Long axis function and torsion in heart failure.

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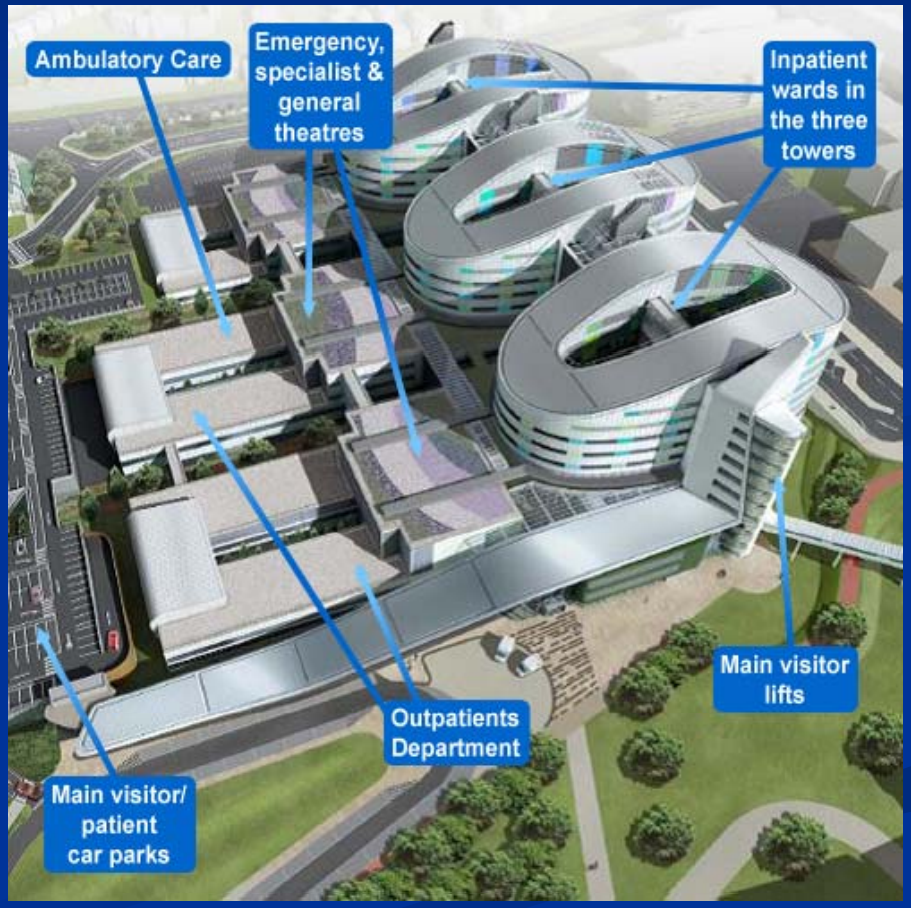
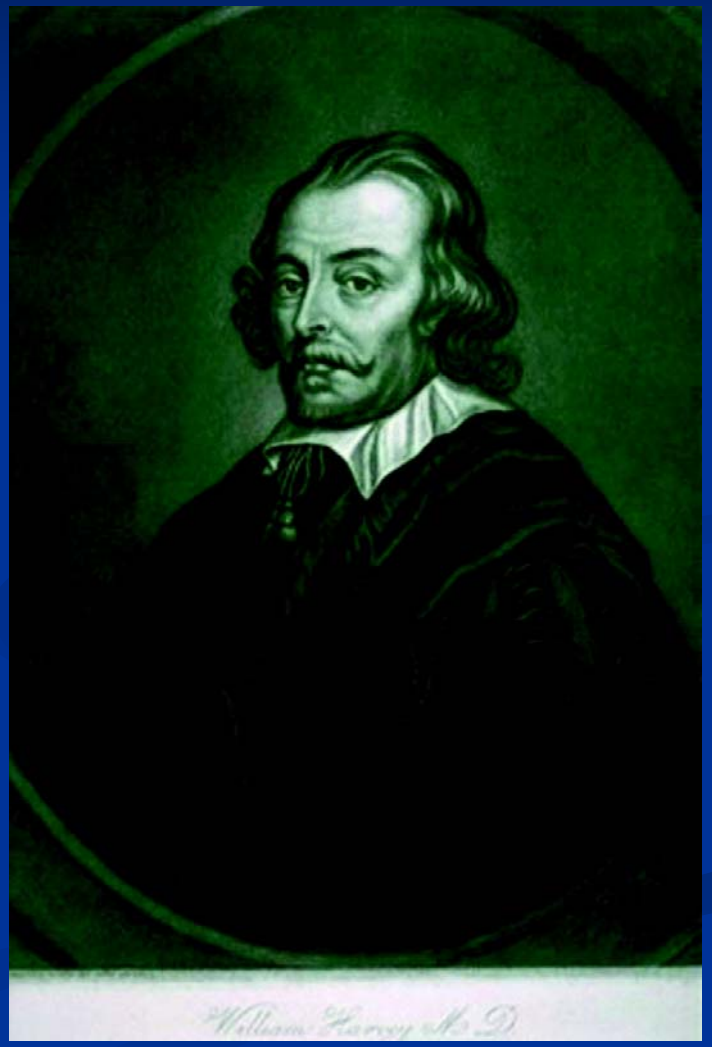


Twisting/rotation

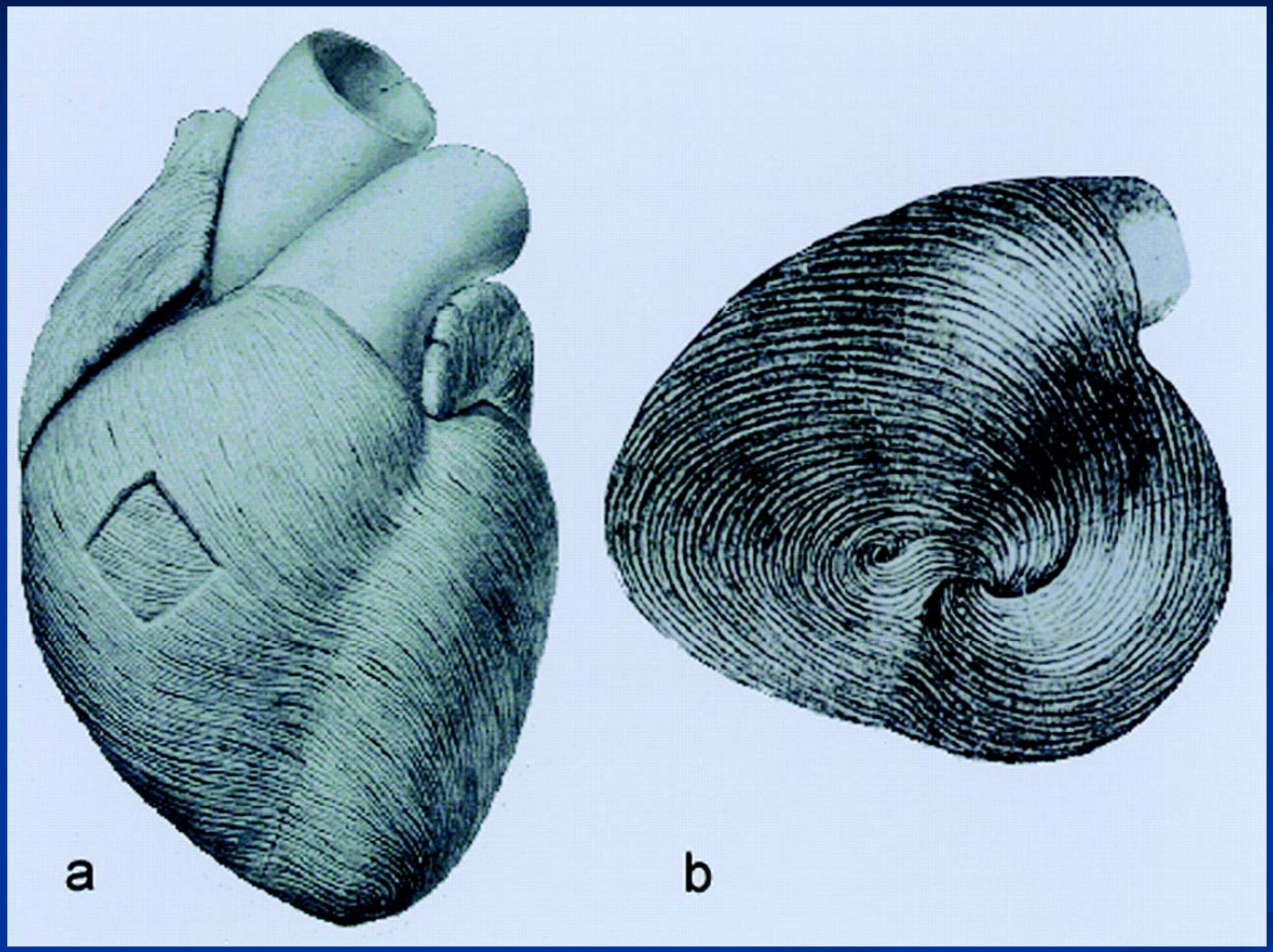
- Sir William Harvey in 1628, 'Exercitatio Anatomica De Motu Cordis et Sanguinis in Animalibus', a twisting motion of the ventricle during contraction was first described after observation of open chested animal hearts.



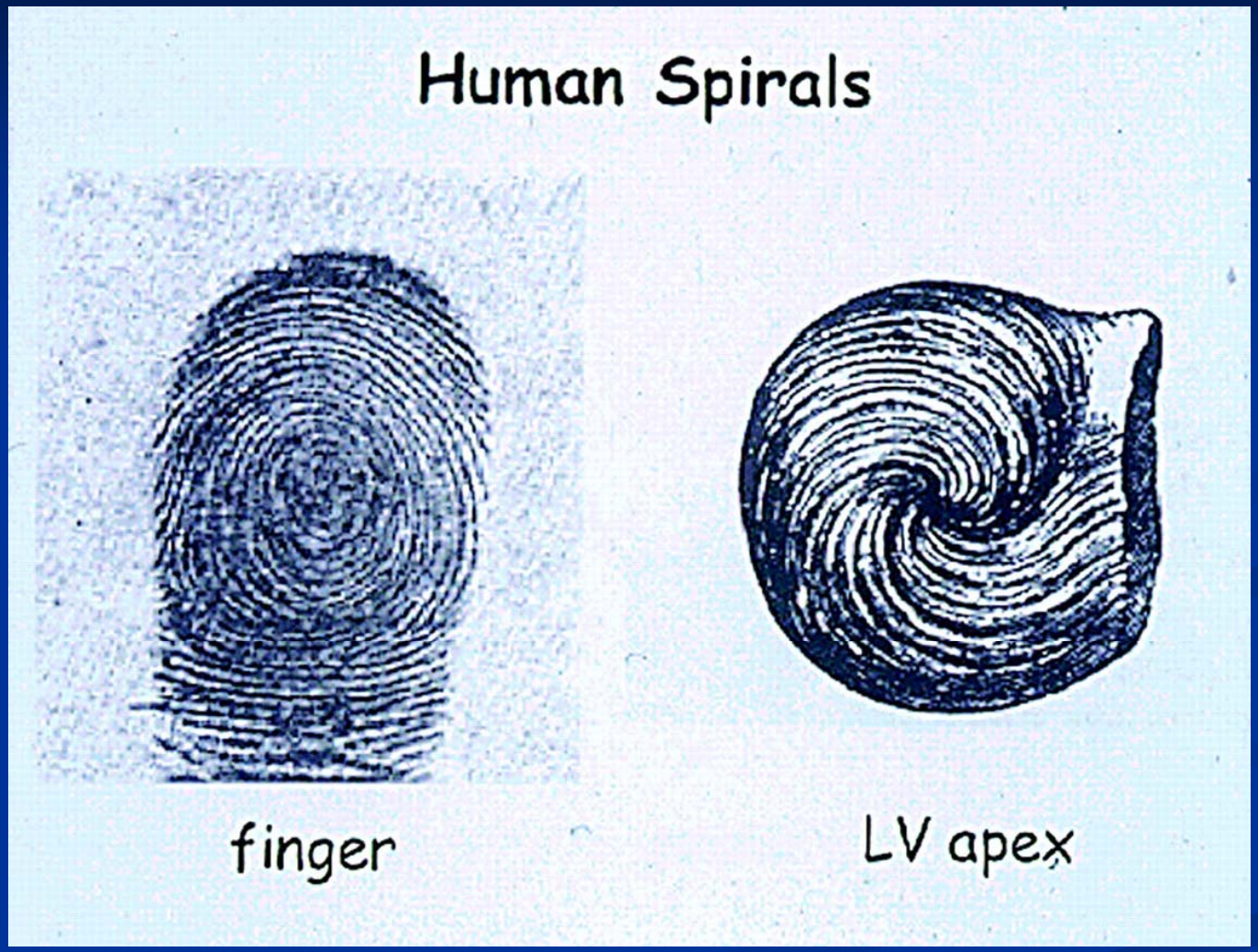
(Harvey W, Leake CD. Exercitatis Anatomica de Motu Cordis et Sanguinis in Animalibus. Frankfurt, 1628.

