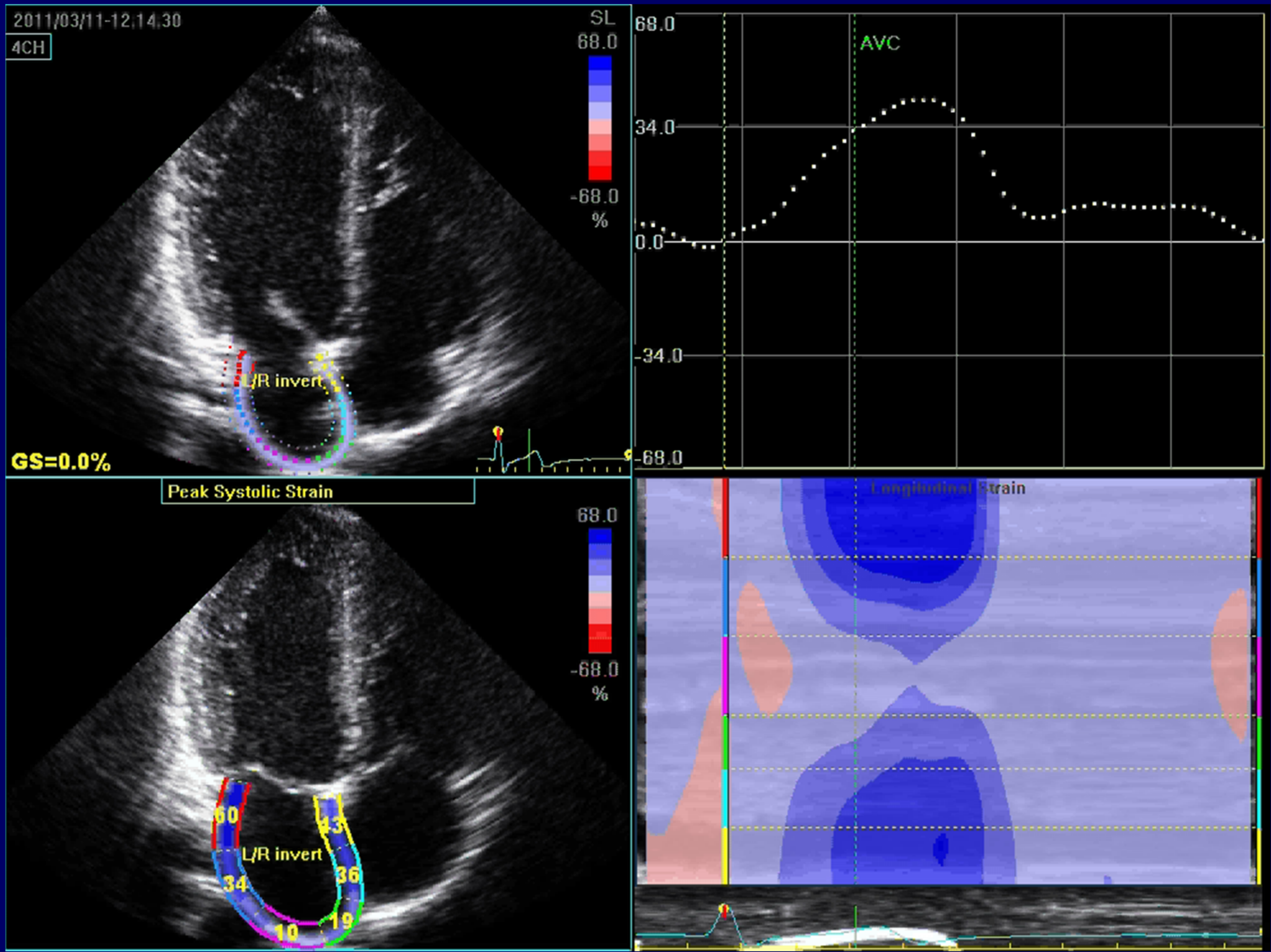
- **Lack of reproducibility**
- **Paucity of data**
- **No reference limits**

Left Atrium: LA Physiology

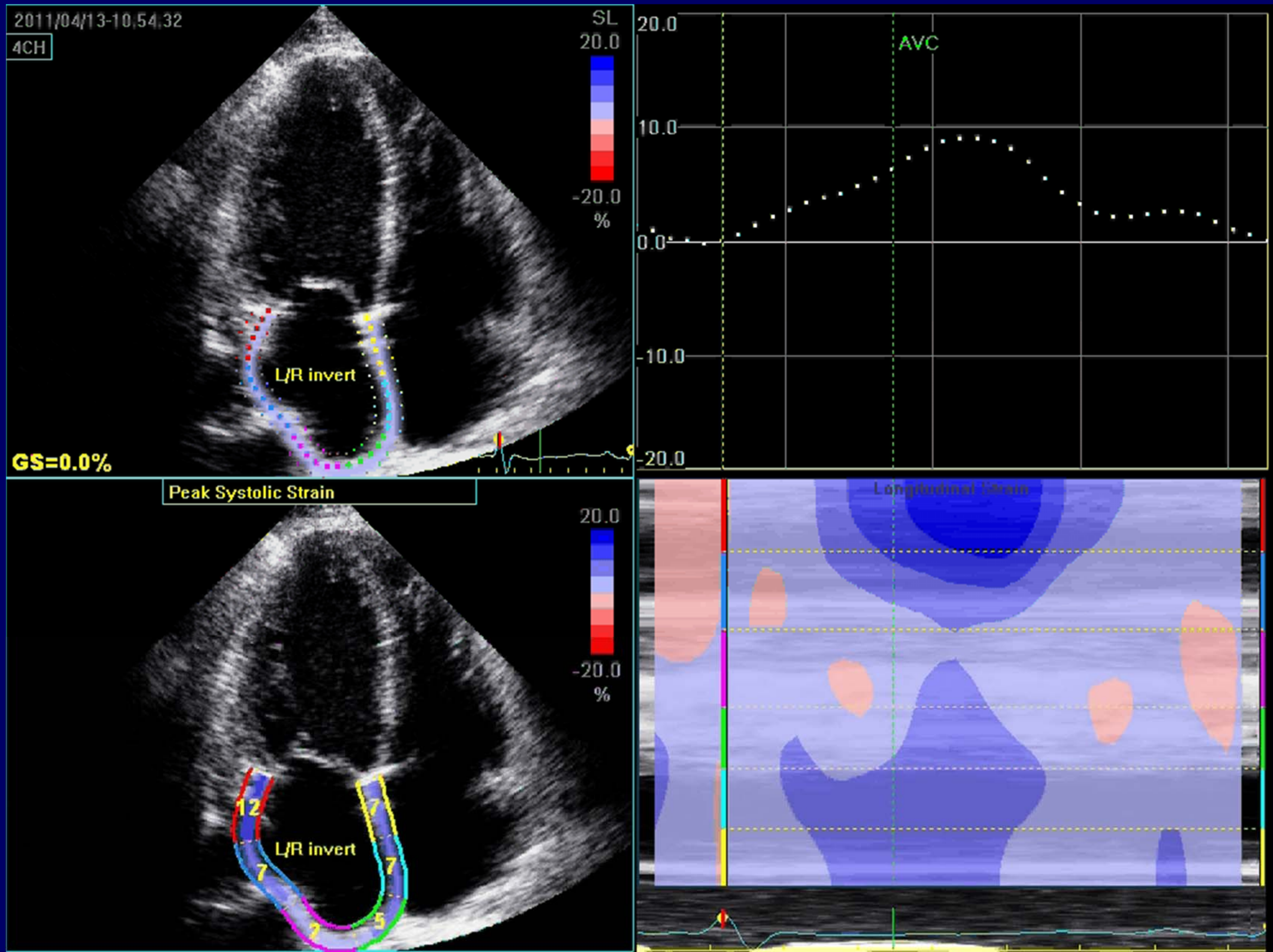


Nikitin NP et al. Eur J Echo 2003;4:36-42

Left atrium: Strain Echocardiography



Left atrium: Strain Echocardiography



LA Strain Measurement: Feasibility

- LA strain and SR measurement

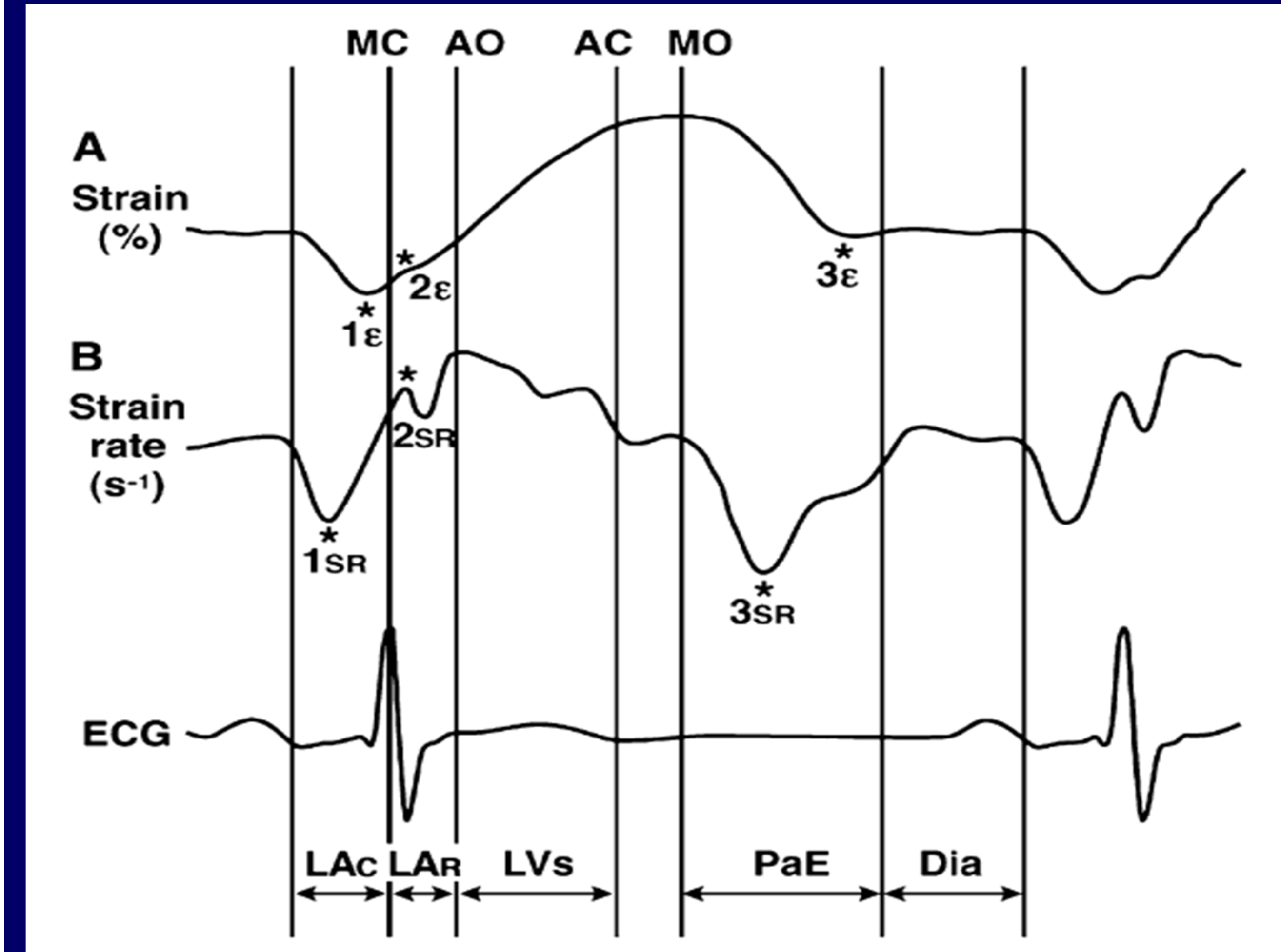
  : Could be measured in 94% (77/84)

- Interobserver and intraobserver variability

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-Pinto R et al. J American Soc Echocardiogr 2009

Left Atrial Strain and Strain Rate: Normal



- LAc: LA contraction
- LAr: LA relaxation
- LVs: LV systole
- PaE: LA passive emptying
- Dia: Diastases

Vianna-Pinto R et al. J American Soc Echocardiogr 2009

Left Atrial Strain and SR during LA Contraction

		Left atrial region				
Variable	Segment	Septal	Lateral	Anterior	Inferior	Inferolateral
Velocity (cm/s)	Annular	5.0 ± 1.4	5.5 ± 1.8	5.0 ± 1.7	6.5 ± 1.7[a]	5.8 ± 1.8
	Mid	2.9 ± 1.3	2.5 ± 1.4	3.3 ± 1.6	3.0 ± 1.5	2.2 ± 1.0
	Roof	0.9 ± 1.2		1.4 ± 1.3		1.5 ± 1.5
Strain, ε (%)	Annular	−13 ± 4.9	−16 ± 6	−15 ± 6	−19 ± 5.5[b]	−15 ± 7.2
	Mid	−14 ± 5.1	−12 ± 4.2	−14 ± 5.3	−17 ± 5.2[c]	−13 ± 5.5
	Roof	−10 ± 6.1		−11 ± 6		−13 ± 6
Strain rate (s^{-1})	Annular	−1.9 ± 0.7	−2.3 ± 0.8	−2.3 ± 1.0	−2.7 ± 0.9[b]	−2.3 ± 0.8
	Mid	−2.0 ± 0.6	−1.8 ± 0.7	−2.2 ± 0.9	−2.4 ± 0.9[c]	−1.9 ± 1.0
	Roof	−1.6 ± 0.7		−1.7 ± 0.9		−1.9 ± 1.1