- Torsion refers to the counterclockwise rotation of LV apex with respect to the LV base during systole, followed by untwisting in the opposite direction during isovolumic relaxation and filling

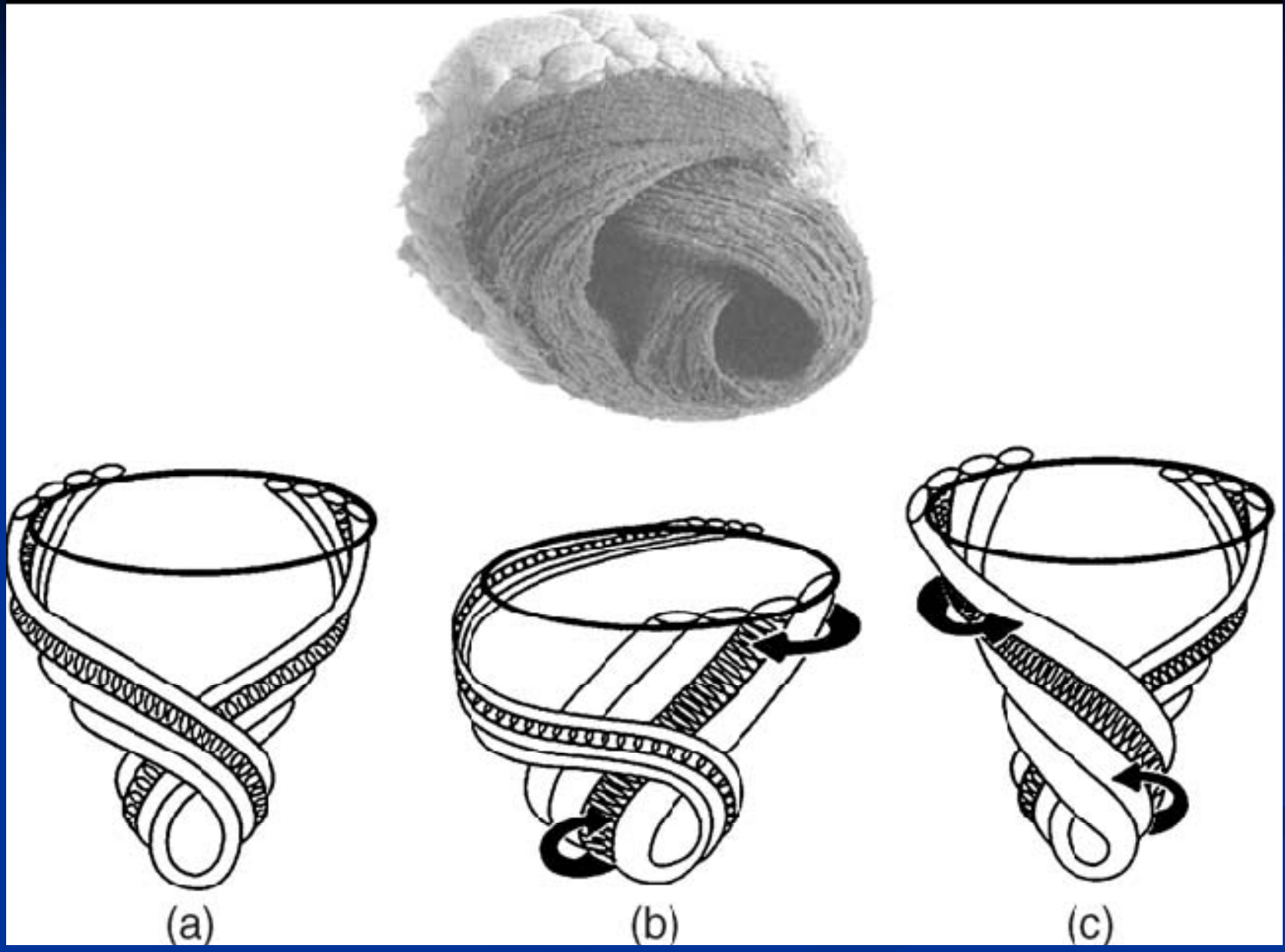
- Ascribed to assymetrical shortening of the internal and the external spiral muscle layers of the ventricular wall resulting in storage of potential energy when released contribute to ventricular suction and early diastolic filling



Buckberg G. D.; J Thorac Cardiovasc Surg 2002;124:863-883

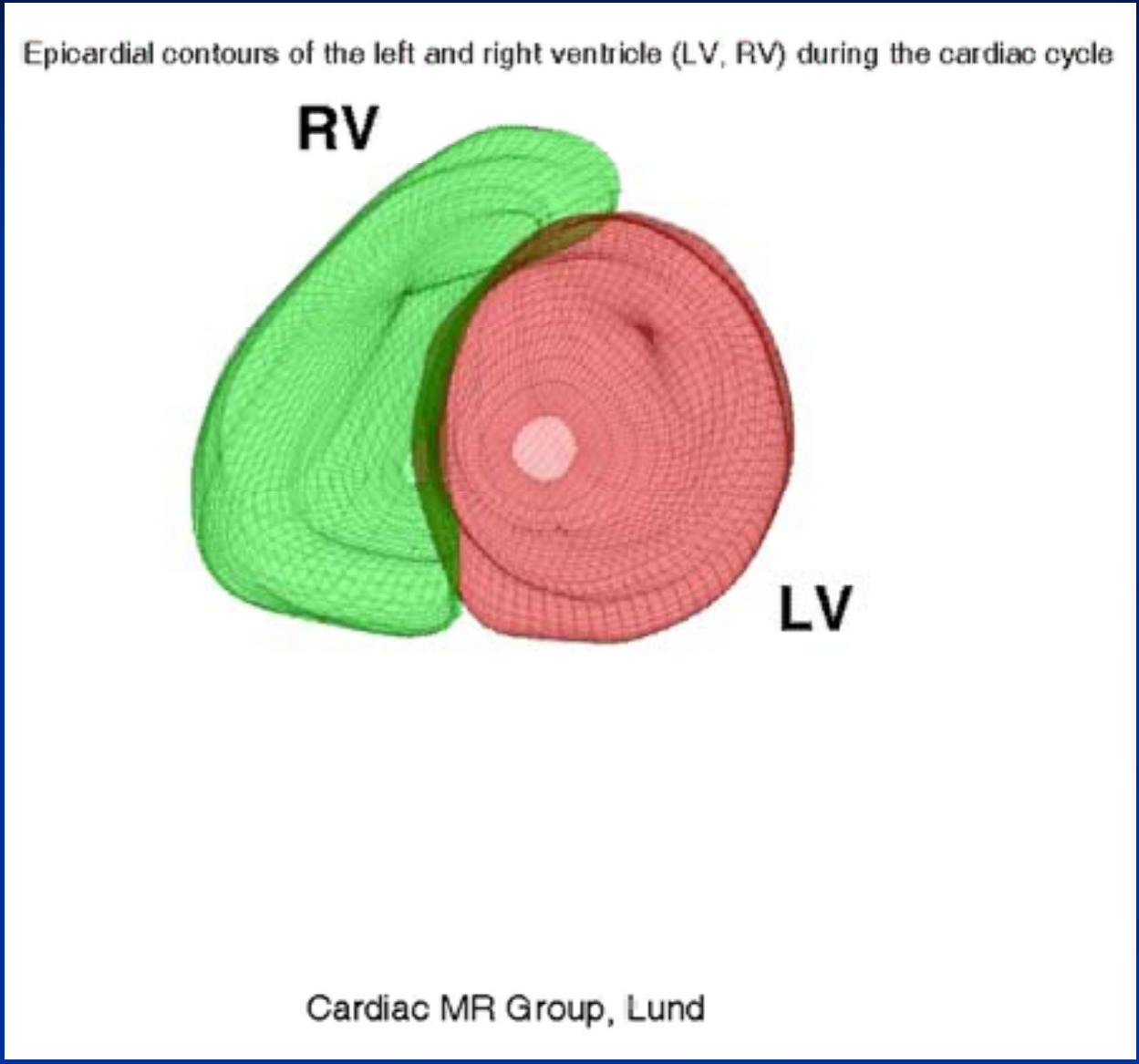


Buckberg G. D.; J Thorac Cardiovasc Surg 2002;124:863-883



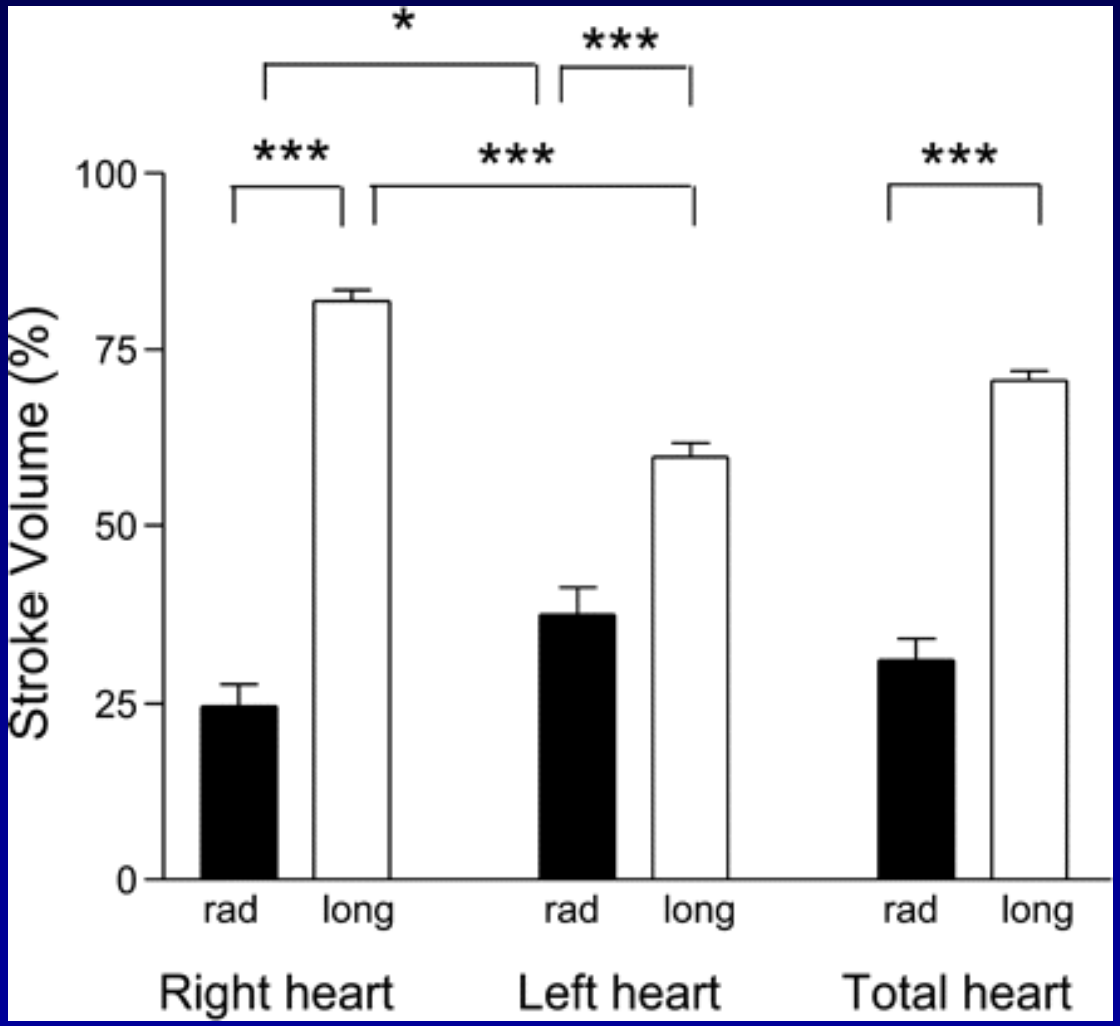
Torrent-Guasp et al Eur J Cardiovasc Surgery 2004;25:376-386