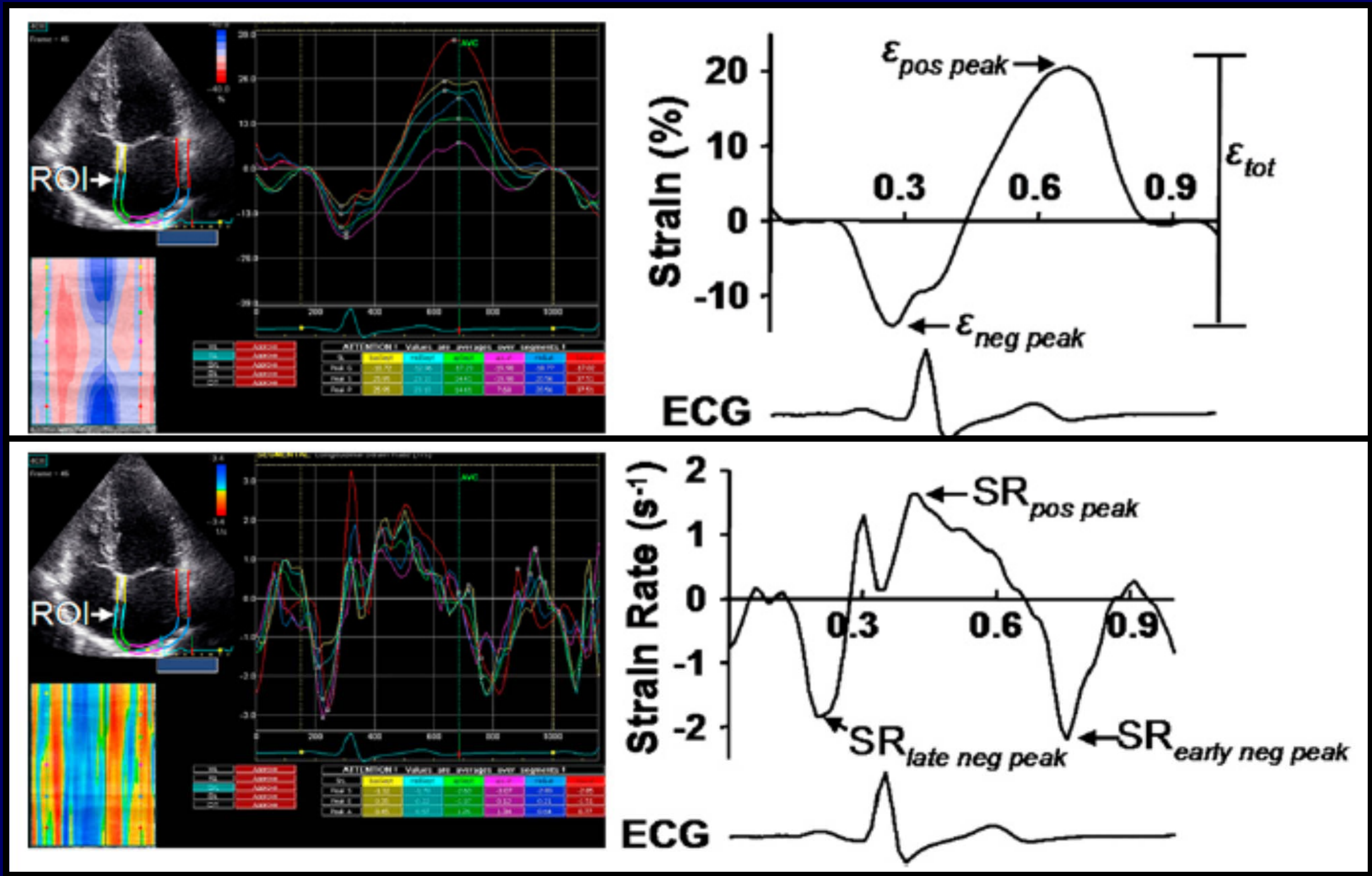
Vianna-Pinto R et al. J American Soc Echocardiogr 2009

Left Atrial Strain and SR during LA Relaxation

Variable	Segment	Left atrial region: Septal	Lateral	Anterior	Inferior	Infero-lat
Velocity (cm/s)	Annular[a]	−4.1 ± 1.5	−3.8 ± 2.5	−4.2 ± 2.0	−4.1 ± 2.5	−2.3 ± 1.9
	Mid	−1.8 ± 1.2	−2.4 ± 1.5	−2.5 ± 1.6	−2.1 ± 1.6	−3.2 ± 8.7
	Roof	−0.8 ± 1.8		−1.1 ± 1.5		−1.7 ± 1.3
Strain, ε (%)	Annular	29 ± 12	33 ± 14[c]	28 ± 14	33 ± 17[c]	27 ± 11[c]
	Mid	28 ± 11	23 ± 8.2	23 ± 11	23 ± 10	17 ± 8.8
	Roof	18 ± 10		11 ± 7.8		14 ± 7
SR (s^{-1})	Annular	1.3 ± 0.8	1.3 ± 1.2	1.5 ± 0.9	1.6 ± 1.1[b]	0.6 ± 0.8
	Mid	1.4 ± 0.8	1.1 ± 0.9	1.4 ± 0.7	1.4 ± 0.7	0.5 ± 0.7
	Roof	1.3 ± 0.9		1.0 ± 0.8		0.8 ± 0.8

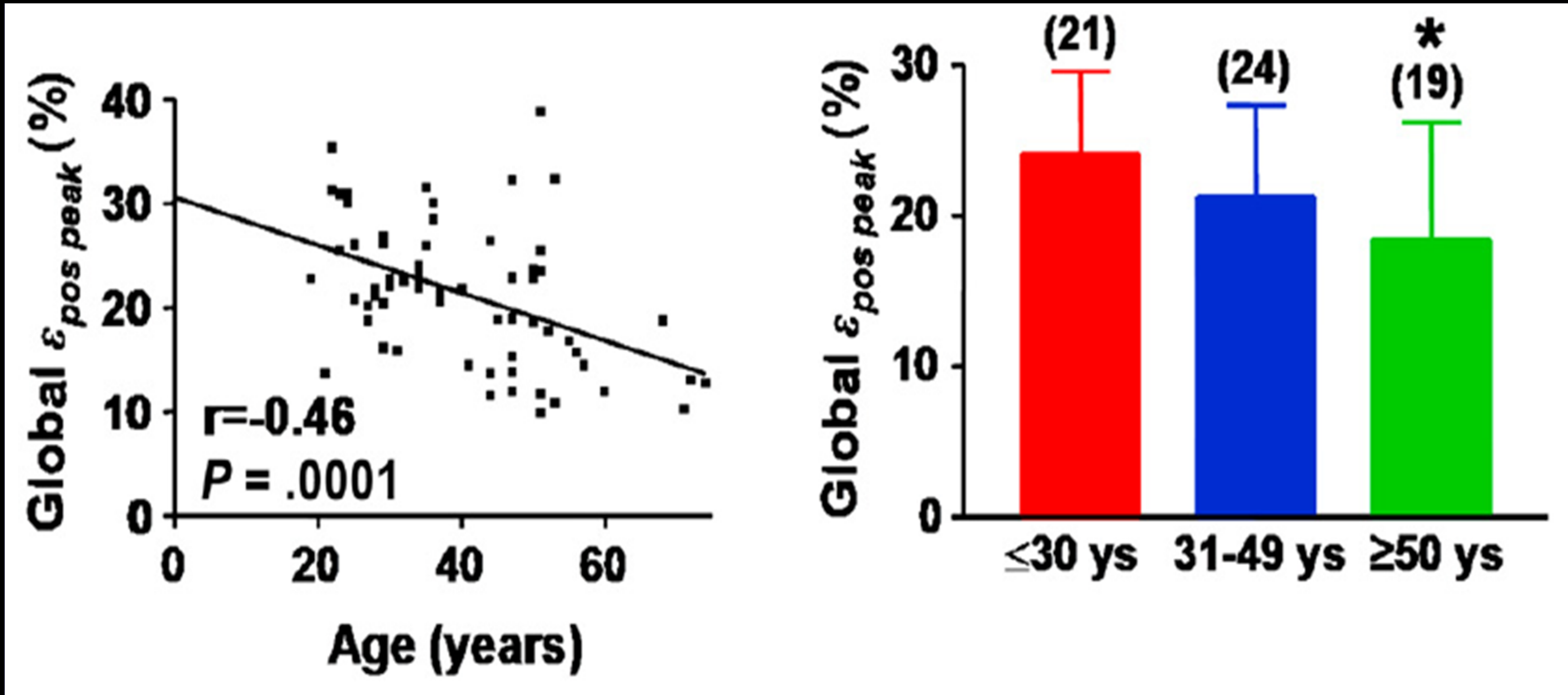
Vianna-Pinto R et al. J American Soc Echocardiogr 2009

Left Atrial Strain and Strain Rate: Normal



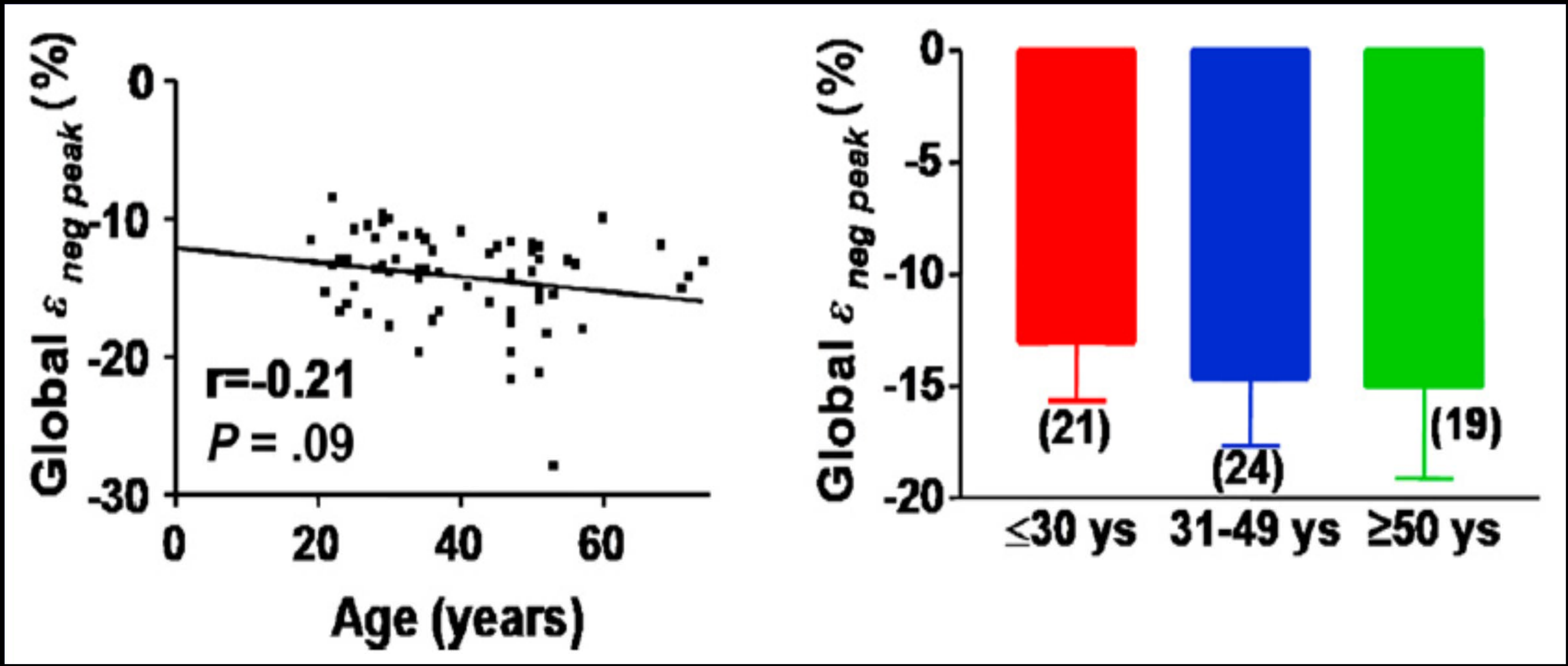
Saraiva RM et al. J American Soc Echocardiogr 2010

Left Atrial Strain and Strain Rate: Normal



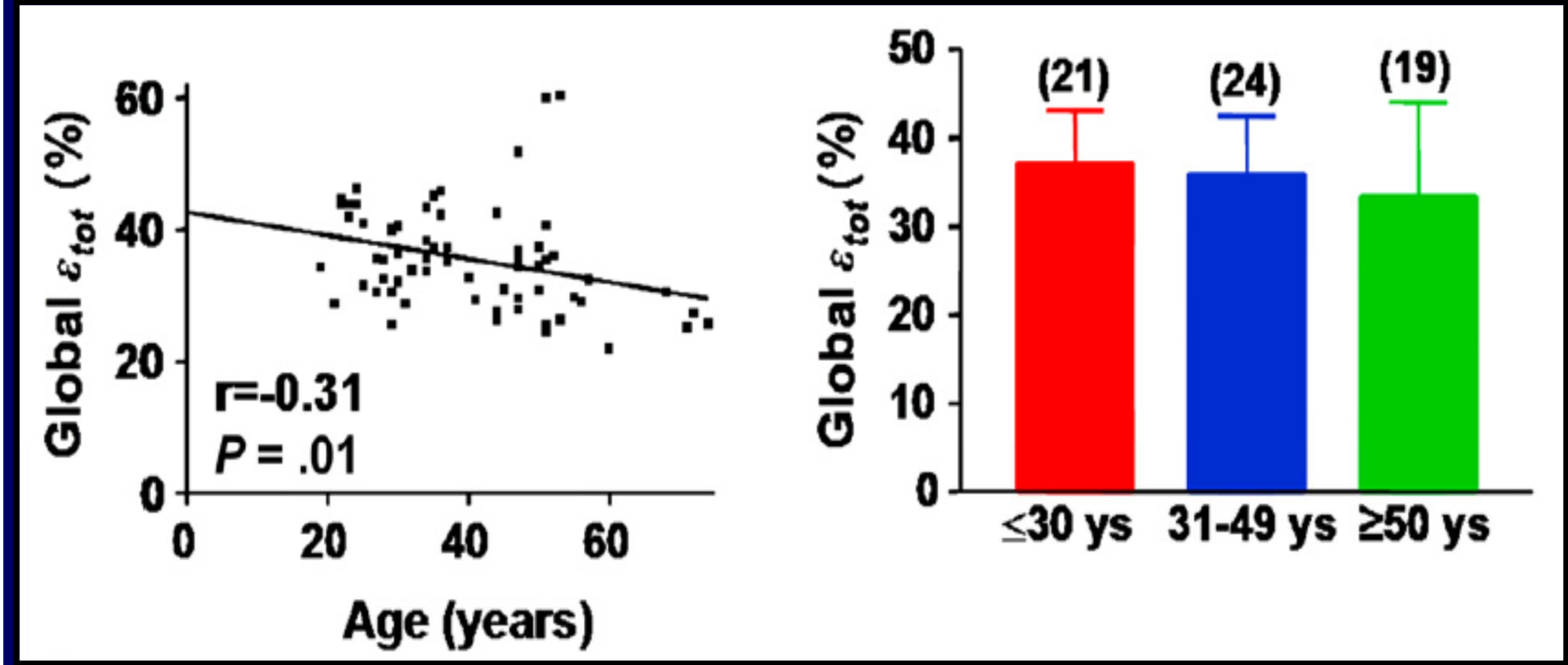
Saraiva RM et al. J American Soc Echocardiogr 2010