Importance of AV plane displacement- long axis function



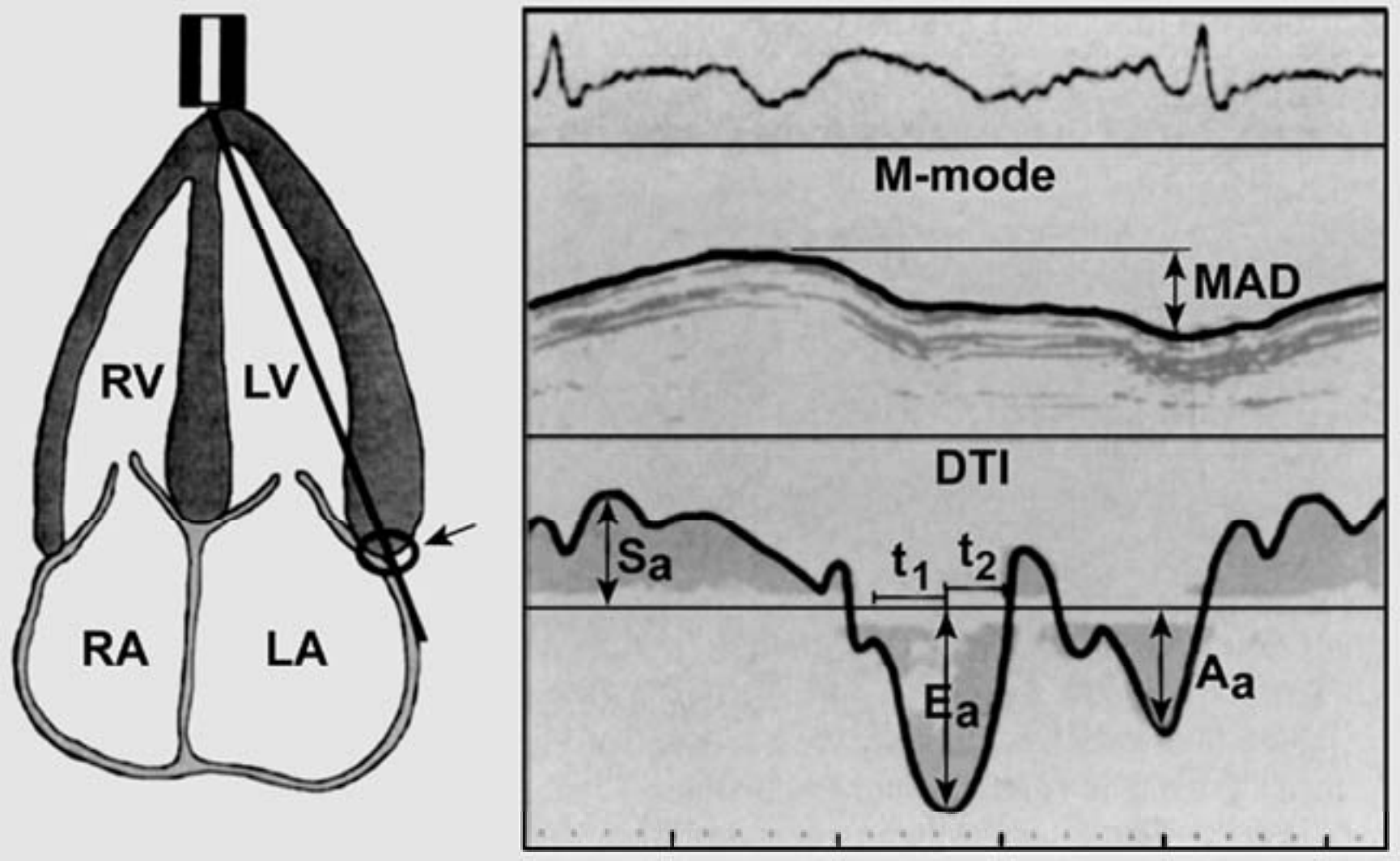
Carlsson M et al Am J Physiol Heart Circ Physiology 2007;H636-H644

Importance of longitudinal ventricular function.

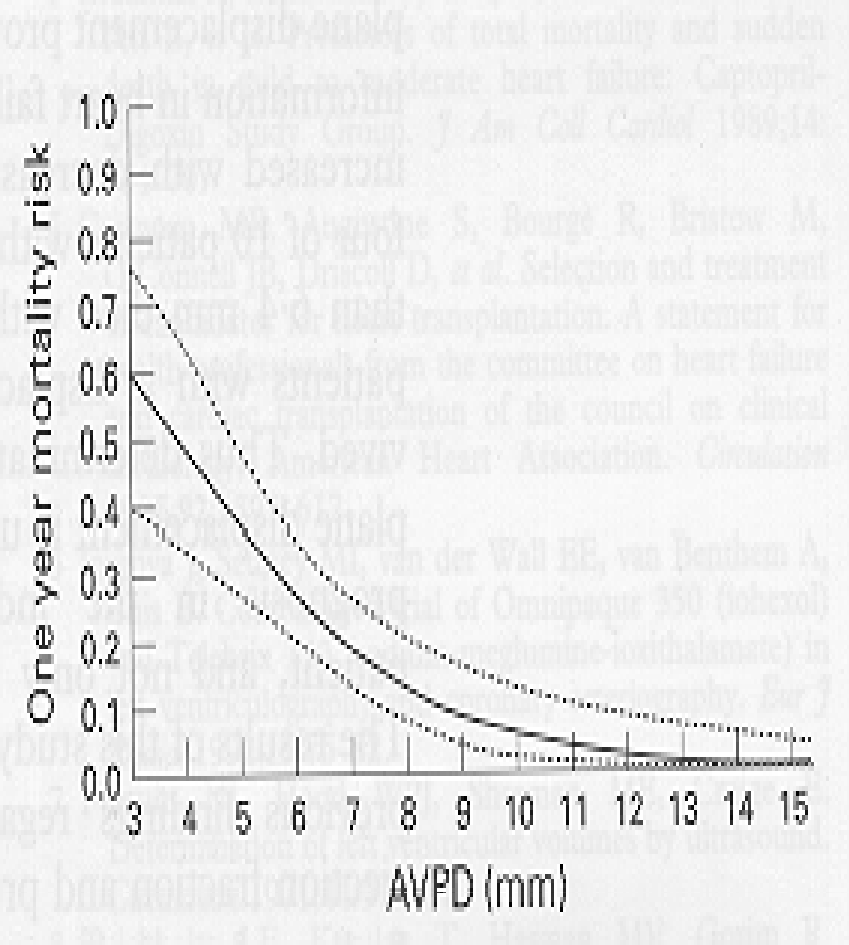


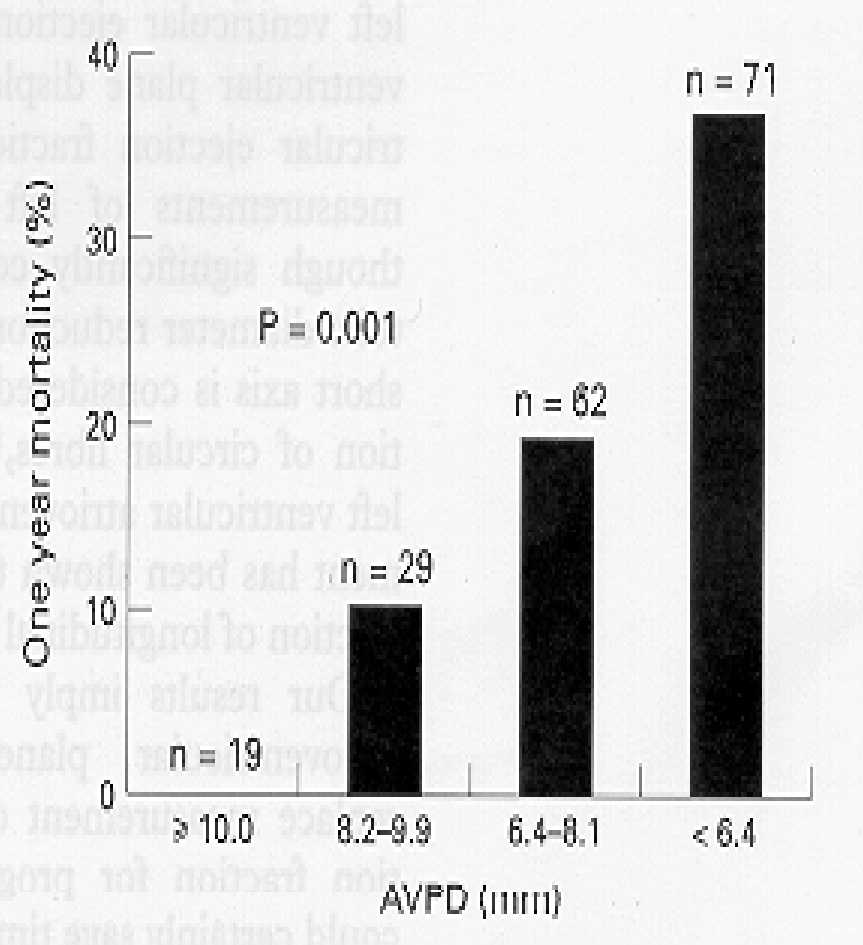
Carlsson, M. et al. Am J Physiol Heart Circ Physiol 2007;293: H636-H644

Mitral Annular Velocity
Tissue Doppler



Long Axis in heart failure-mortality





EF (%)= (AVPD (mm) x 5.5) - 5

(**Willenheimer** et al Heart 1997;78:230-236)

Ventricular long-axis function is of major importance for long-term survival in patients with heart failure

B Grüner Sveälv, E L Olofsson and B Andersson

Heart 2008;94;284-289; originally published online 17 Jun 2007;
doi:10.1136/hrt.2006.106294

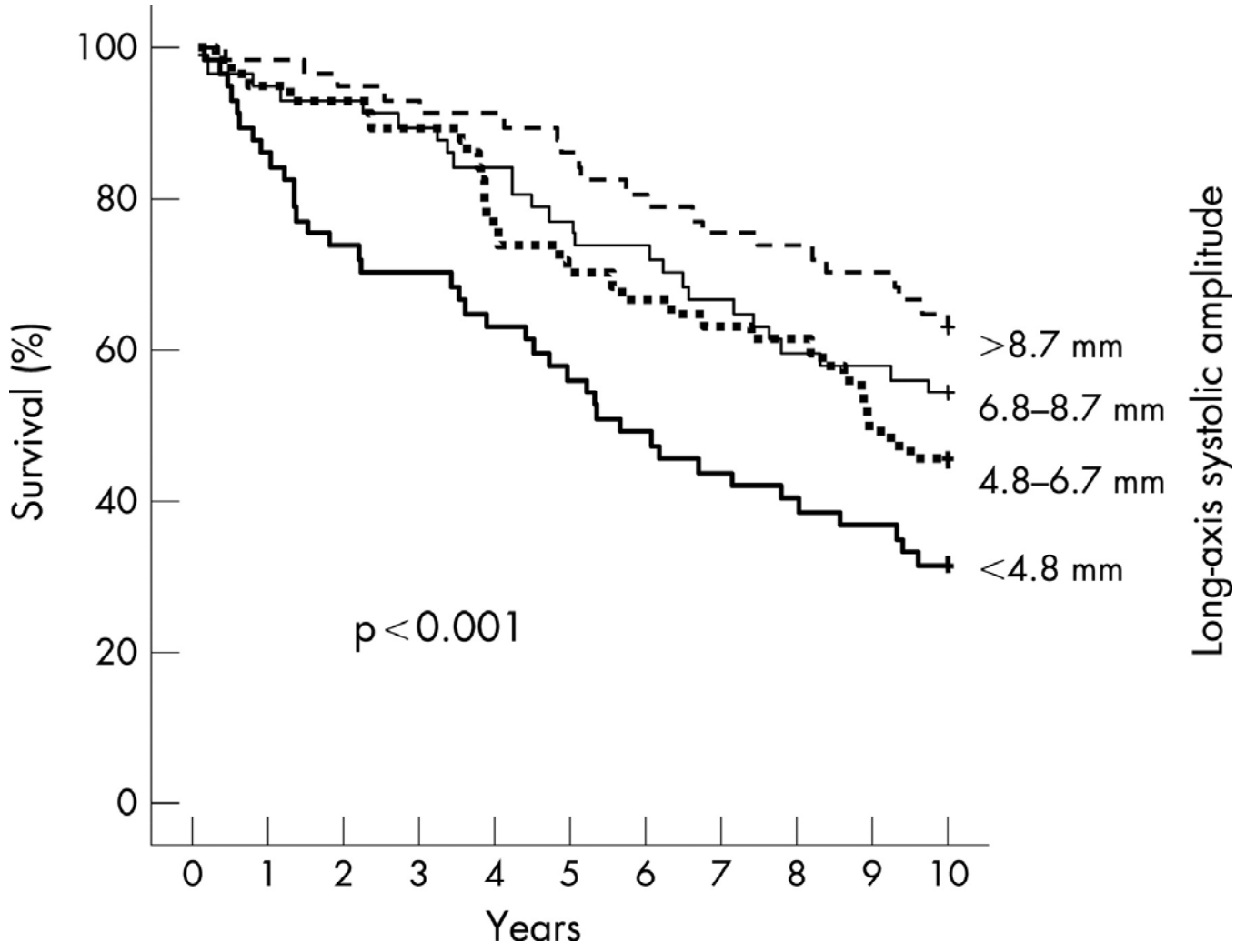
Table 2 Predictors of 10-year mortality in 228 patients with chronic heart failure

	Univariate association		Multivariate association	
Predictors	**p Value**	**HR (95% CI)**	**p Value**	**HR (95% CI)**
Gender	0.20	0.76 (0.50 to 1.16)	0.32	
Age	0.55	0.99 (0.97 to 1.01)	0.53	
Heart rate (bpm)	0.42	1.02 (0.97 to 1.08)	0.51	
SBP (mm Hg)	0.002	0.93 (0.89 to 0.98)	0.21	
LA (mm)	0.001	1.22 (1.08 to 1.36)	0.30	
LVEDD (mm)	<0.001	1.30 (1.20 to 1.42)	0.06	
SAX FS (%), n = 199	<0.001	0.72 (0.65 to 0.81)	0.16	
LVLAX syst ampl (mm)	<0.001	0.83 (0.77 to 0.89)	0.024	0.80 (0.66 to 0.97)
LVLAX syst vel (cm/s)	<0.001	0.71 (0.60 to 0.83)	0.12	
LVLAX EDFV (cm/s)	0.014	0.88 (0.79 to 0.97)	0.30	
RV LAX syst ampl (mm)	<0.001	0.93 (0.89 to 0.97)	0.60	
RV LAX syst vel (cm/s), n = 206	0.007	0.90 (0.84 to 0.97)	0.24	
RV LAX EDFV (cm/s)	0.001	0.88 (0.81 to 0.94)	0.09	

Univariate and multivariate Cox regression analysis of 10 years' mortality. Calculations were performed on continuous data. Changes of five units were used for age, heart rate, systolic blood pressure, left atrial dimension, left ventricular end-diastolic dimension, and short-axis fractional shortening. Remaining variables have low numeric value and changes are expressed for one unit.

EDFV, early diastolic filling velocity; LA, left atrium; LVEDD, left ventricular end-diastolic dimension; LVLAX, left ventricular long axis; RV LAX, right ventricular long axis; SAX FS, short-axis fractional shortening; SBP, systolic blood pressure.

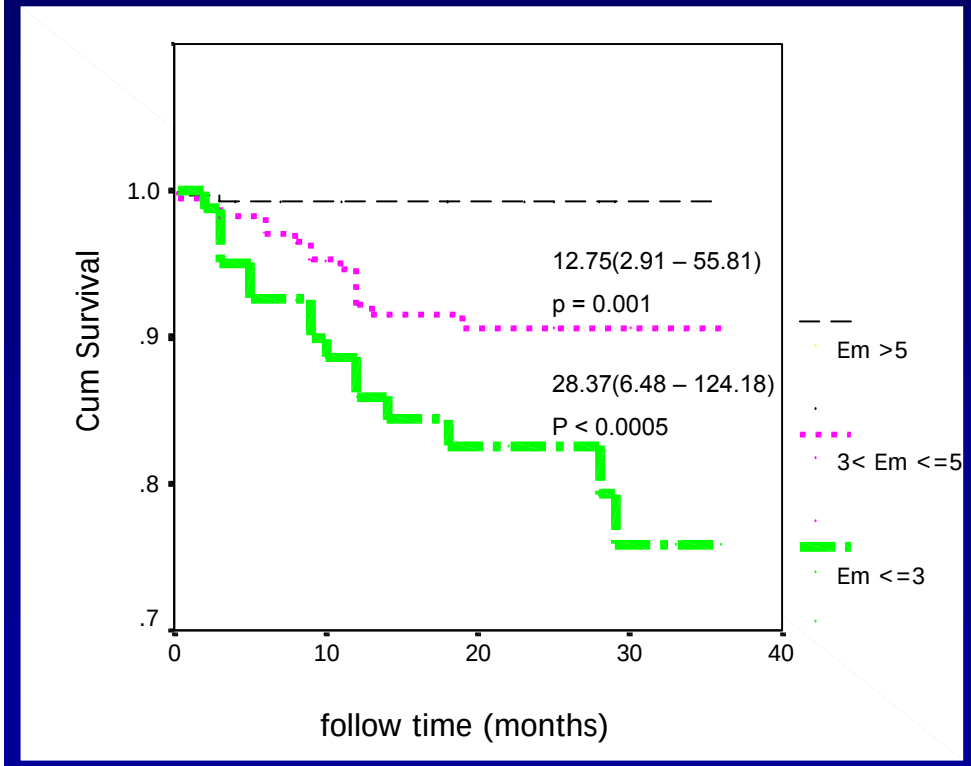
Figure 1 Survival curves are displayed for each quartile of left ventricular long-axis systolic amplitude. There was an overall difference between the curves as assessed by the log-rank test (p8.7 mm. Q3 vs Q4, hazard ratio (HR) = 0.72 (95% confidence interval 0.41 to 1.29), p = 0.27. Q2 vs Q4, HR = 0.76 (0.57 to 0.99), p = 0.049. Q1 vs Q4, HR = 0.72 (0.60 to 0.86), p



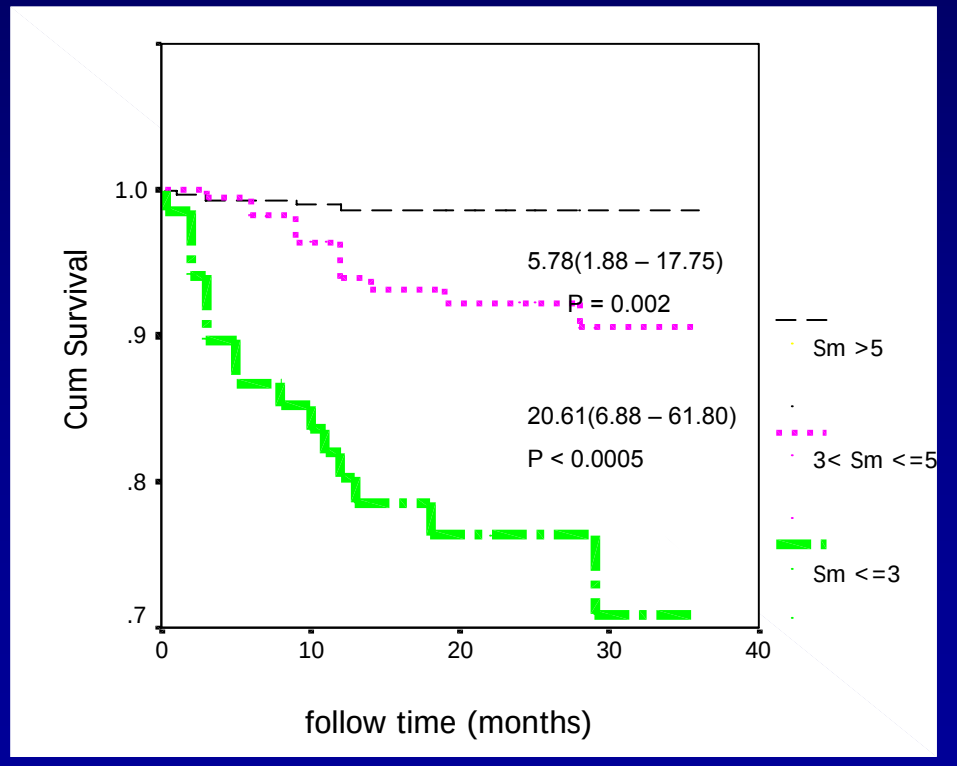
Svealv, B G. et al. Heart 2008;94:284-289

Mitral annular velocities by TDI in systole (Sm) and early diastole (Em) are Important Predictors of Mortality in CVS Disease.

Em



Sm



Wang M et al, J Am Coll Cardiol 2003;41:820-6

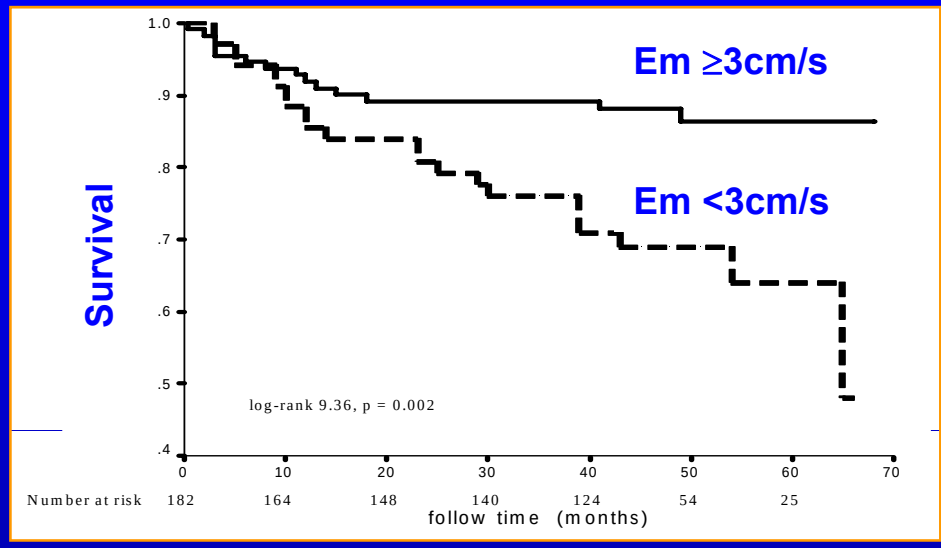
Incremental Predictive Value of Em & E/Em in Heart Failure -

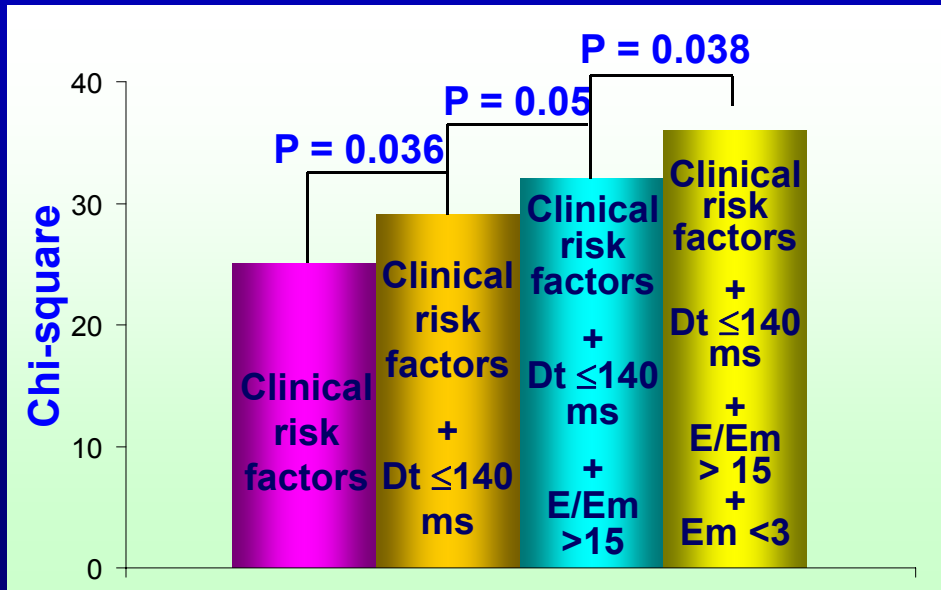
Wang M, et al, JACC 2005;45:272-7.

- 182 CHF pts with EF <50%
- Median F.U. : 48 months
- End-point : Cardiac mortality

Results :

- Em independently predicted cardiac mortality (RR = 0.61; CI = 0.45-0.82)
- Em < 3cm/s predicted mortality
- Incremental prognostic value by E/Em >15



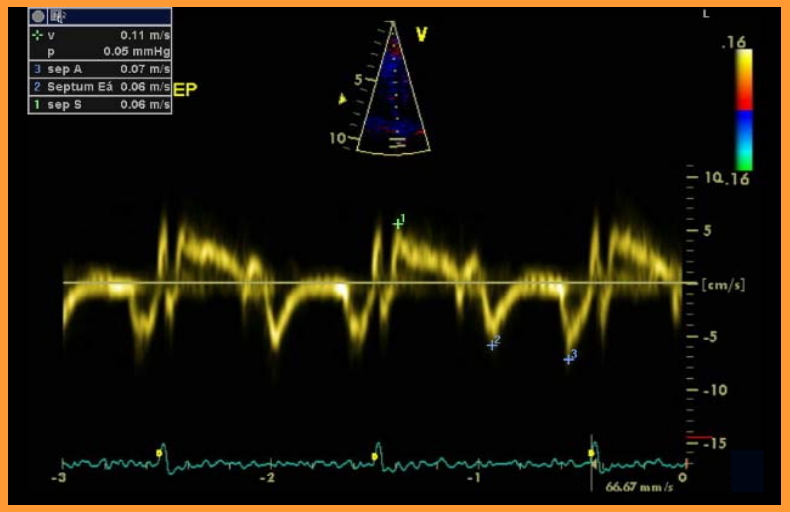


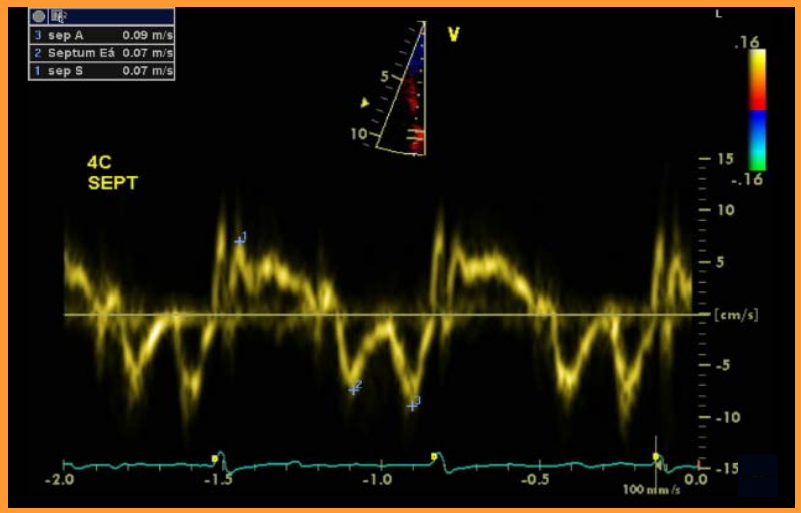
Longitudinal Functional Reserve Index (LFR Index)