Left Atrial Strain and Strain Rate: Normal



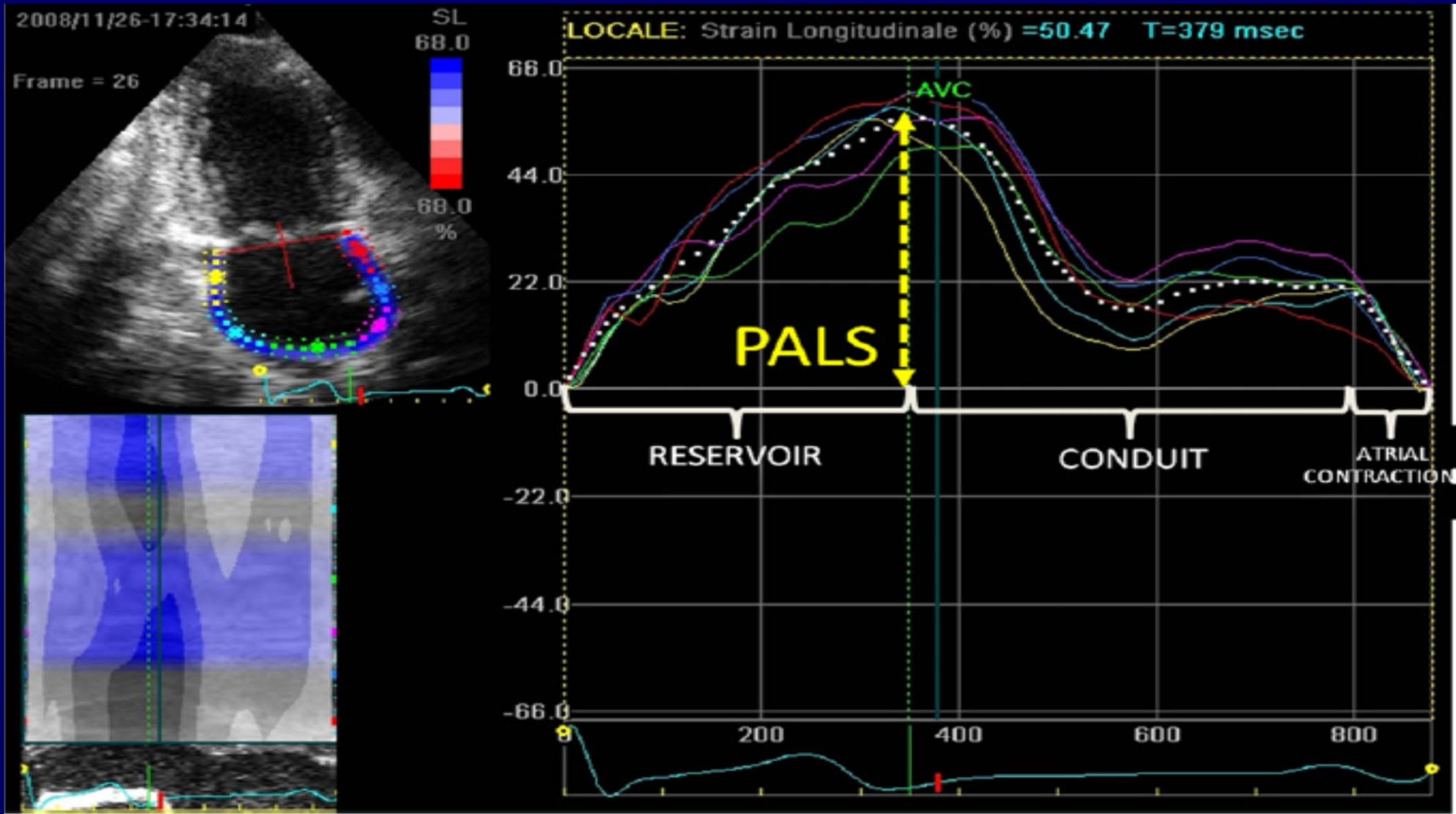
Saraiva RM et al. J American Soc Echocardiogr 2010

Left Atrial Strain and Strain Rate: Normal



Saraiva RM et al. J American Soc Echocardiogr 2010

LA Strain and LV filling Pressure in HF



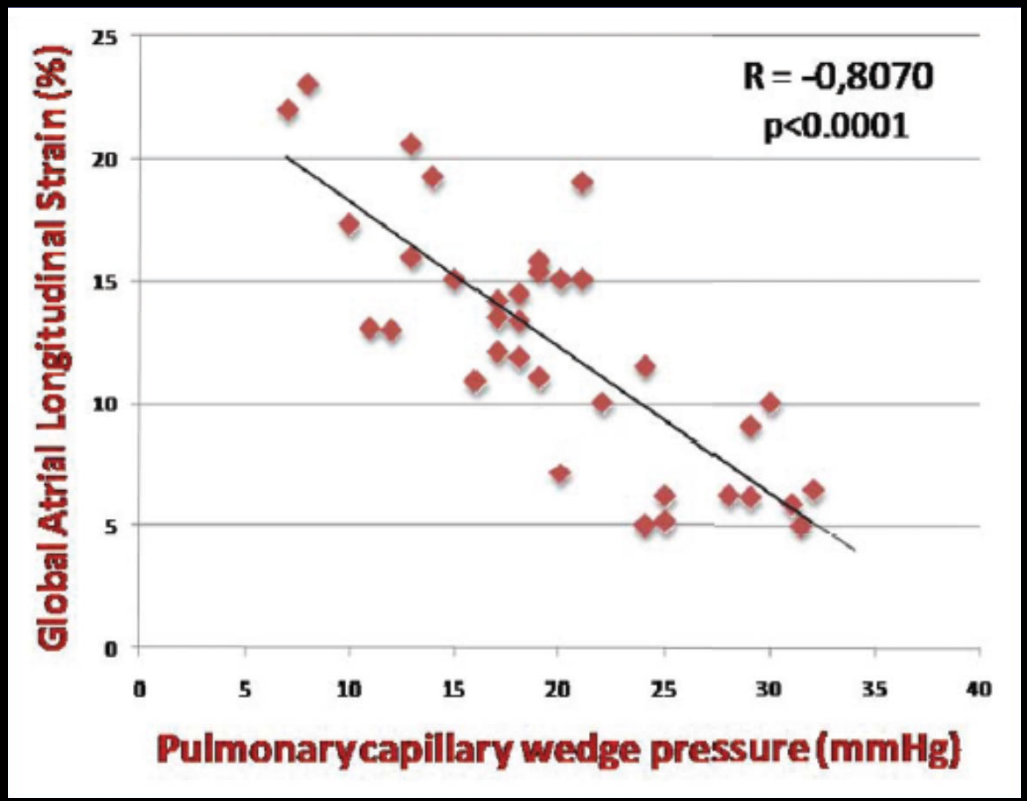
Cameli M et al. Cardiovascular Ultrasound 2010

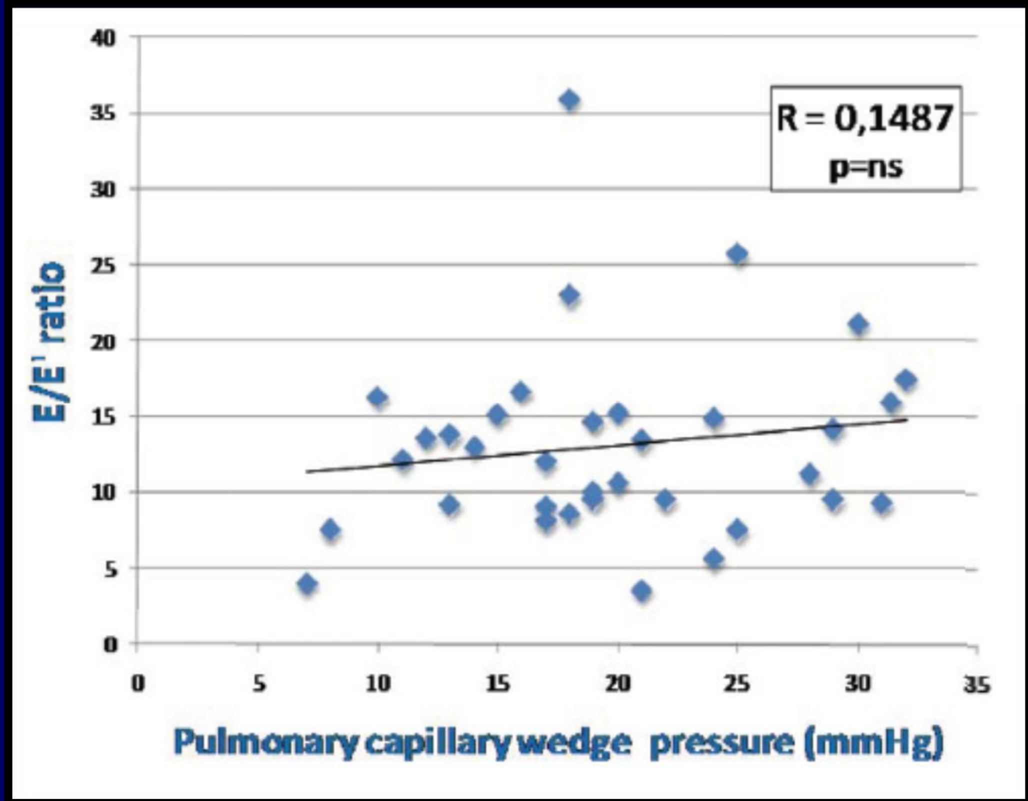
LA Strain and LV filling Pressure in HF

	PCWP <18 mmHg (n = 15)	PCWP ≥18 mmHg (n = 21)	p Value
Left atrial area (cm^2)	26.9 ± 5.9	33.1 ± 6.6	0.02
Left atrial volume indexed (ml/m^2)	30.2 ± 9	41.1 ± 10.1	0.009
End-diastolic LV diameter (mm)	57.3 ± 8.3	63.0 ± 8.0	0.01
LV mass index (g/m^2)	116.6 ± 31.3	118.3 ± 33.5	0.21
LV Ejection Fraction (%)	26.5 ± 3.5	25.7 ± 4.3	0.15
Mitral E (cm/s)	82.6 ± 33	99.4 ± 46	<0.001
Mitral E/A ratio	2.19 ± 1.1	3.66 ± 1.3	<0.001
Sm (cm/s)	5.0 ± 1.1	5.0 ± 1.2	0.81
Em (cm/s)	6.6 ± 1.8	6.2 ± 1.8	0.24
E/Em (cm/s)	12.6 ± 6.4	15.9 ± 7.9	0.01
Global PALS (%)	16.9 ± 4.0	9.8 ± 4.2	<0.001
4-chamber PALS (%)	14.3 ± 3.8	8.0 ± 3.6	<0.001
2-chamber PALS (%)	18.0 ± 4.6	11.2 ± 4.5	<0.001
Global TPLS (ms)	445 ± 81	410 ± 78	0.09

Cameli M et al. Cardiovascular Ultrasound 2010

LA Strain and LV filling Pressure in HF

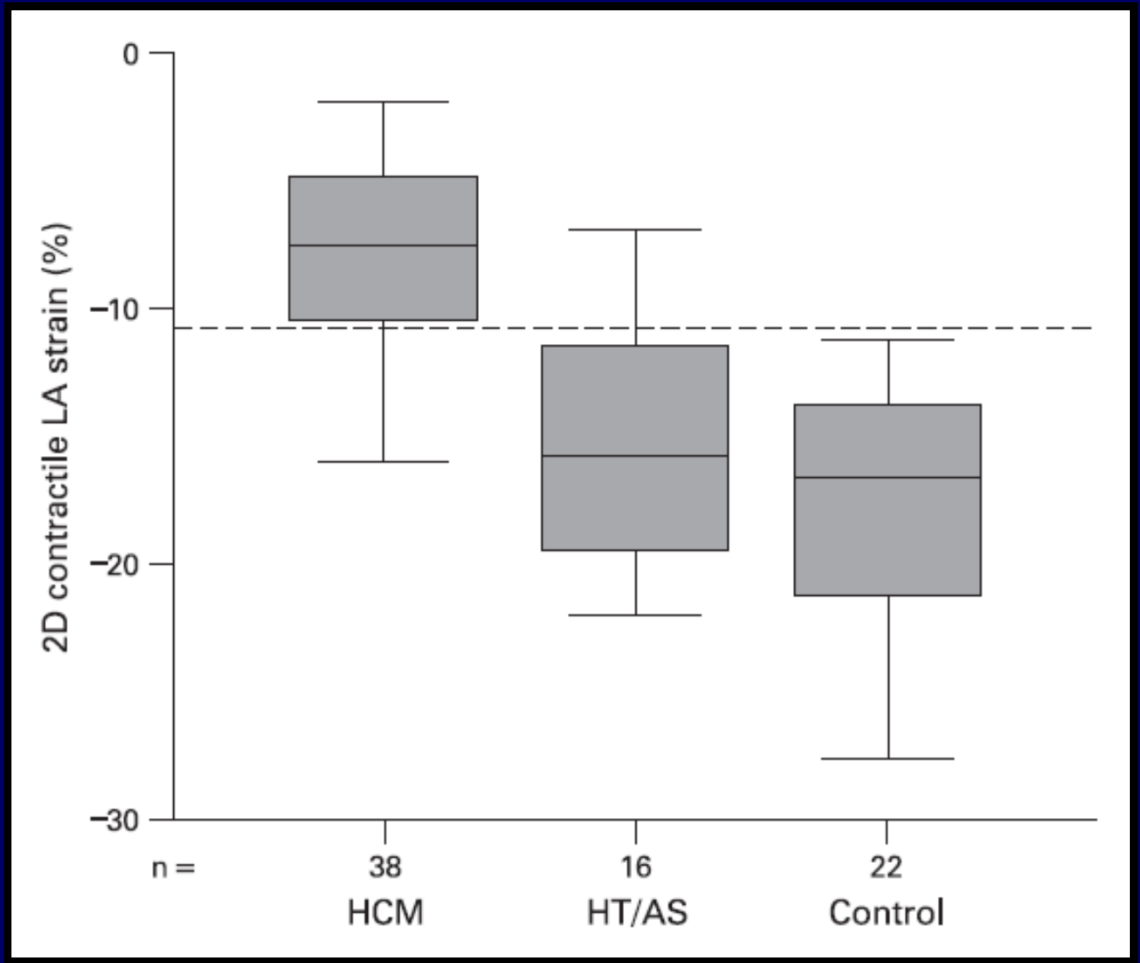




- PCWP showed strong inverse correlation with global atrial strain, but not with E/E` in patients with HF