Patient, ♀ 77 years

Control, ♀ 72 years

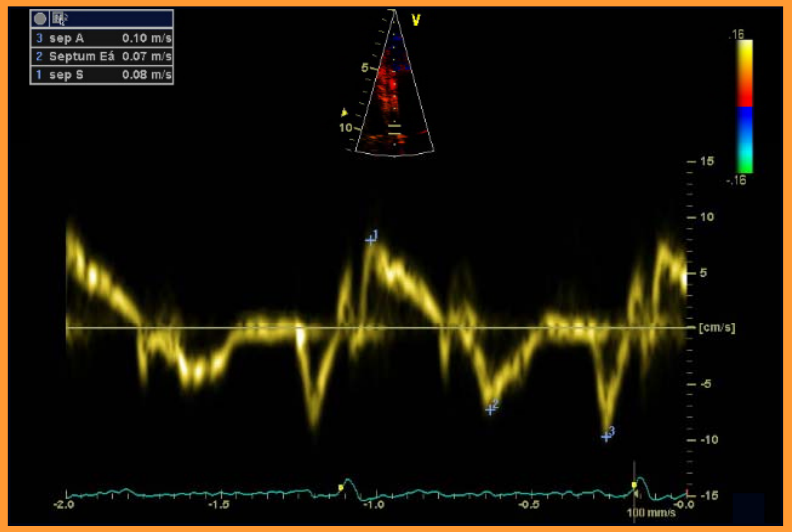
Rest





Rest

Exercise



Exercise

Diastolic (Systolic) LFR Index = ΔEm (or Sm) * (1-1/Em (or Sm) at rest) *

*(Ha et al., Heart 2007)

Longitudinal Functional Reserve Index (LFR Index)

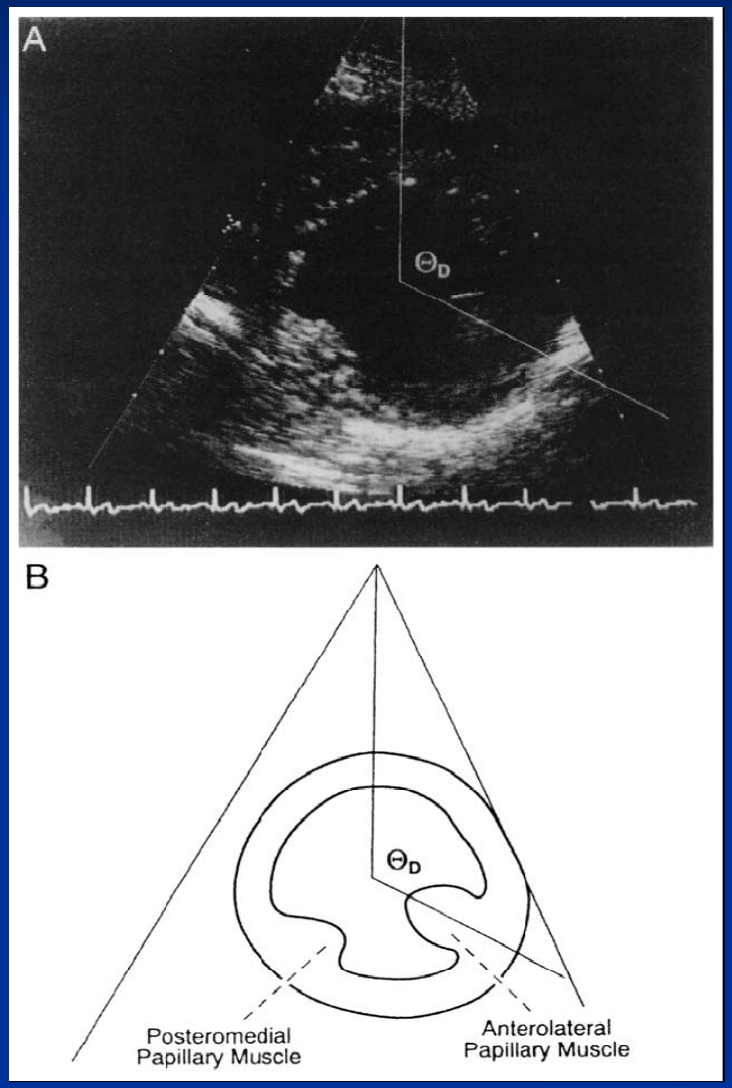
Echo Results	Patients (n=39)	Controls (n=21)
Em at Rest (cm/s)	7.9±4.2	7.9±2.1
Em at Exercise (cm/s)	9.9±2.3 p=0.000	12.5±2.6
Sm at Rest (cm/s)	7.9±1.6	8.0±1.5
Sm at Exercise (cm/s)	8.9±1.9 p=0.003	10.6±2.2
Diastolic LFR Index (cm/s)	2.0±1.5 p=0.001	3.9±2.4
Systolic LFR Index (cm/s)	0.9±1.5 p=0.001	2.3±1.5

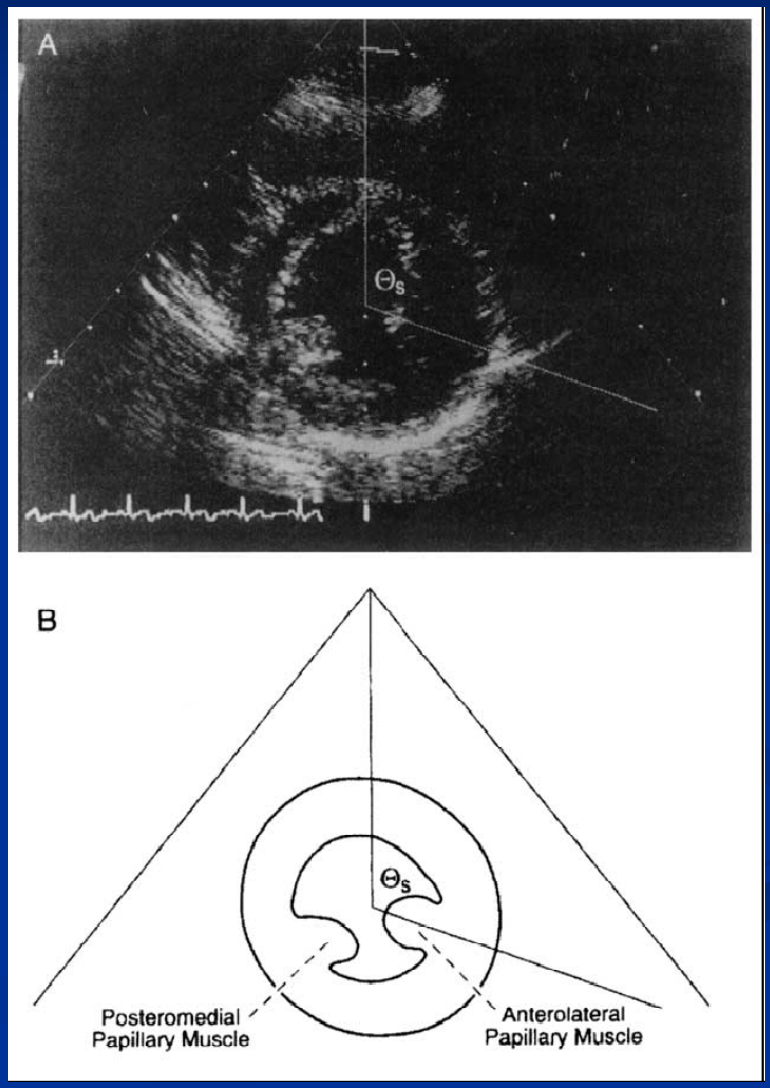
Quantification of Torsion

- Cineangiography of radio-opaque markers/sonomicrometry
- 2 D Echocardiography
- Magnetic resonance imaging
- Tissue Doppler Imaging
- 2-dimensional (2D) echocardiography – speckle tracking

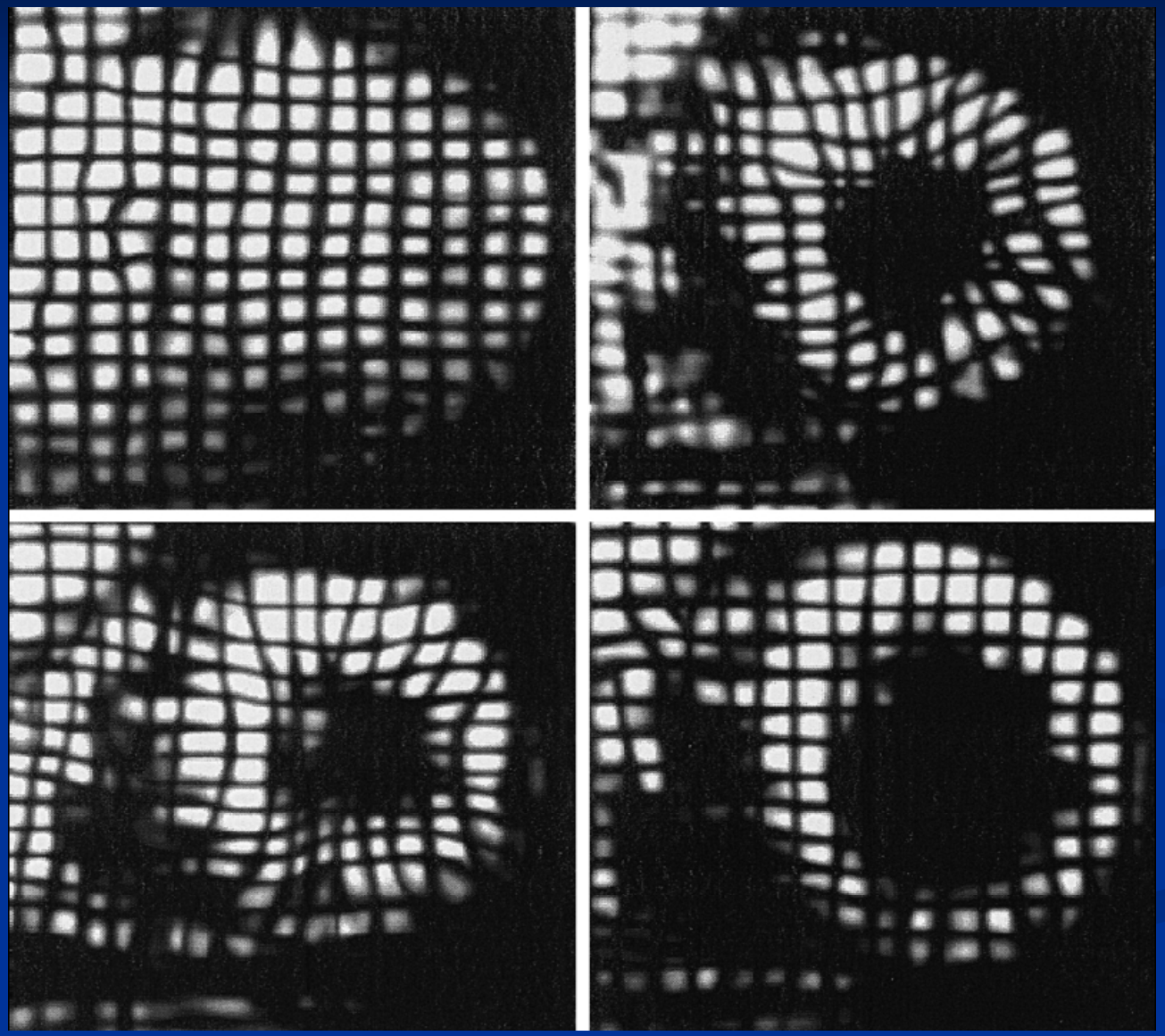
Simple 2D Echocardiography

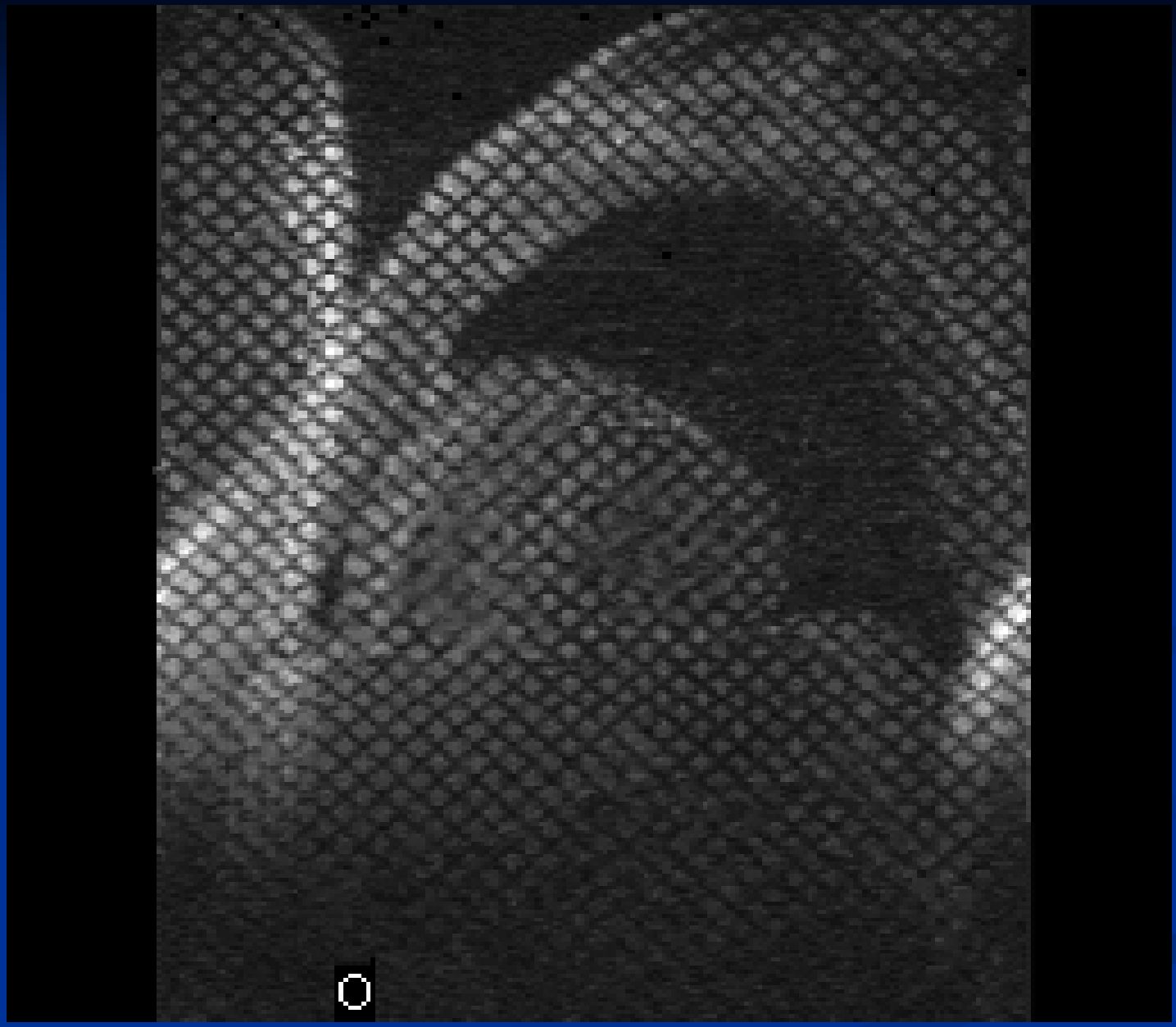
Tischler et al Am Soc J Echo 2003





MRI Tagging

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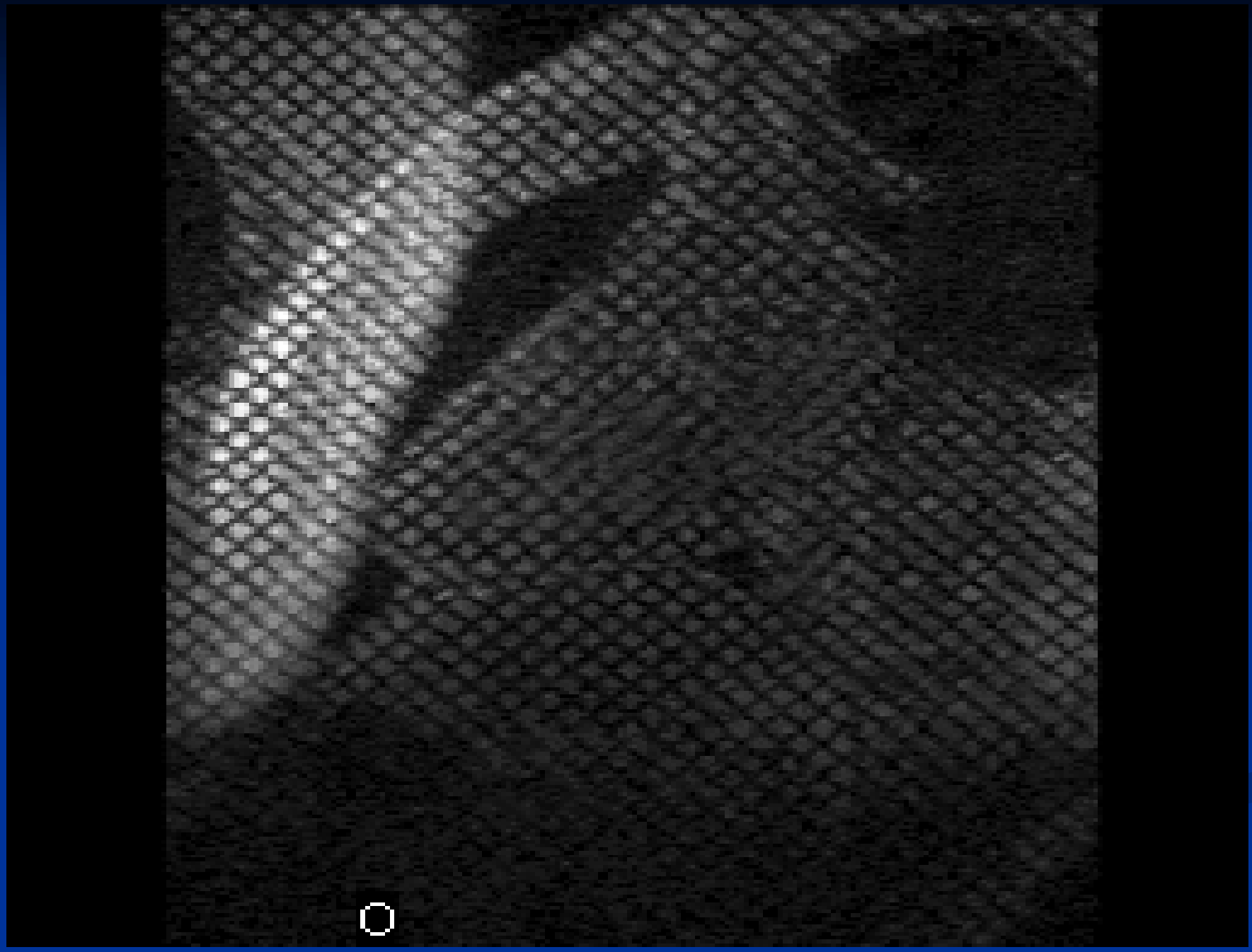
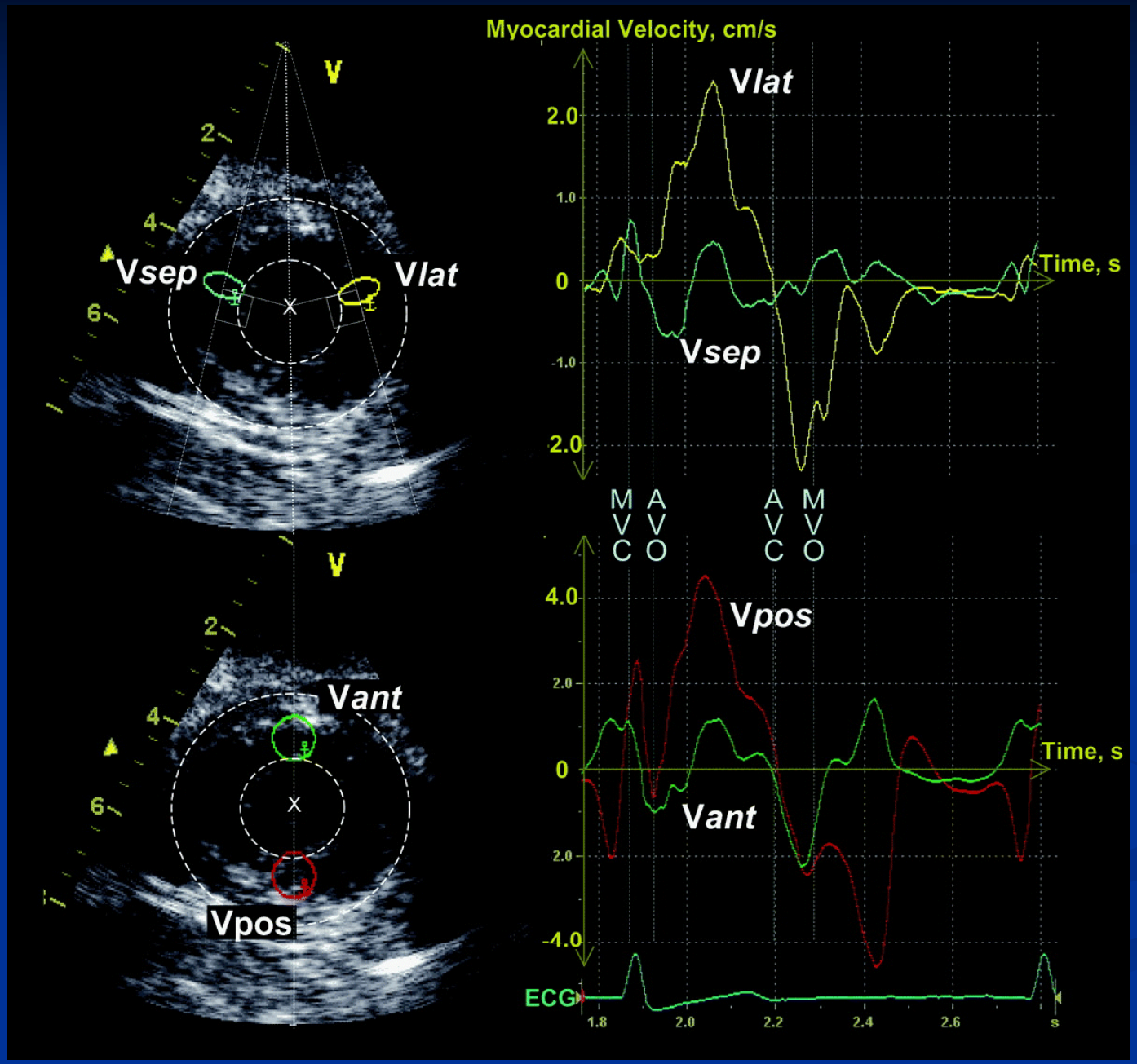
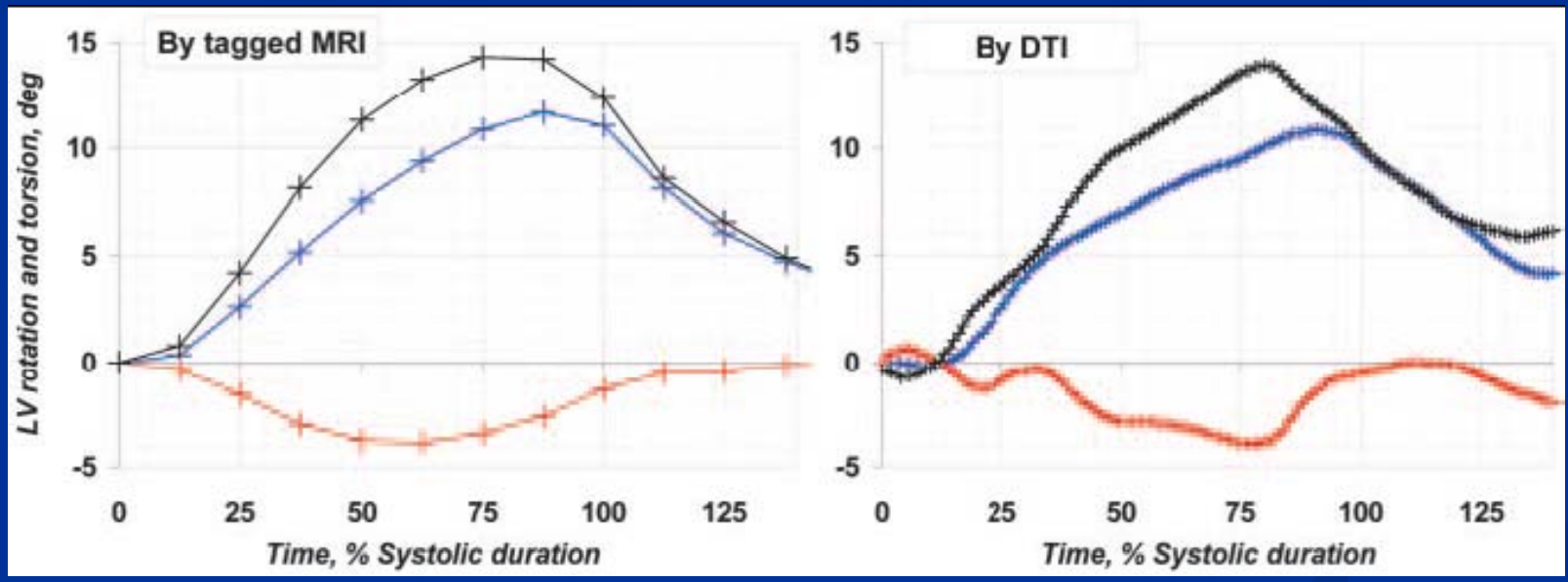