Cameli M et al. Cardiovascular Ultrasound 2010

LA Strain: HCM vs Non-HCM LVH



- LA strain has an additive value in differentiating HCM from non-HCM LVH
- Optimal cutoff value

  : -10.82% of LA strain

  : Sensitivity 82%

  : Specificity 81%

Paraskevaidis IA et al. Heart 2009

LA Strain Measurement: Clinical Significances

- Predicts success or failure of cardioversion for AF

  (Wang T et al. Int J cardiol 2007)

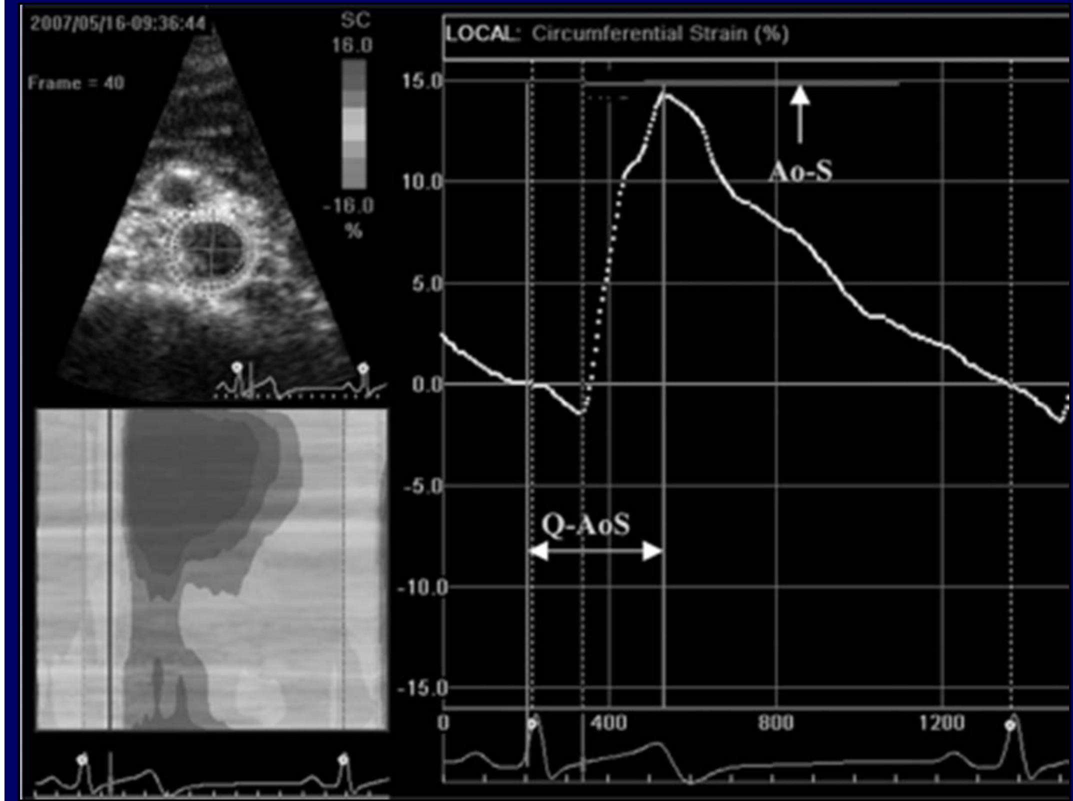
- LA strain and SR inversely correlate with LA wall fibrosis measured by cardiac MRI in patients with AF

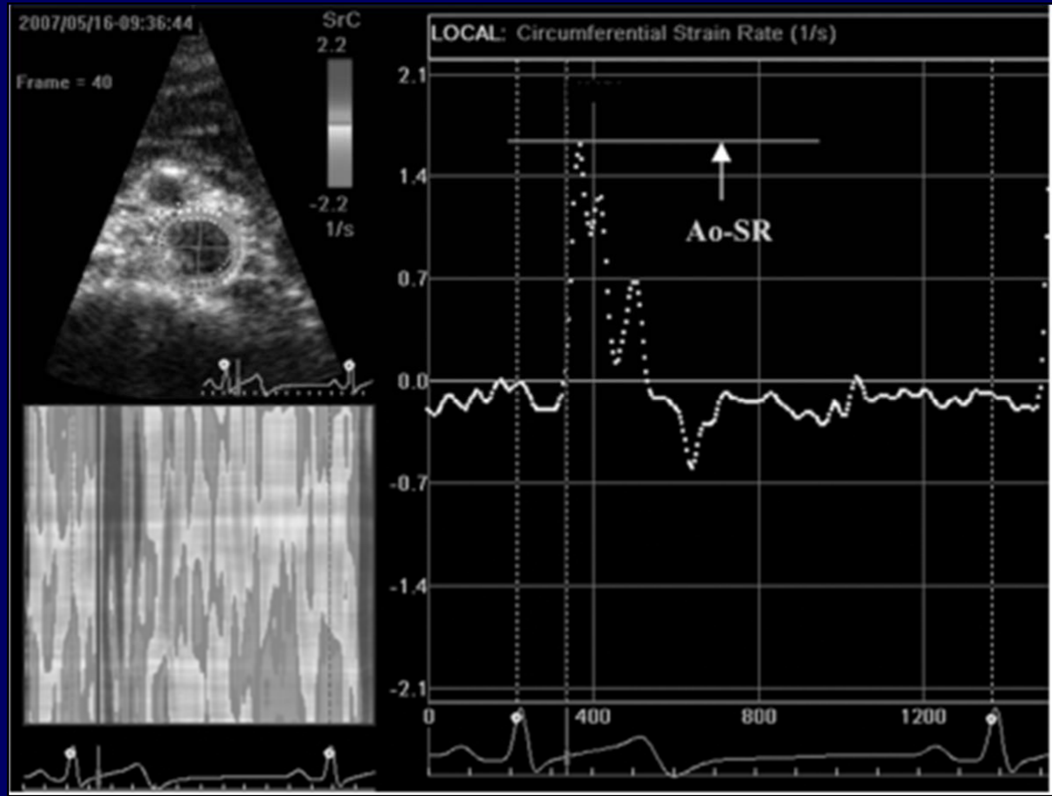
  (Kuppahally SS et al. Circ Cardiovasc Imaging 2010)

- LA strain is significantly reduced and LA stiffness index defined by the ratio of PCWP/LA systolic strain is the most accurate index identifying patients with diastolic heart failure

  (Kurt M et al. Circ Cardiovasc Imaging 2009)

Aortic Strain and Strain Rate





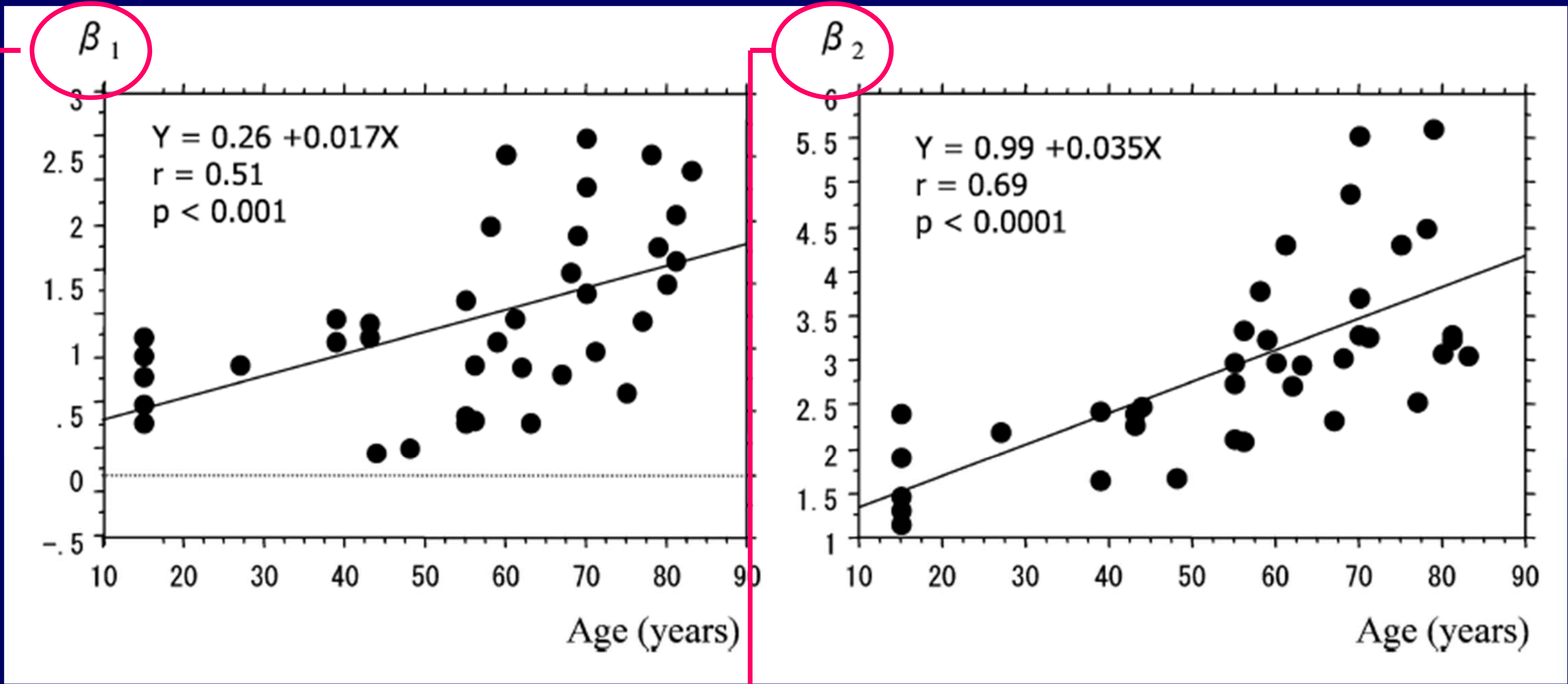
Oishi et al. Echocardiography 2008

Aortic Strain and Strain Rate

- Measurement of aortic circumferential strain/strain rate
  - : Short-axis images of the abdominal aorta
  - : Measured by 2D speckle tracking image method
- Peak circumferential Ao-S and Ao-SR
  - : Strongly correlated with age (r=-0.79, -0.81, respectively)
  - : Significantly lower in the middle-aged (30–60 years) and old-aged groups than in the young-aged group

Oishi et al. Echocardiography 2008

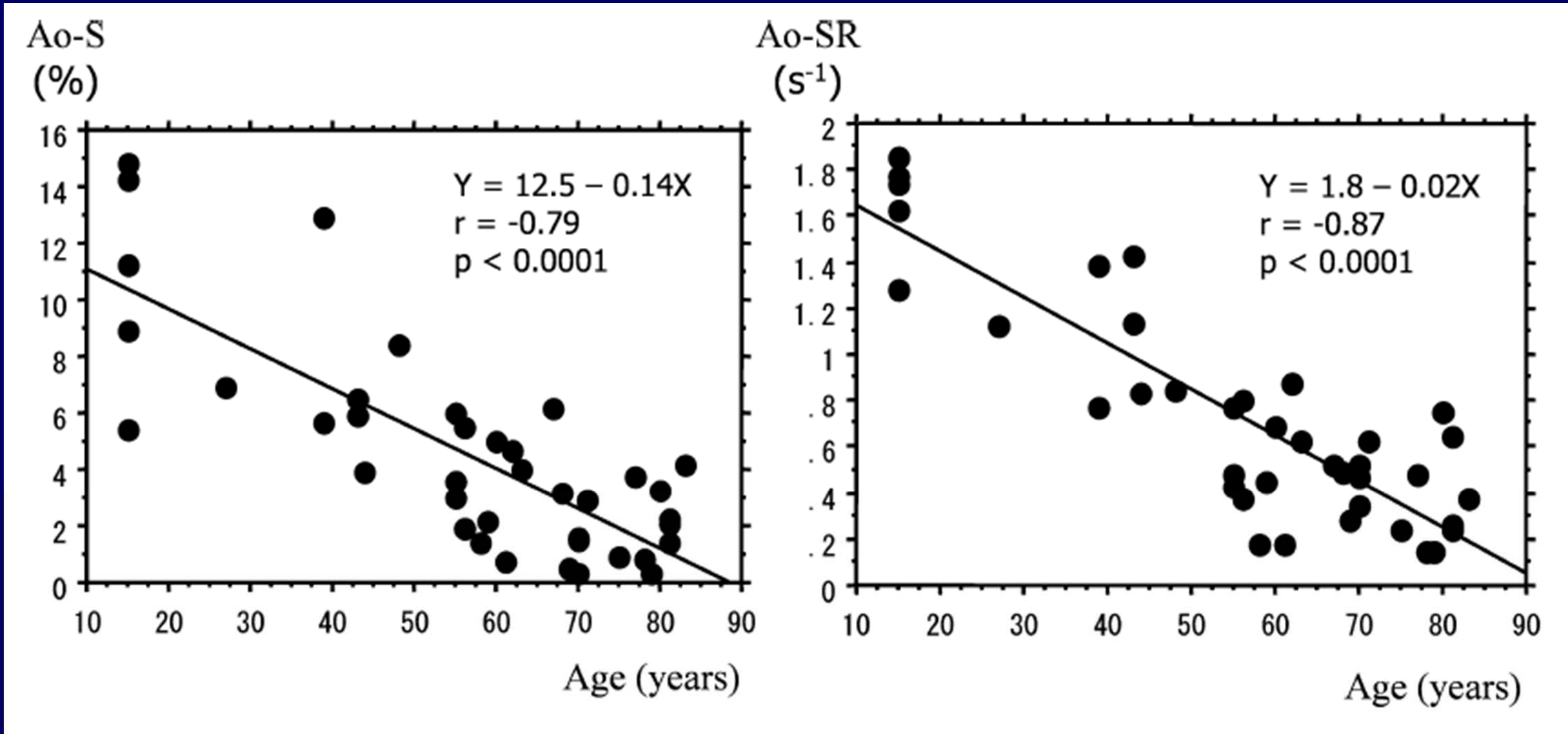
Aortic Stiffness Parameter β1/β2 and Ageing



Ln (SBP-DBP)/AoS by M-mode

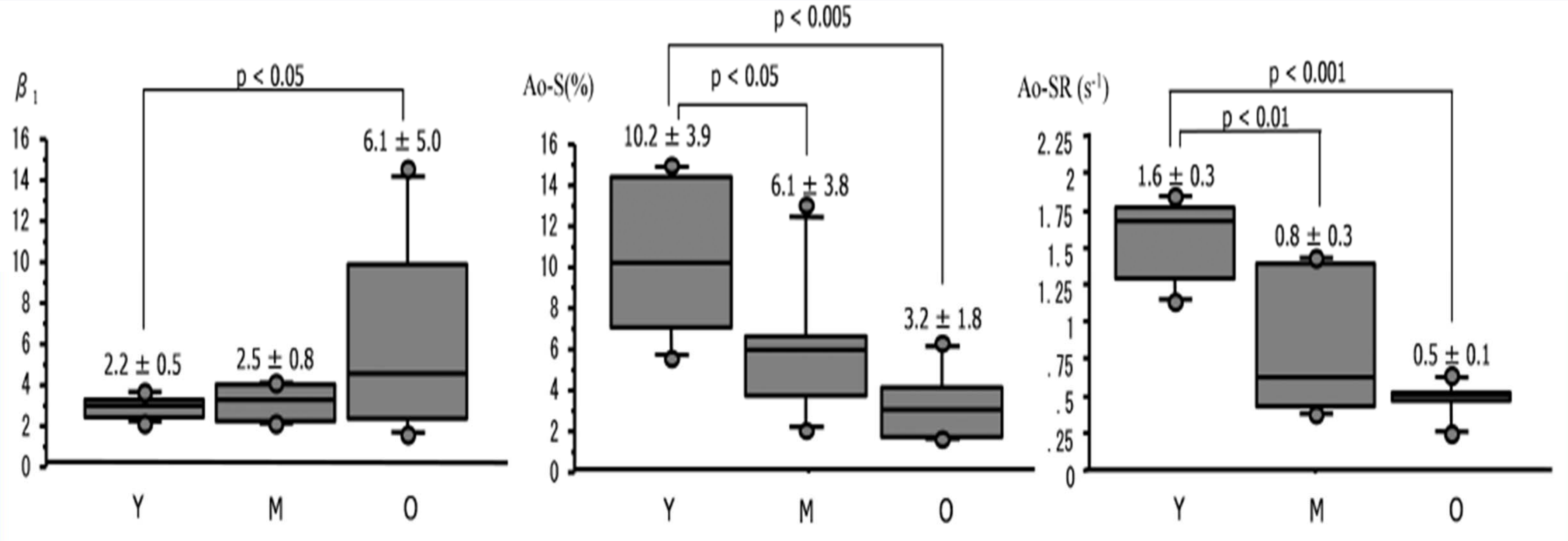
Ln (SBP-DBP)/AoS by 2D strain

Aortic Strain/Strain Rate and Ageing



Oishi et al. Echocardiography 2008

Aortic Stiffness and Ageing



Oishi et al. Echocardiography 2008

J Am Soc Echocardiogr. 2009 Dec;22(12):1382-8.

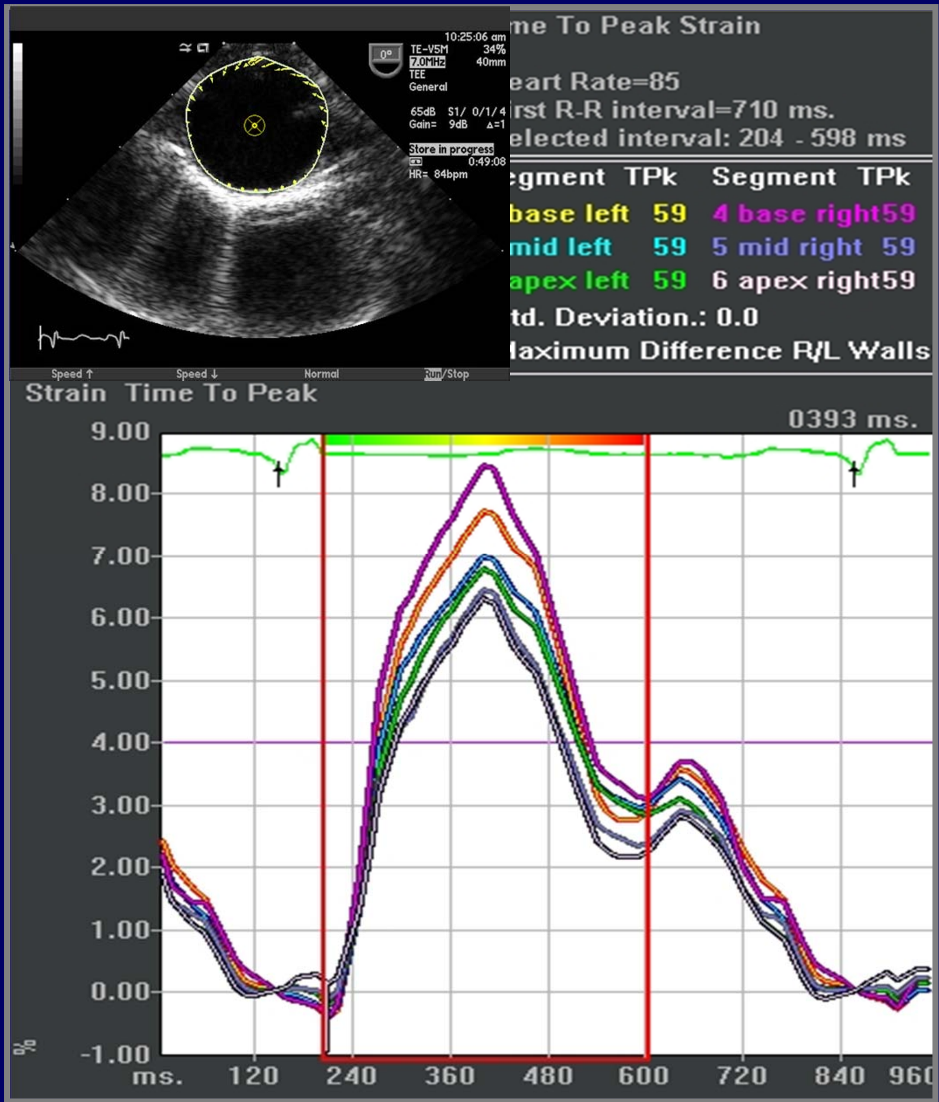
Usefulness of aortic strain analysis by velocity vector imaging as a new echocardiographic measure of arterial stiffness.

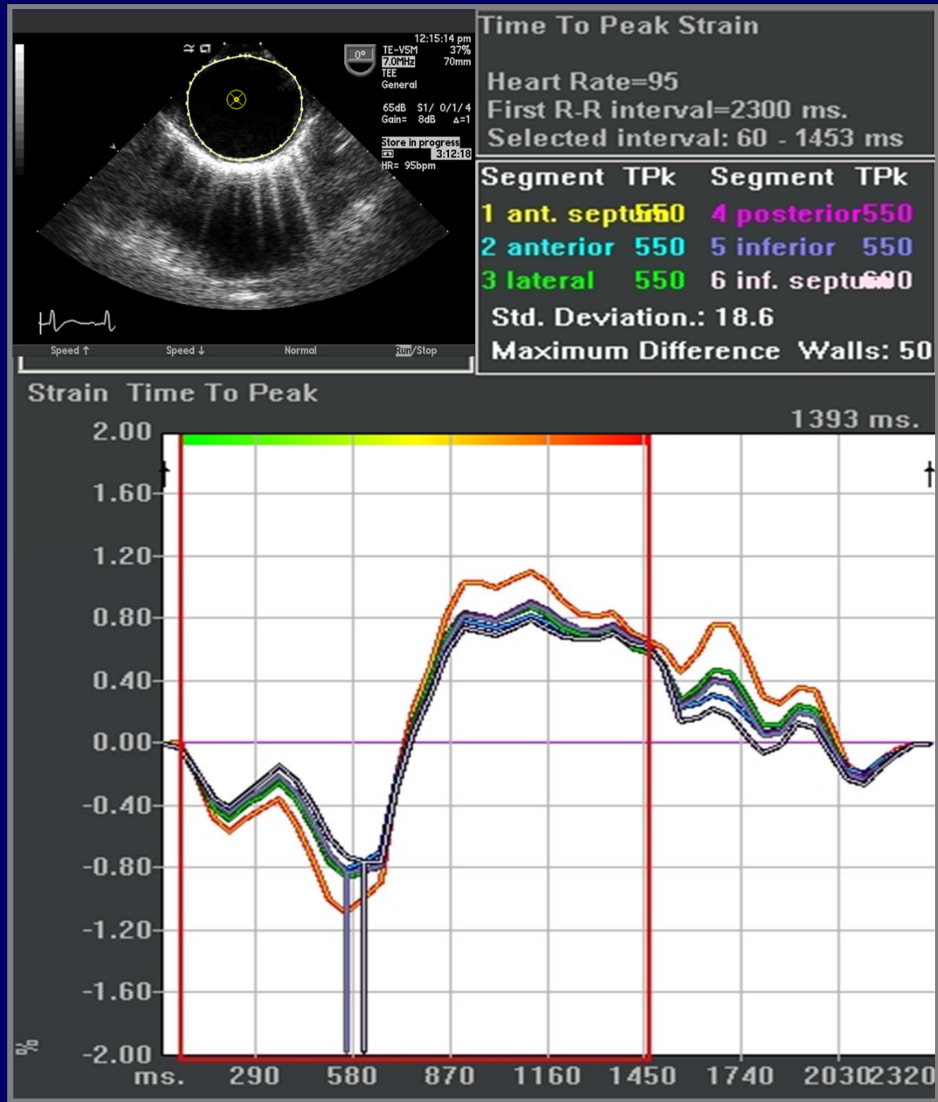
Kim KH, Park JC, Yoon HJ, Yoon NS, Hong YJ, Park HW, Kim JH, Ahn Y, Jeong MH, Cho JG, Kang JC.

The Heart Center of Chonnam National University Hospital, Chonnam National University Research Institute of Medical Sciences, Gwangju, Korea.

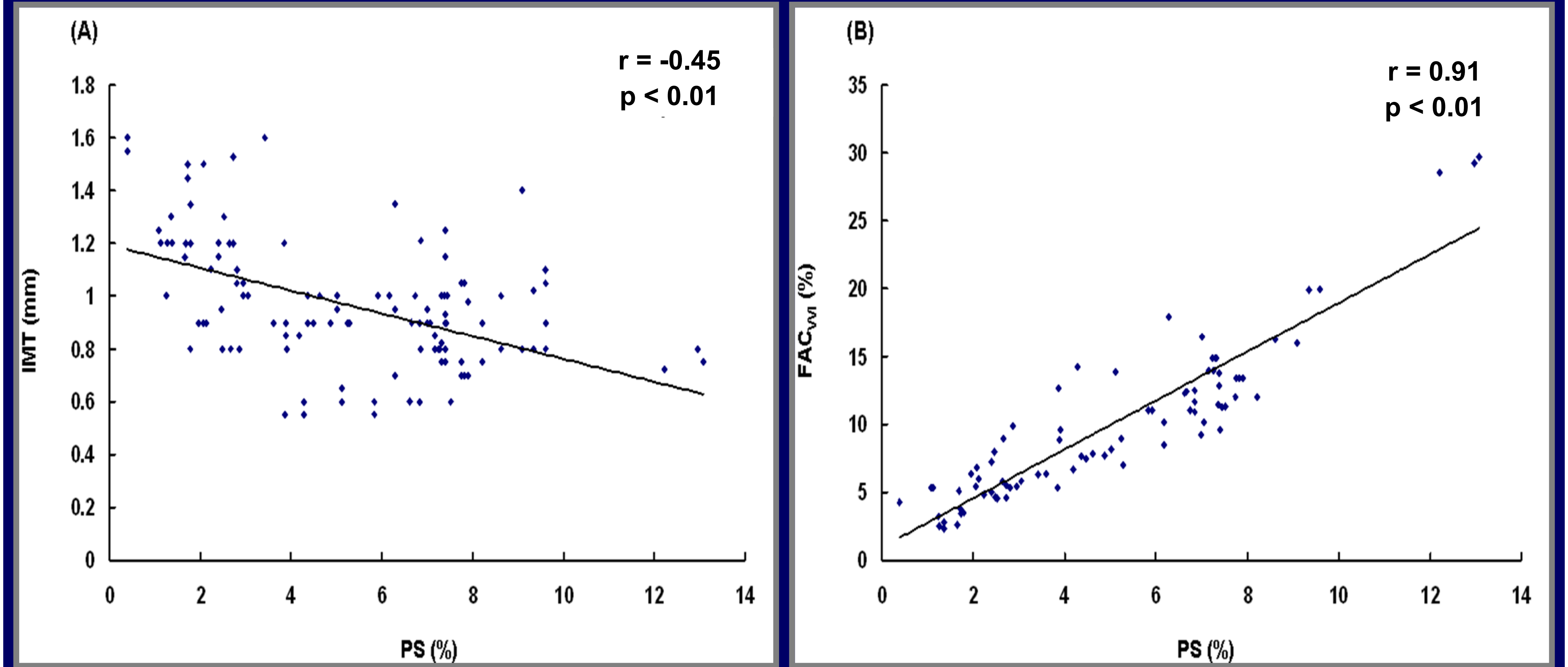
BACKGROUND: The role of velocity vector imaging (VVI) in evaluating arterial stiffness is not well known. We investigated the usefulness of vascular strain analysis by VVI in evaluating arterial stiffness. METHODS: Heart-femoral and brachial-ankle pulse wave velocities (PWVs) were measured as standard parameters of arterial stiffness. Intima-media thickness (IMT), fractional shortening (FS), fractional area change (FAC) by two-dimensional (2D) and VVI methods, and peak circumferential strain (PS) of the descending thoracic aorta were measured as echocardiographic parameters of arterial stiffness and compared with PWV in 137 patients (53.8 +/- 13.4 years, 71 male). RESULTS: Heart-femoral PWV was 9.0 +/- 2.4 m/s, and brachial-ankle PWV was 14.1 +/- 3.0 m/s. Aortic IMT was 0.97 +/- 0.23 mm, and FS was 10.0% +/- 4.0%. FAC was 10.9% +/- 5.2% by 2D tracing and 10.3% +/- 5.1% by the VVI method. PS was 5.4% +/- 3.0%. PS showed significant negative correlation with aortic IMT (r = -0.49, P < .01) and PWV (heart-femoral: r = -0.67, brachial-ankle: r = -0.75, P < .01). PS showed significant positive correlation with FS (r = 0.80, P < .01) and FAC (2D tracing: r = 0.86, VVI: r = 0.88, P < .01). Aortic IMT showed significant positive correlation with PWV (heart-femoral: r = 0.44, brachial-ankle: r = 0.60, P < .01) and negative correlation with FS (r = -0.61, P < .01) and FAC (2D tracing: r = -0.51, VVI: r = - 0.51, P < .01). FS showed significant negative correlation with PWV (heart-femoral: r = -0.54, brachial-ankle: r = -0.72, P < .01). FAC showed significant negative correlation with heart-femoral (2D method: r = -0.61, VVI: r = -0.62, P < .01) and brachial-ankle (2D tracing: r = -0.71, VVI: r = -0.73, P < .01) PWV. CONCLUSION: PS and FAC measured by VVI were significantly associated with parameters of arterial stiffness and thus can be used as new echocardiographic parameters of arterial stiffness.