Twisting and Untwisting by TDI

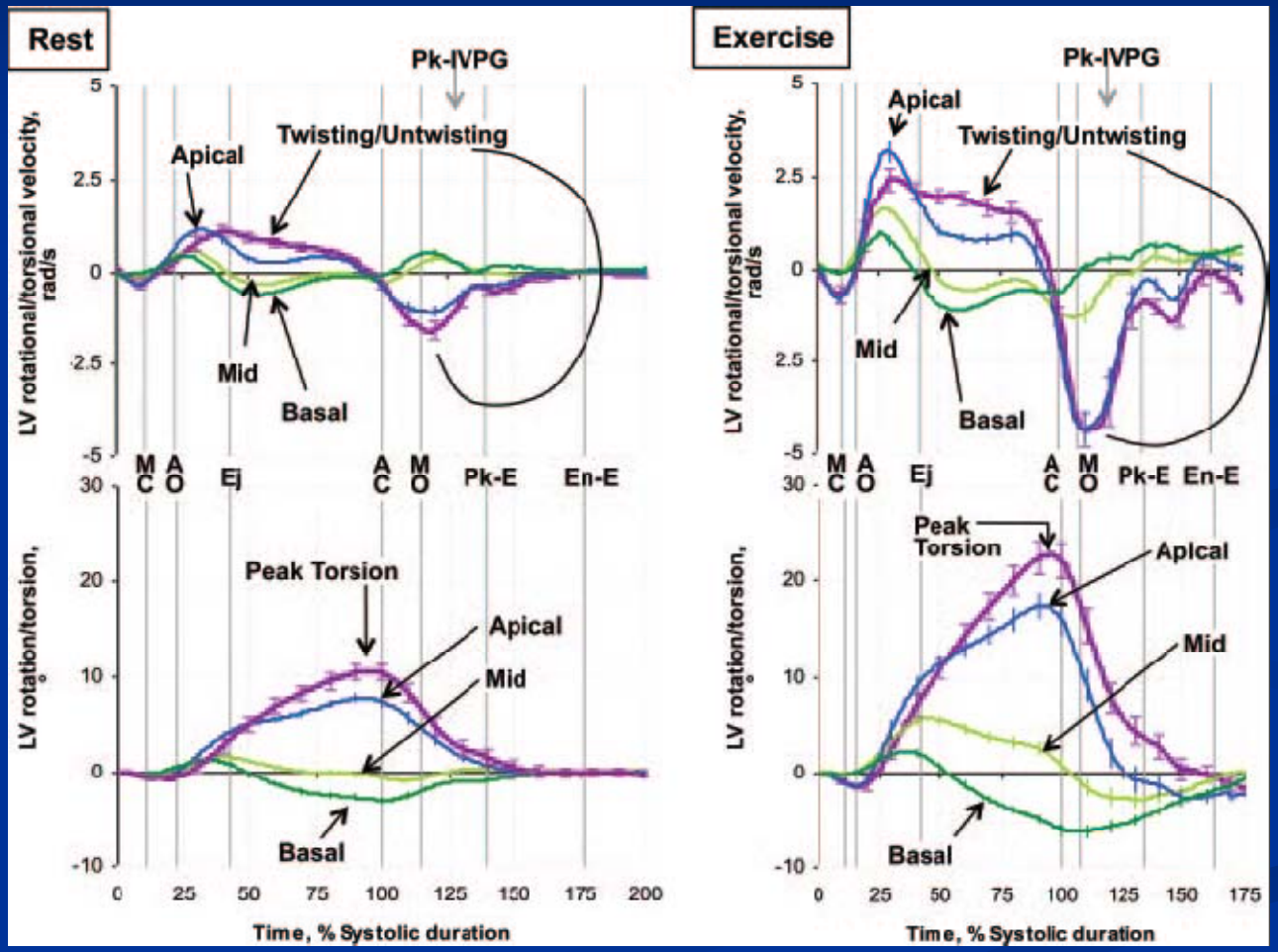
Notomi et al
Circulation
2006;113;2524

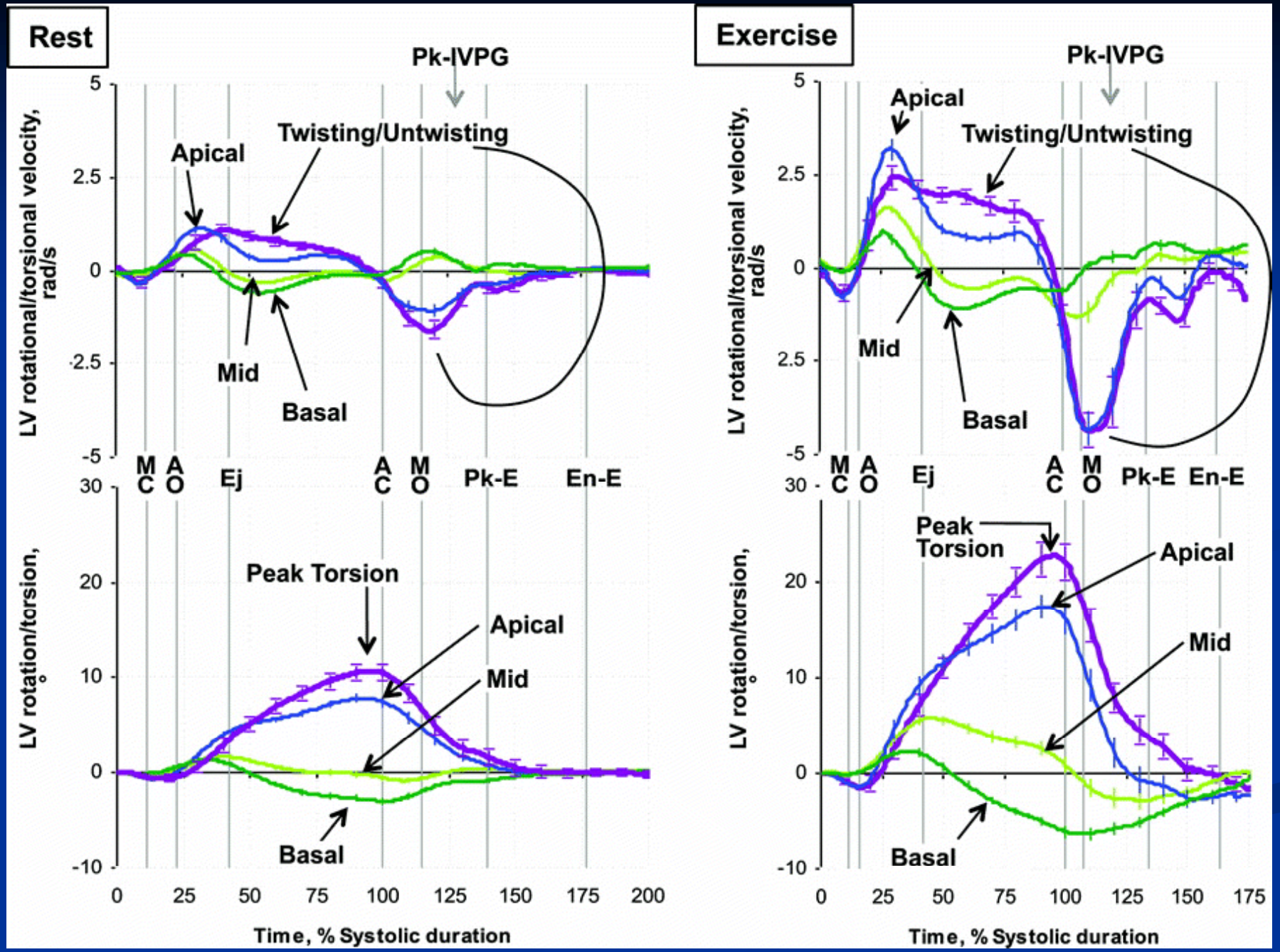
Assessment of Left Ventricular Torsional Deformation by Doppler Tissue Imaging
Validation Study With Tagged Magnetic Resonance Imaging
Notomi Y et al Circ 2005



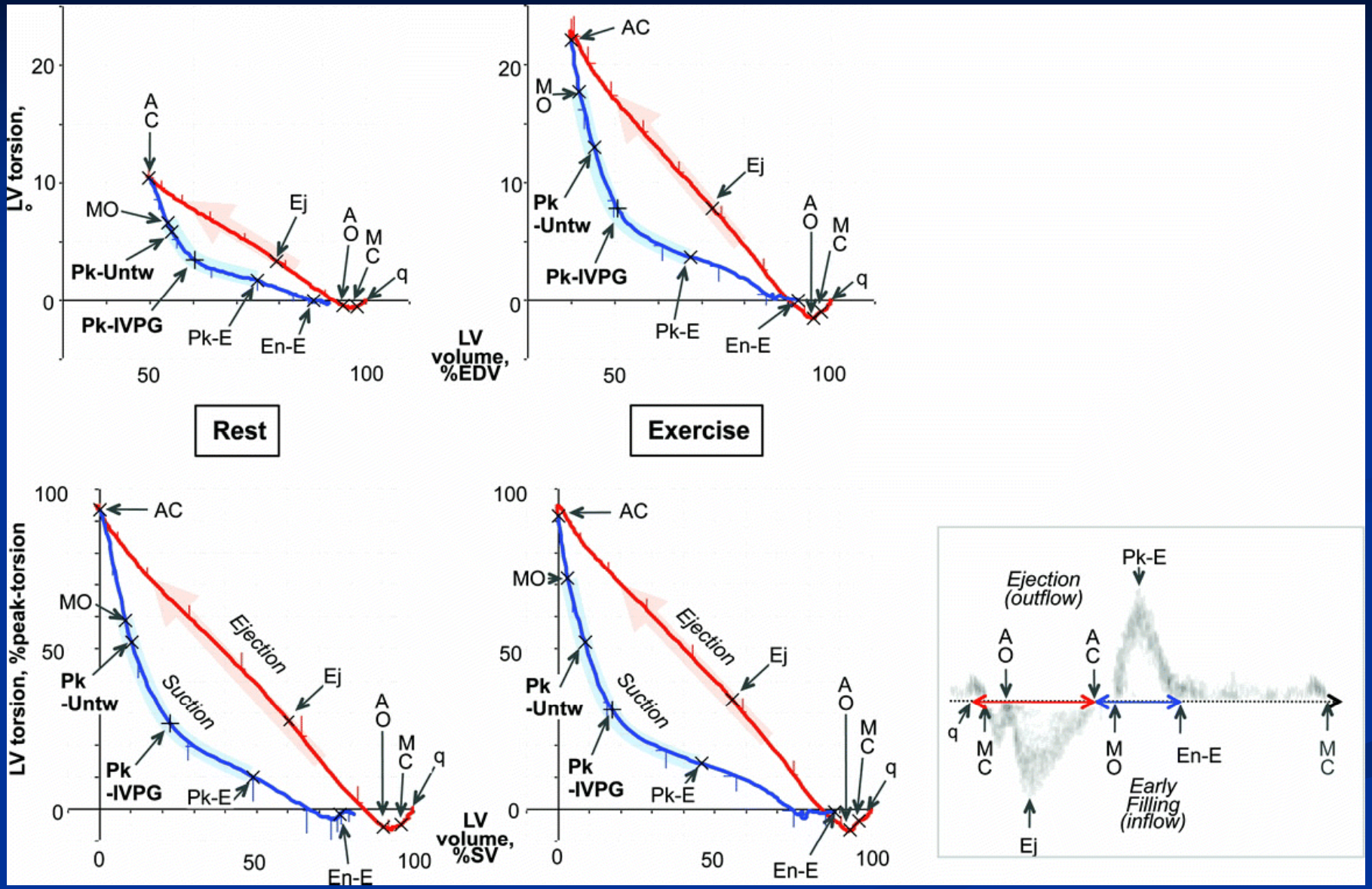
Enhanced Ventricular Untwisting During Exercise A Mechanistic Manifestation of Elastic Recoil Described by Doppler Tissue Imaging