Aortic Strain: VVI Measurements



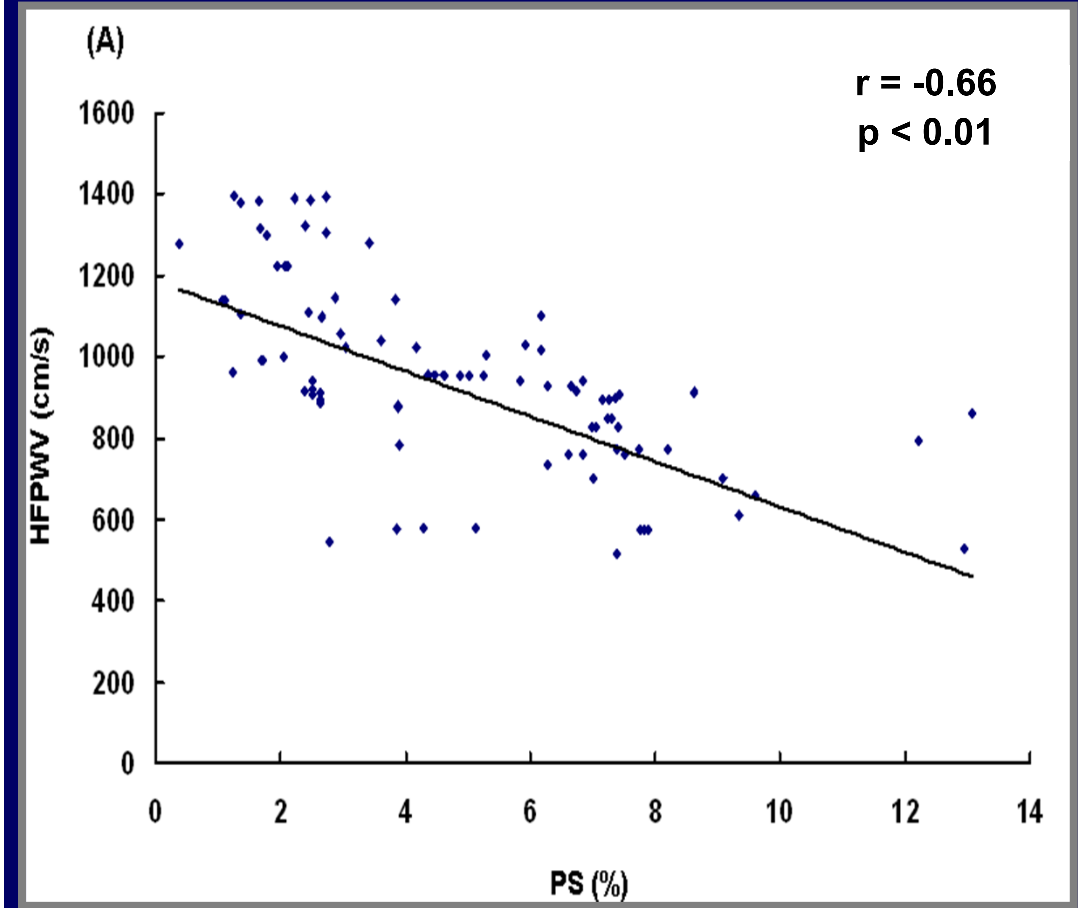


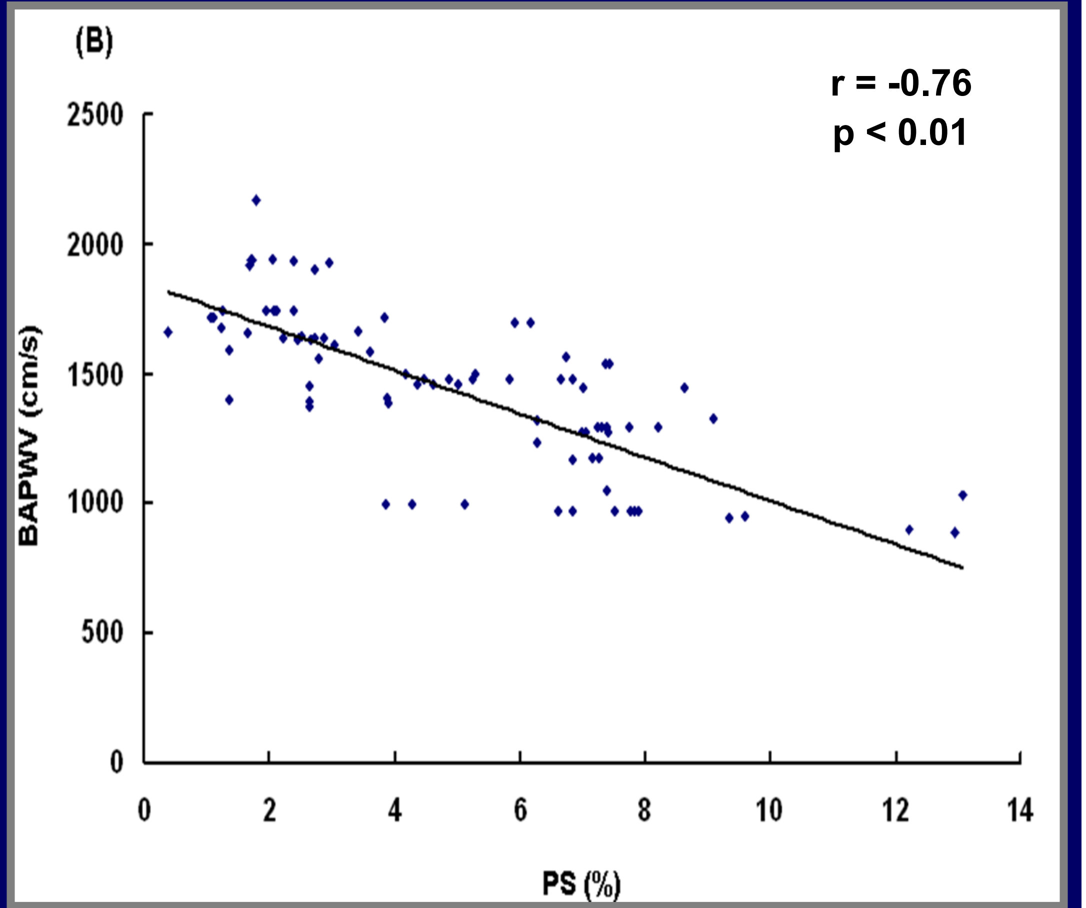
Peak Aortic Strain and IMT or FAC_{VVI}



Kim KH et al. J American Soc Echocardiogr 2009

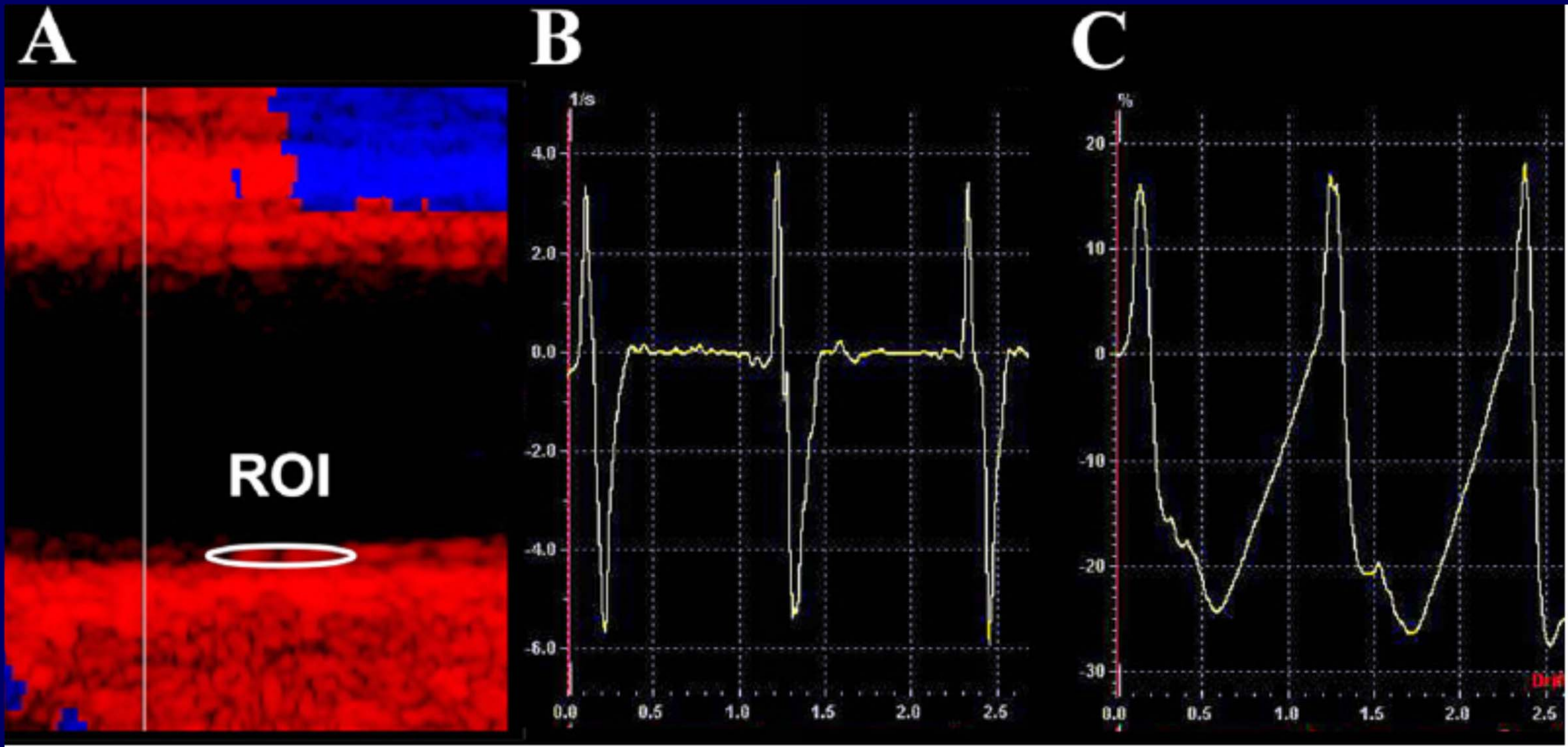
Peak Aortic Strain and Arterial Stiffness





Kim KH et al. J American Soc Echocardiogr 2009

Carotid Strain Measurement



Kawasaki T et al. JASE 2009

Direct Measurement of Wall Stiffness for Carotid Arteries by Ultrasound Strain Imaging

Toshihiro Kawasaki, RDCS, Shota Fukuda, MD, Kenei Shimada, MD, Kumiko Maeda, RDCS, Ken Yoshida, MD, Hiroe Sunada, RDCS, Hitoshi Inanami, MD, Hidemasa Tanaka, MD, Satoshi Jissho, MD, Haruyuki Taguchi, MD, Minoru Yoshiyama, MD, and Junichi Yoshikawa, MD, *Osaka, Japan*

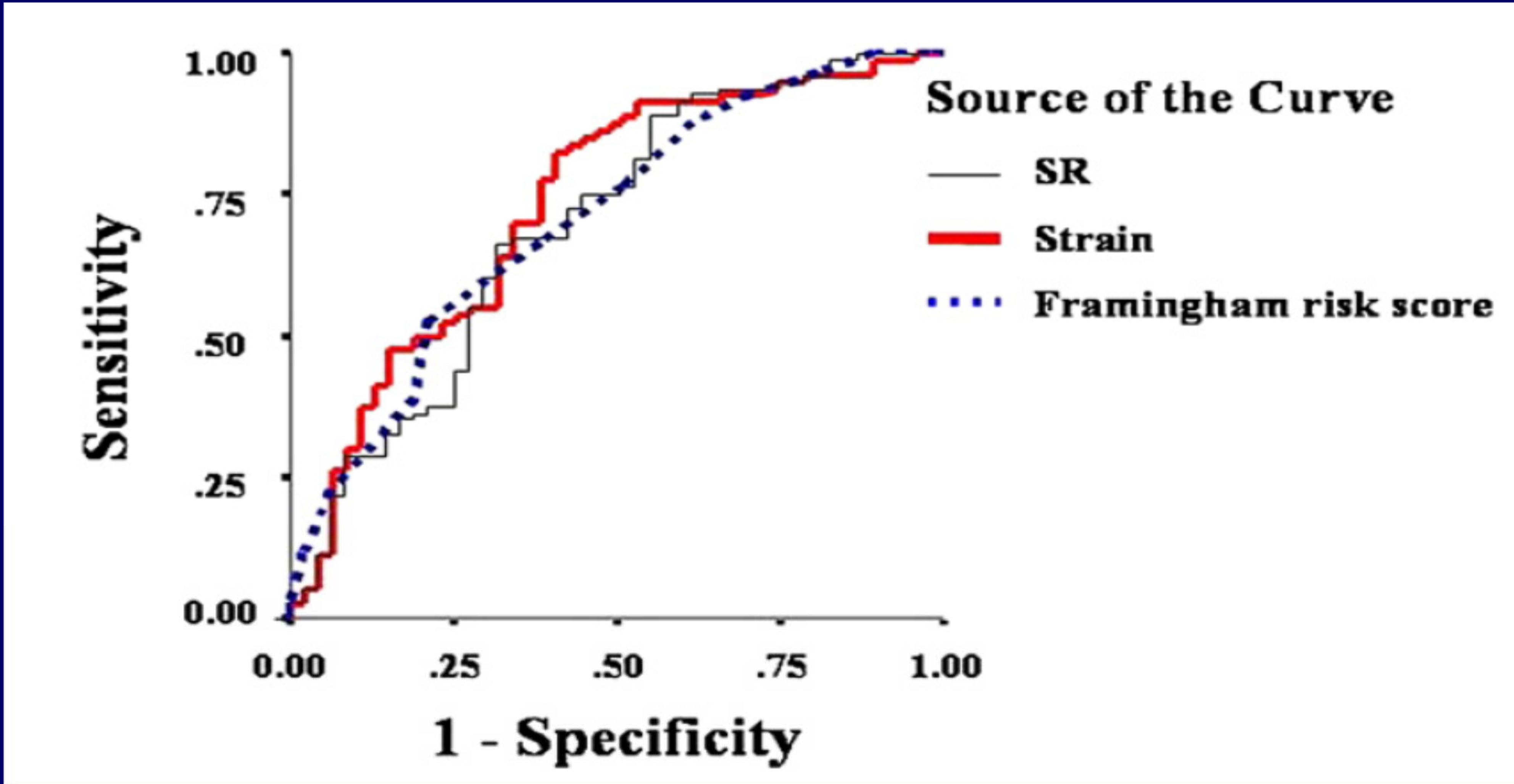
Objective: The elastic properties of the carotid arterial wall have not been directly characterized in the clinical setting. Strain rate (SR) imaging is a newly developed echocardiographic method developed for imaging the

Results: Age and Framingham risk score were significantly related to SR and strain, respectively ($r = 0.62$-0.67, all $P < .001$). These strain measurements were significantly correlated with distensibility coefficient and intima–media thickness, respectively ($r = 0.30$-0.56, all $P < .001$). Similar values of the areas under the receiver operating characteristic curves were obtained among Framingham risk score (0.70 ± 0.05), SR (0.67 ± 0.05), and strain (0.73 ± 0.05).

Conclusion: This study demonstrated that the elastic properties of the carotid artery wall were directly characterized by using SR imaging in patients with CAD. (J Am Soc Echocardiogr 2009;22:1389-95.)

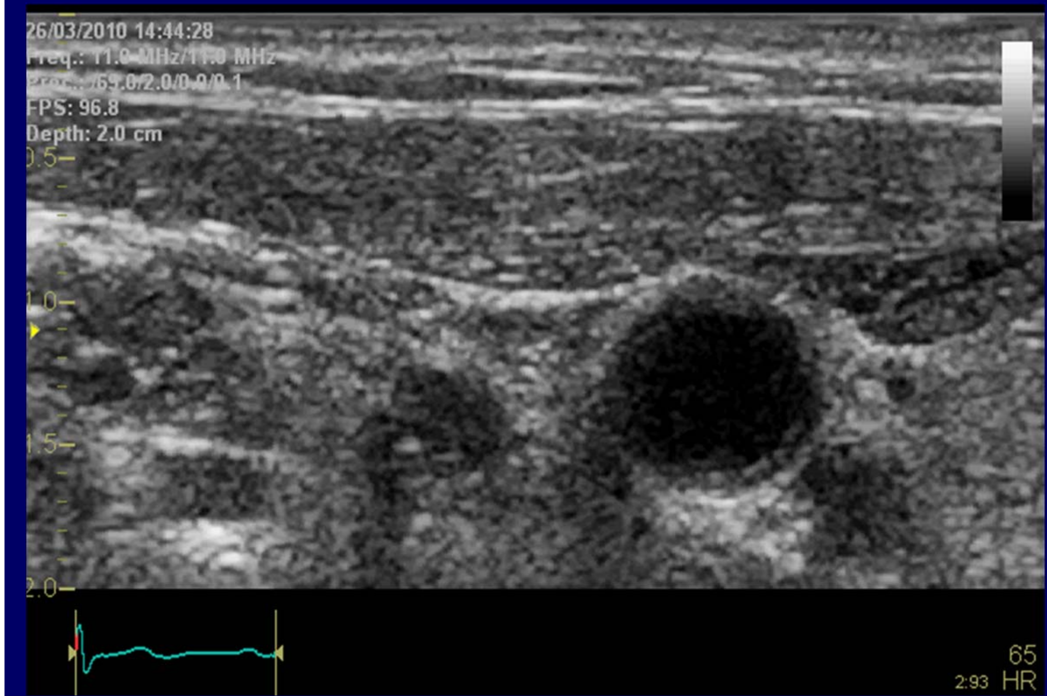
Keywords: Atherosclerosis, Carotid arteries, Coronary artery disease, Strain rate imaging

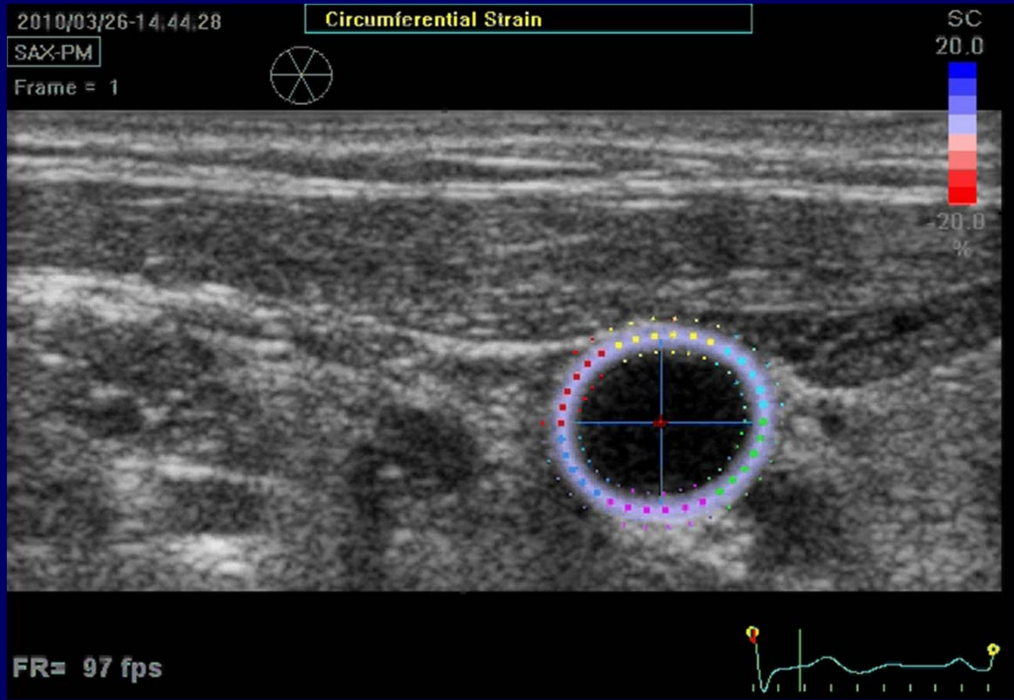
Prediction of Coronary Stenosis



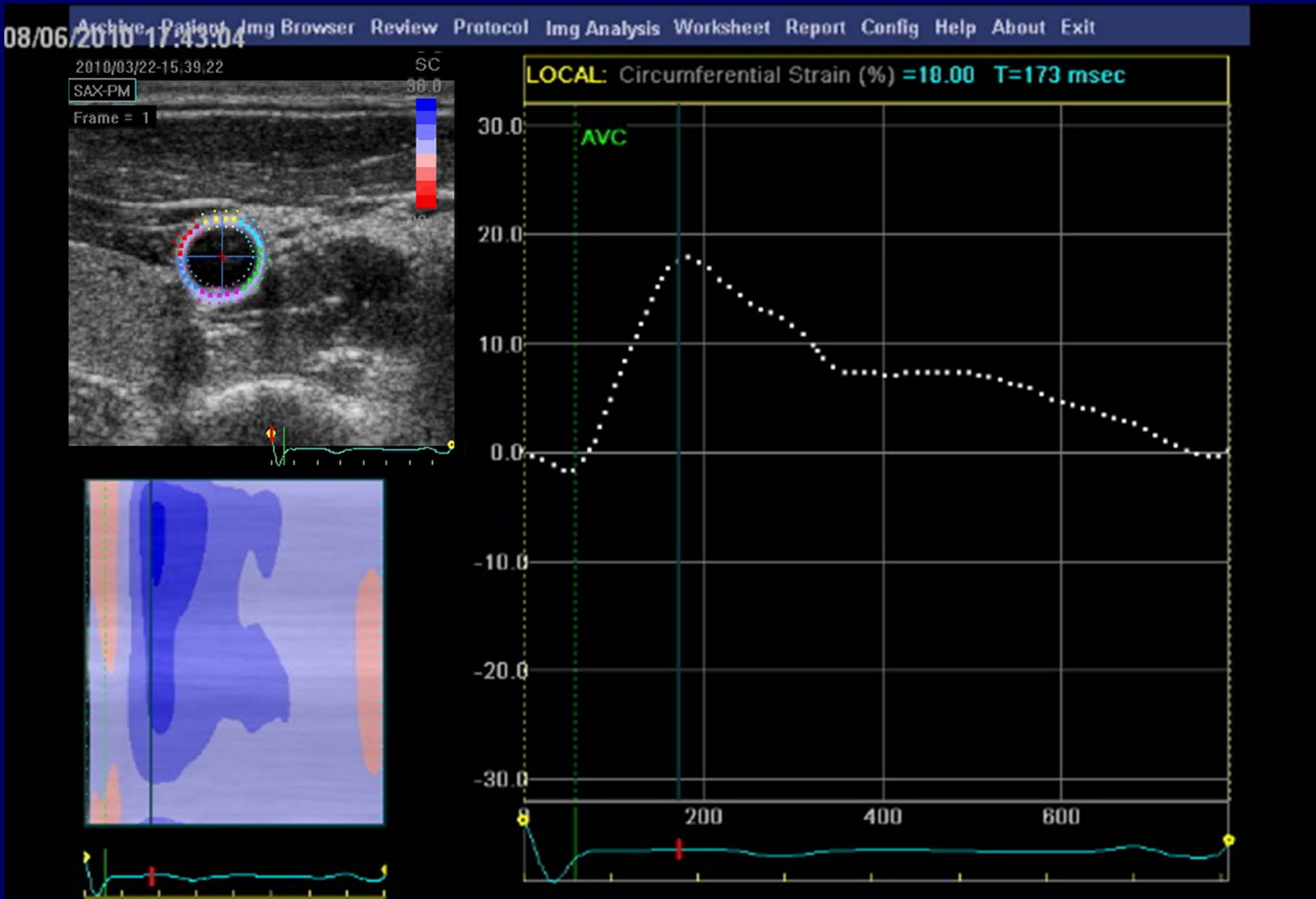
Kawasaki T et al. JASE 2009

2D Strain of Carotid Artery

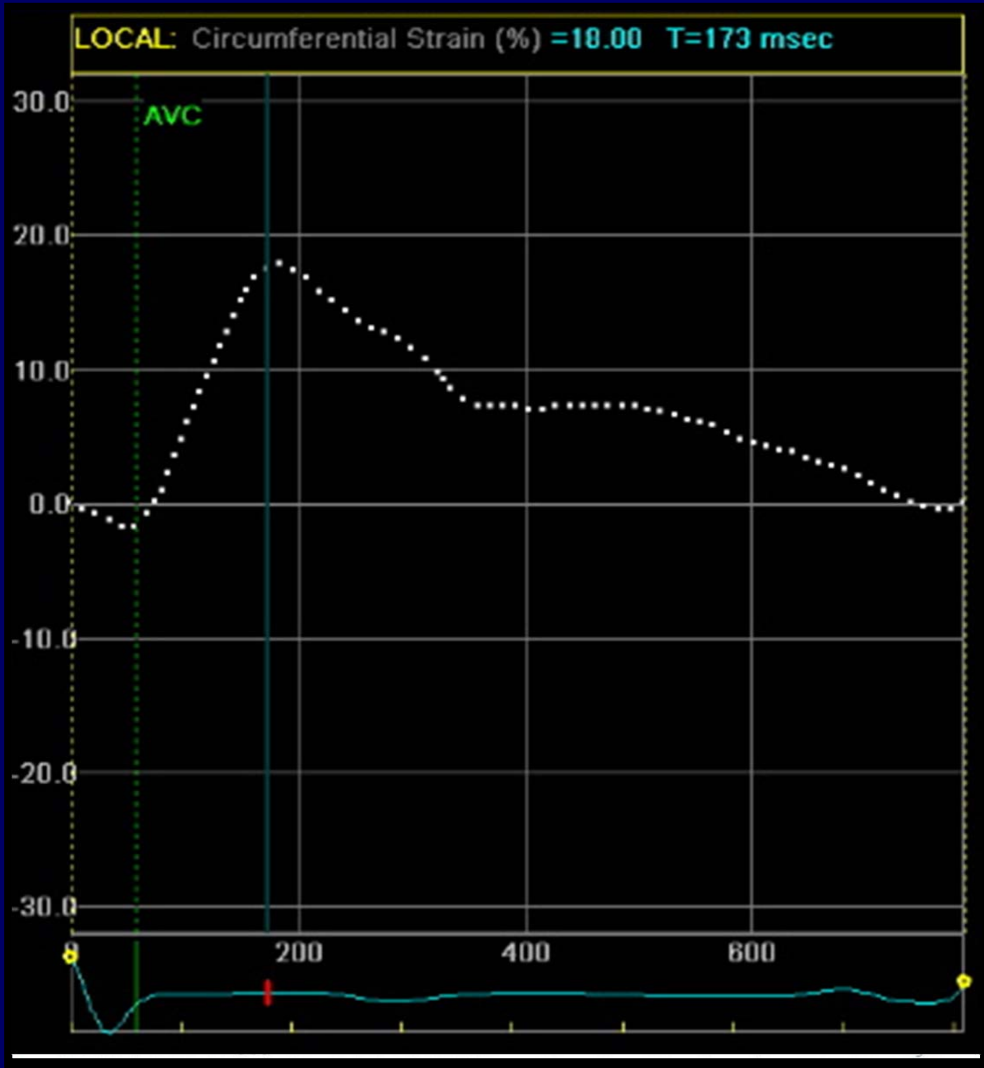


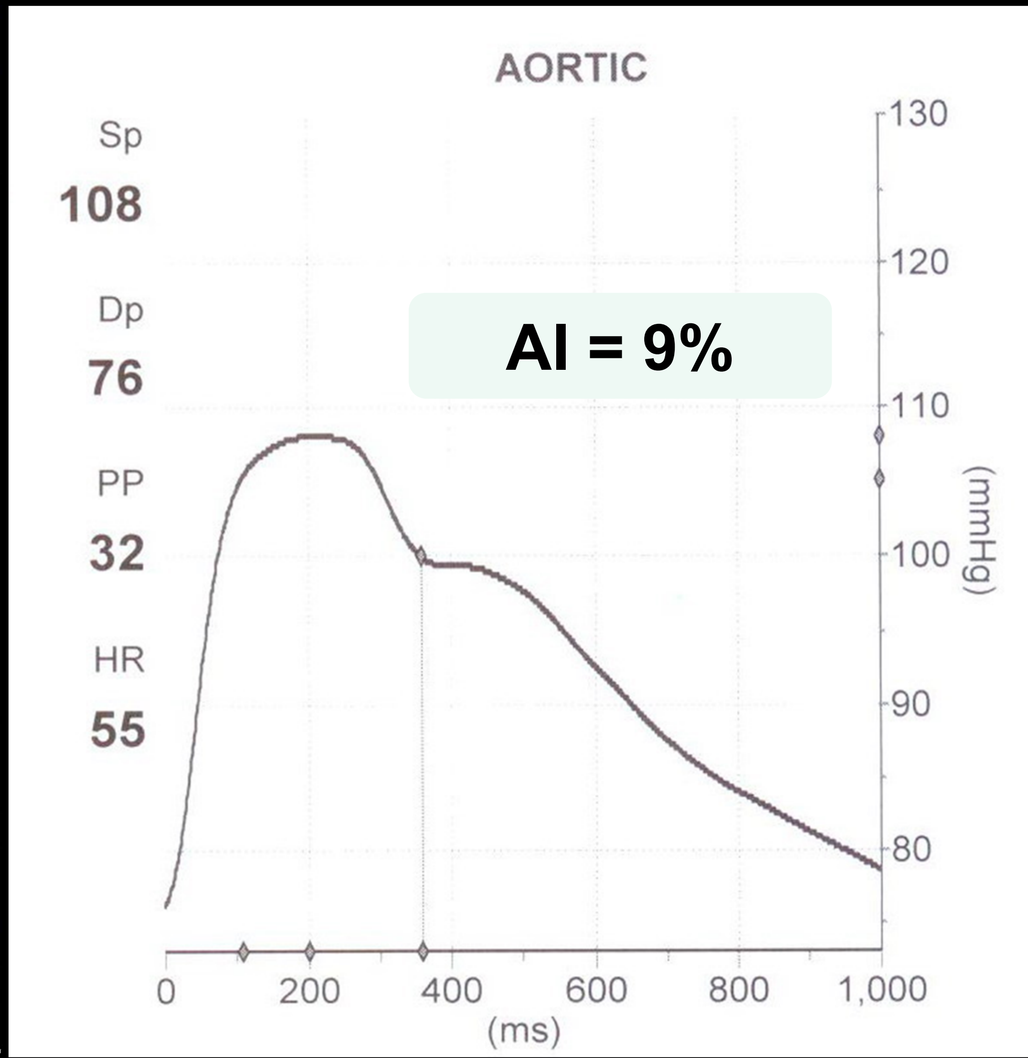


2D Strain of Carotid Artery

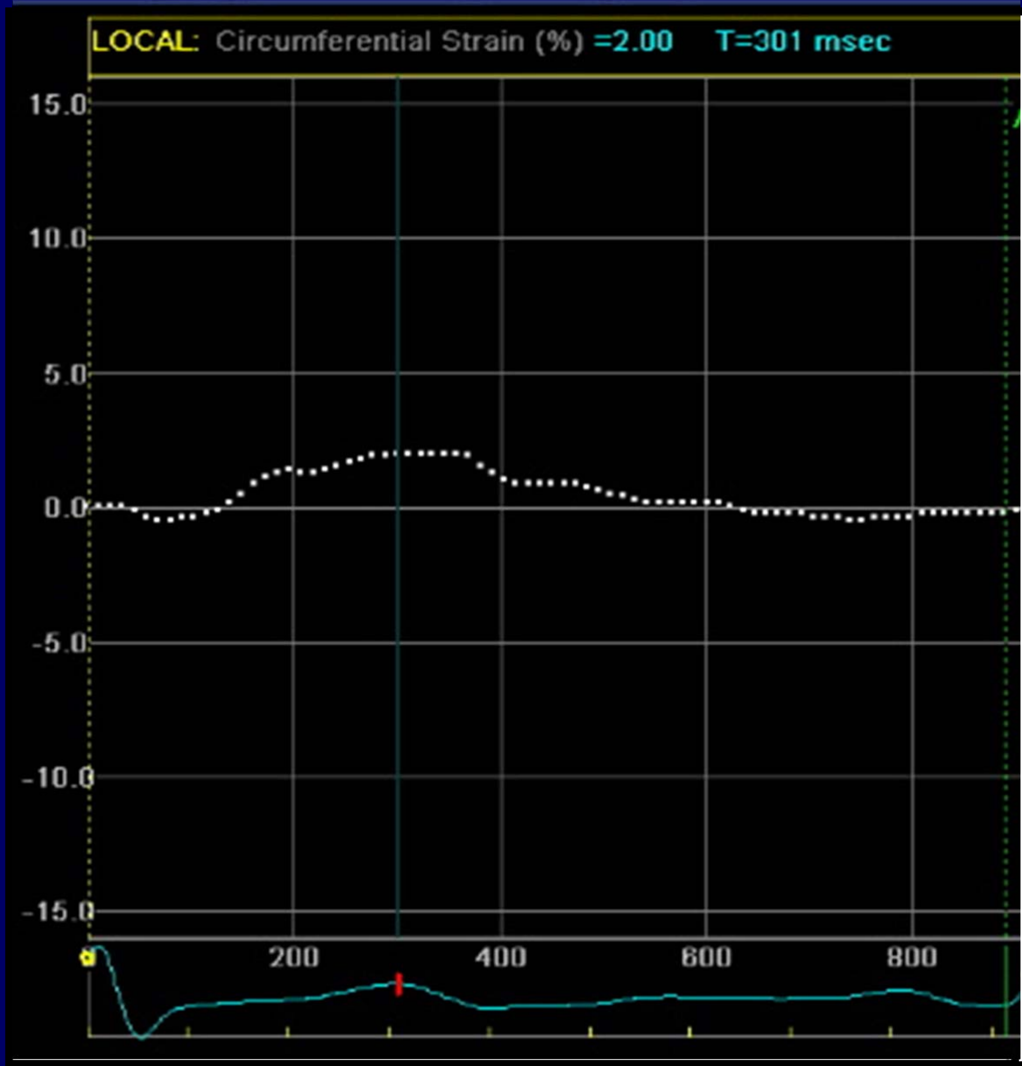


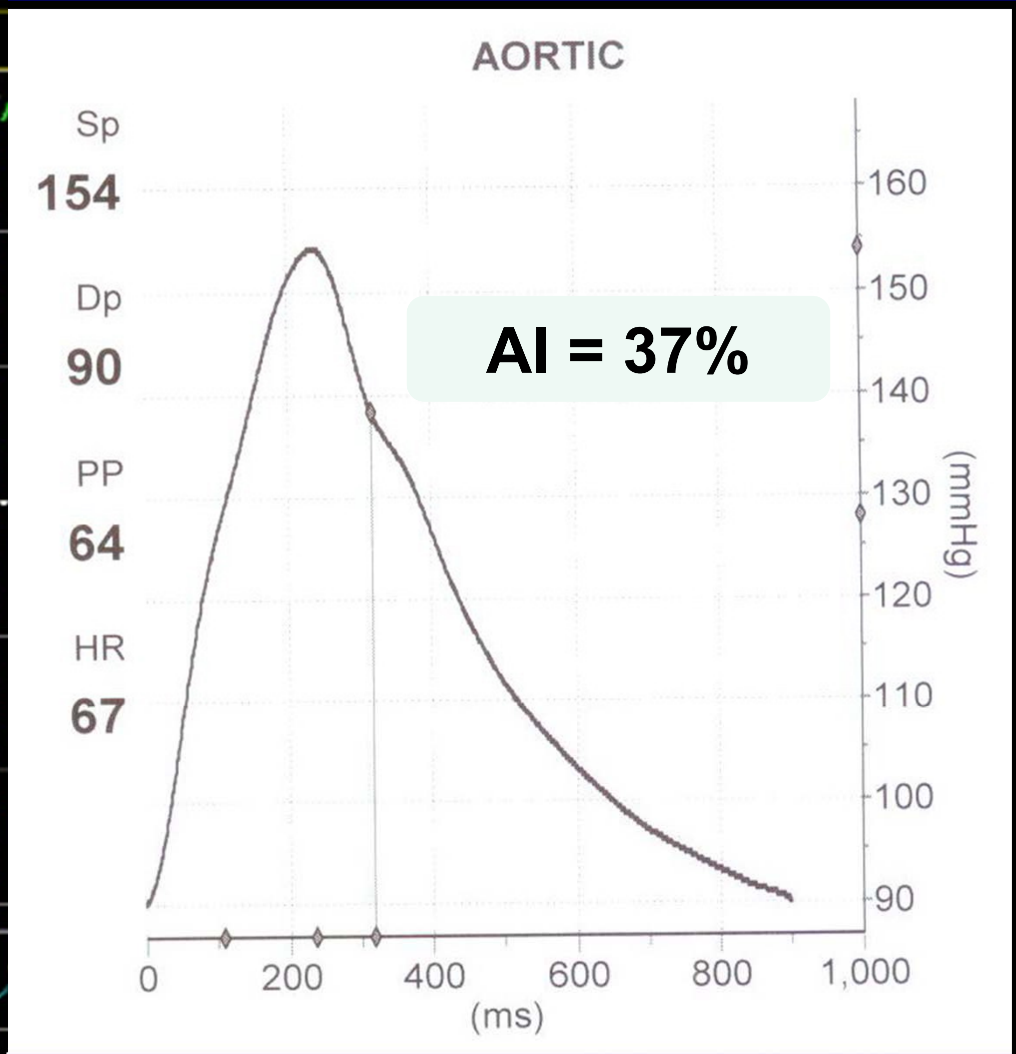
Carotid 2D Strain and Arterial Stiffness





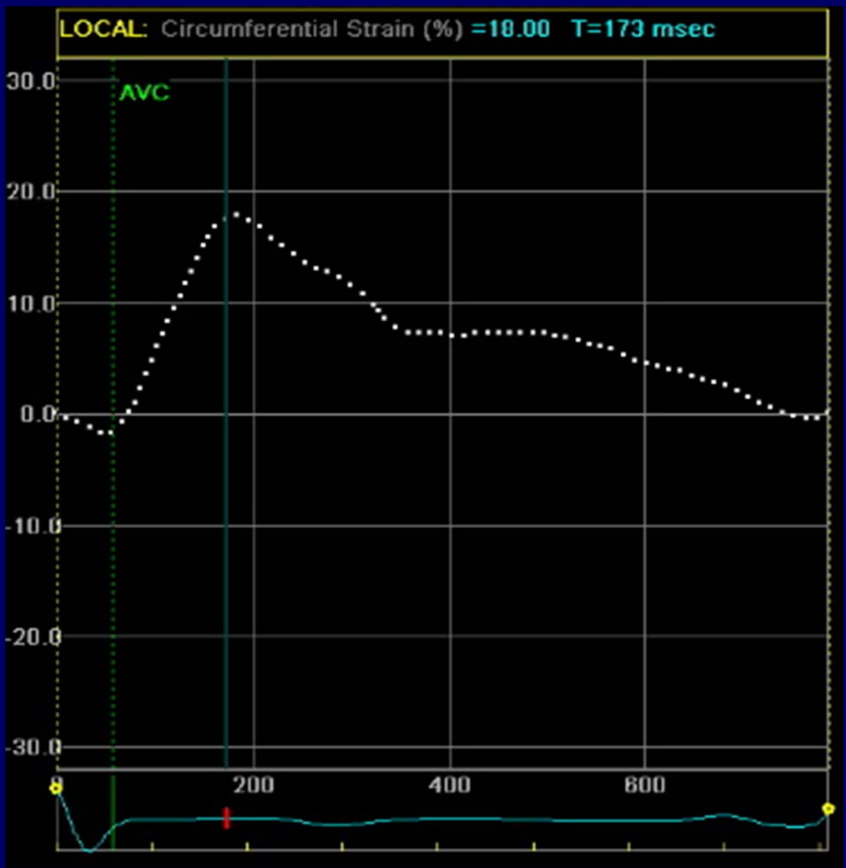
Carotid 2D Strain and Arterial Stiffness



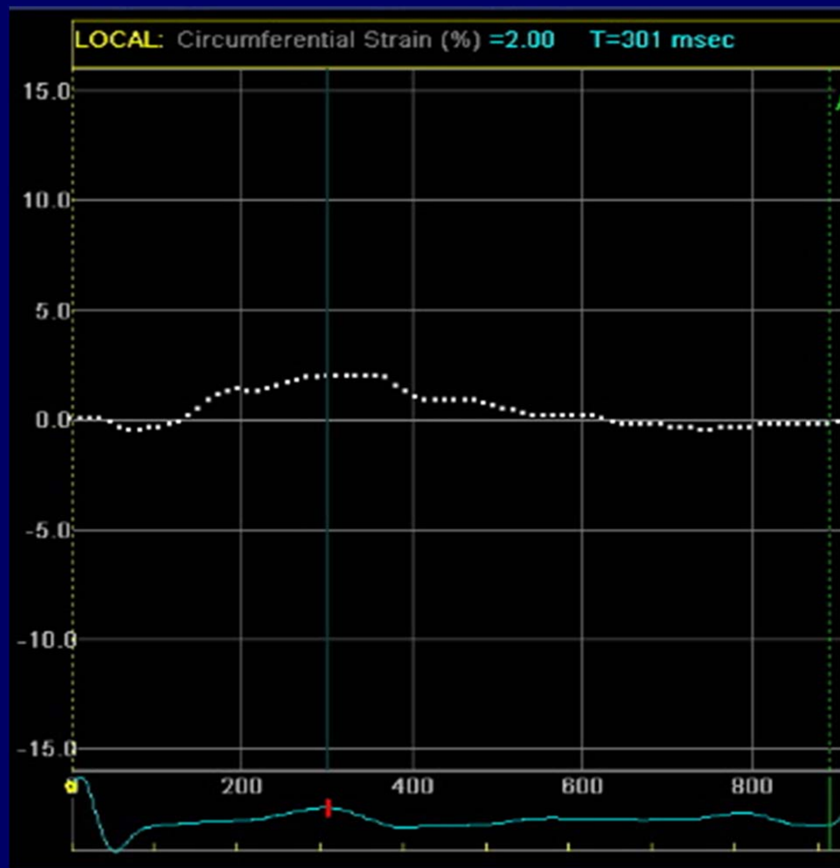


2D Strain of Carotid Artery

Normal, young adult



Old, hypertensive patient



Take Home Messages

- Strain imaging to other than LV
  : Feasible
  : May be useful in various clinical settings
- Not recommend in routine clinical practice
  : Lack of reproducibility
  : Paucity of data
- Remain research tool in experienced labs until their limitations can be overcome
- Further larger studies will be needed