Notomi Y et al Circ 2006





Notomi et al Circulation 2006;113:2524-2533



Normal subjects

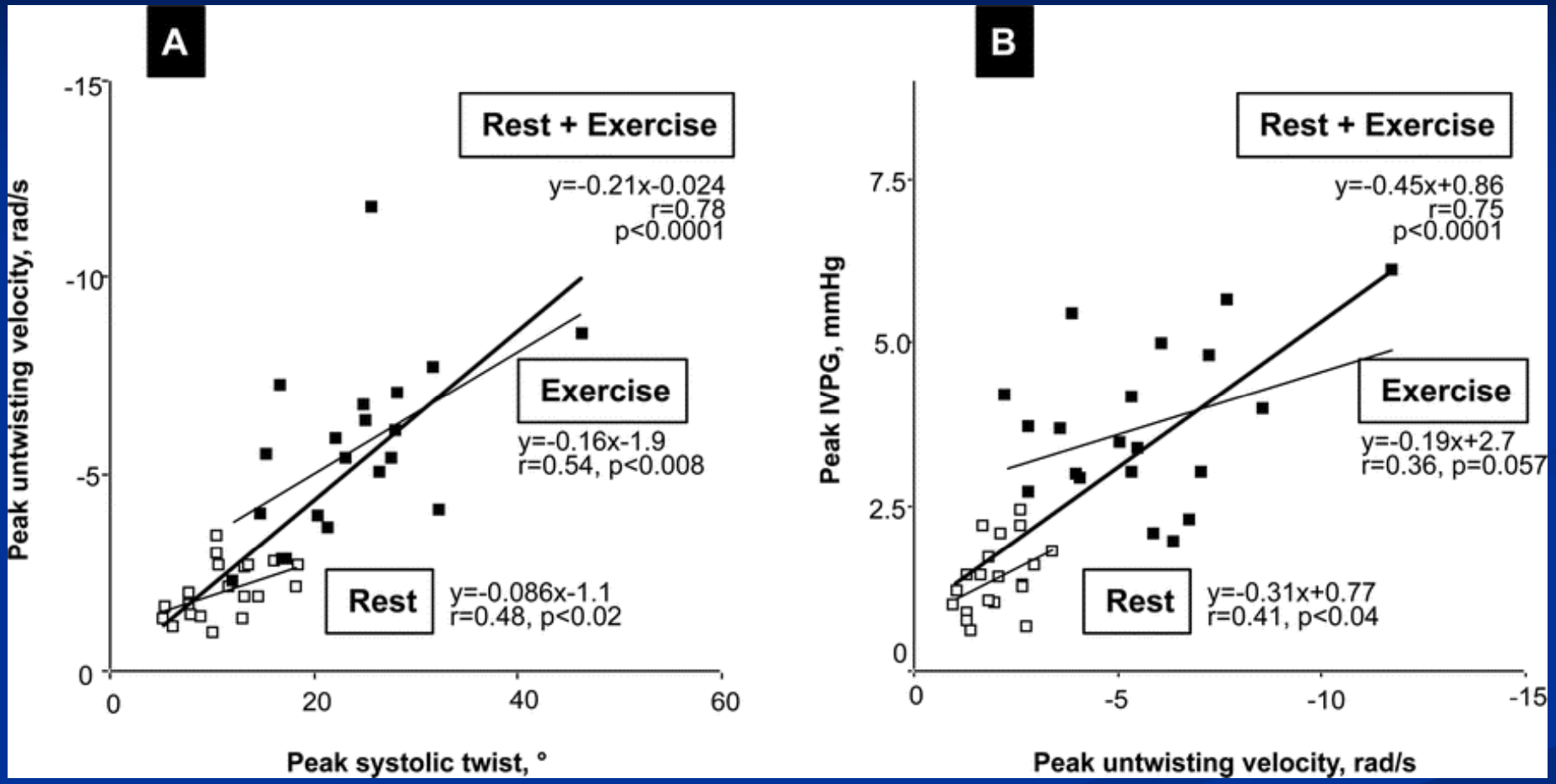
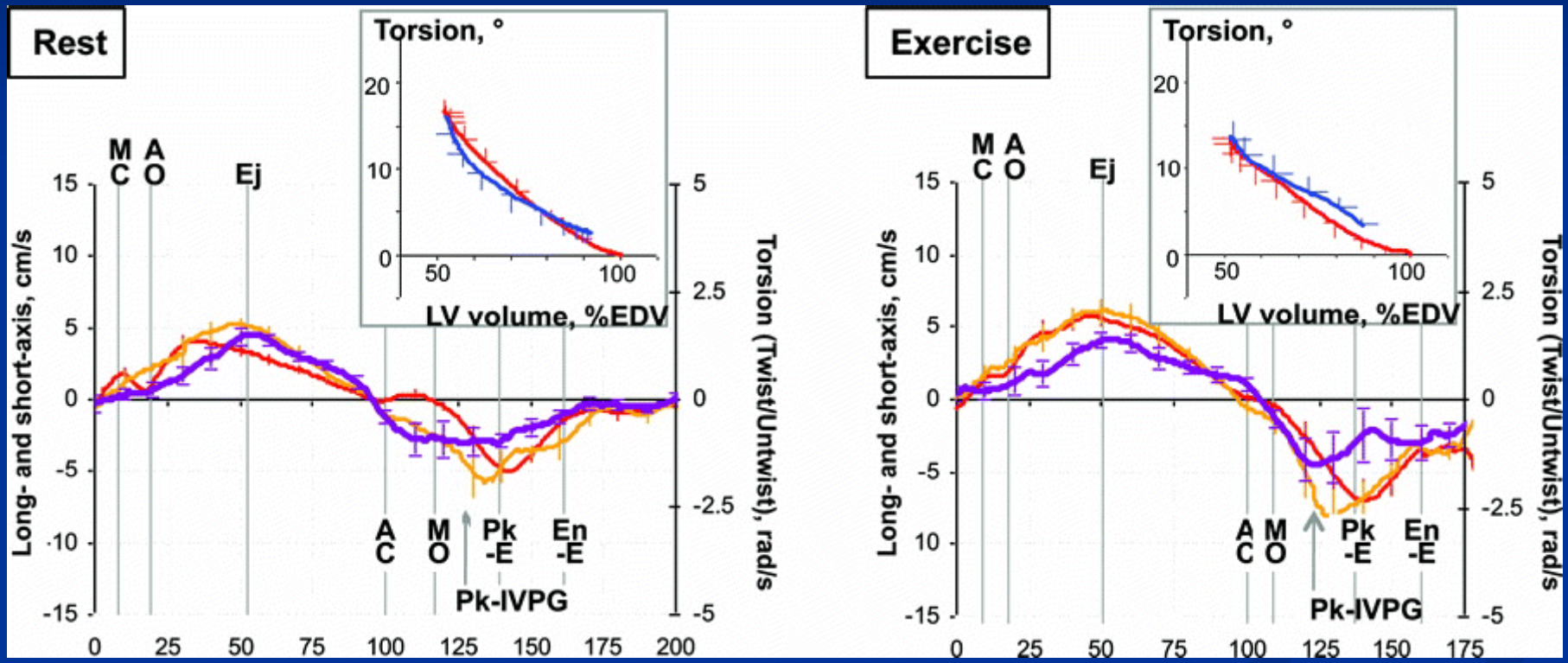

A
Rest + Exercise
y=-0.21x-0.024
r=0.78
p<0.0001
Exercise
y=-0.16x-1.9
r=0.54, p<0.008
Rest
y=-0.086x-1.1
r=0.48, p<0.02
Peak untwisting velocity, rad/s
Peak systolic twist, °
-15
-10
-5
0
0
20
40
60
B
Rest + Exercise
y=-0.45x+0.86
r=0.75
p<0.0001
Exercise
y=-0.19x+2.7
r=0.36, p=0.057
Rest
y=-0.31x+0.77
r=0.41, p<0.04
Peak IVPG, mmHg
Peak untwisting velocity, rad/s
7.5
5.0
2.5
0
0
-5
-10
-15

TABLE 2. Correlation Between LV Untwisting Velocity and Diastolic Function Indices

	Rest		Exercise		Rest+Exercise	
Peak untwisting velocity versus:	*r*	*P*	*R*	*P*	*r*	*P*
Early diastolic peak velocity	0.31	0.092	0.23	0.170	0.59	<0.0001
Time to early diastolic peak velocity	0.31	0.090	0.16	0.170	0.73	<0.0001
Acceleration velocity	0.43	0.029	0.30	0.096	0.66	<0.0001
Long-axis peak early-diastolic velocity	0.42	0.032	0.55	0.011	0.69	<0.0001
Short-axis peak early-diastolic velocity	0.01	0.476	0.09	0.353	0.54	0.0002

Notomi et al Circulation 2006;113:2524-2533

HCM patients (n=7)



Am J Physiol Heart Circ Physiol 294: H505–H513, 2008.
First published November 21, 2007; doi:10.1152/ajpheart.00975.2007.

Ventricular untwisting: a temporal link between left ventricular relaxation and suction

Yuichi Notomi, Zoran B. Popović, Hirotsugu Yamada, Don W. Wallick, Maureen G. Martin, Stephanie J. Oryszak, Takahiro Shiota, Neil L. Greenberg, and James D. Thomas

Department of Cardiovascular Medicine, The Cleveland Clinic Foundation, Cleveland, Ohio

To understand the interaction between LV mechanics and inflow during early diastole, Doppler tissue images (DTI) and catheter-derived pressures (apical and basal LV, left atrial, and aortic) and LV volume data were obtained at baseline, during varying pacing modes, and during dobutamine and esmolol infusion in 7 closed-chest anesthetized dogs. LV torsion and torsional rate profiles were analyzed from DTI data sets (apical and basal short-axis images) with high temporal resolution (6.5±0.7ms).

Table 4. Results of stepwise multiple regression analysis

Dependent Variables	Relaxation time constant (tau)		Intravenricular pressure gradient	
multiple r	0.66		0.57	
Independent Variables	partial r	(p-value)	partial r	(p-value)
Heart Rate	-0.35	(0.005)	ns	(0.497)
Maximum dP/dt	ns	(0.953)	ns	(0.638)
Peak LVP	0.28	(0.025)	ns	(0.561)
Peak LV Torsion	ns	(0.259)	ns	(0.924)
Peak LV Untwisting velocity	-0.62	(<0.0001)	0.57	(<0.0001)
Relaxation time constant (tau)	*na*		ns	(0.116)

Partial r indicates partial regression coefficient. The corresponging p-value are showing in parentheses.

ns, no significance. Na, not available for comparison.

Figure 1-a. ***Averaged left ventricular (LV) torsion and torsional velocity profile altered by electrical activation sequence.***

RV-p indicates right ventricle pacing; LVa-p, left ventricular apical pacing.

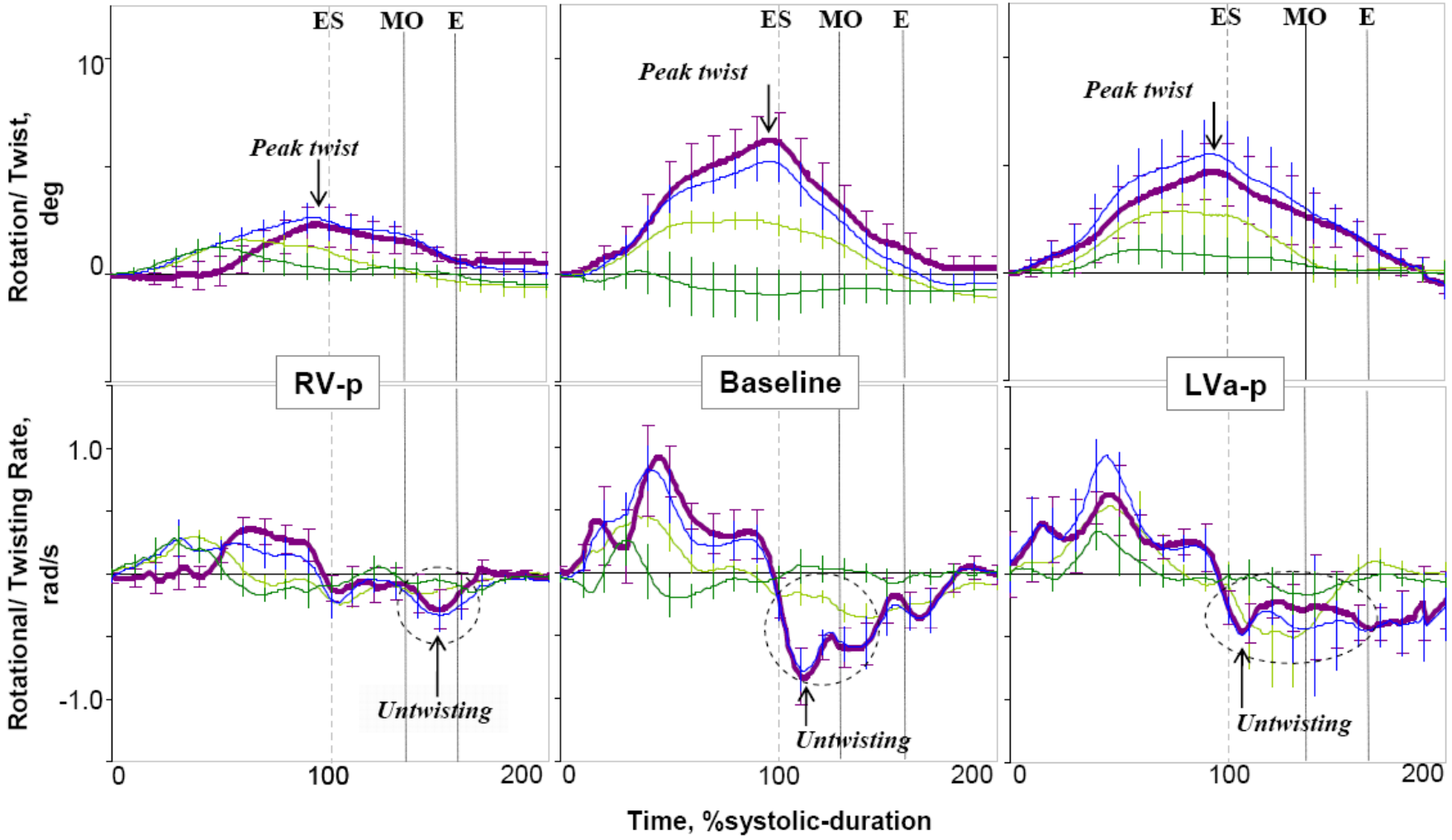
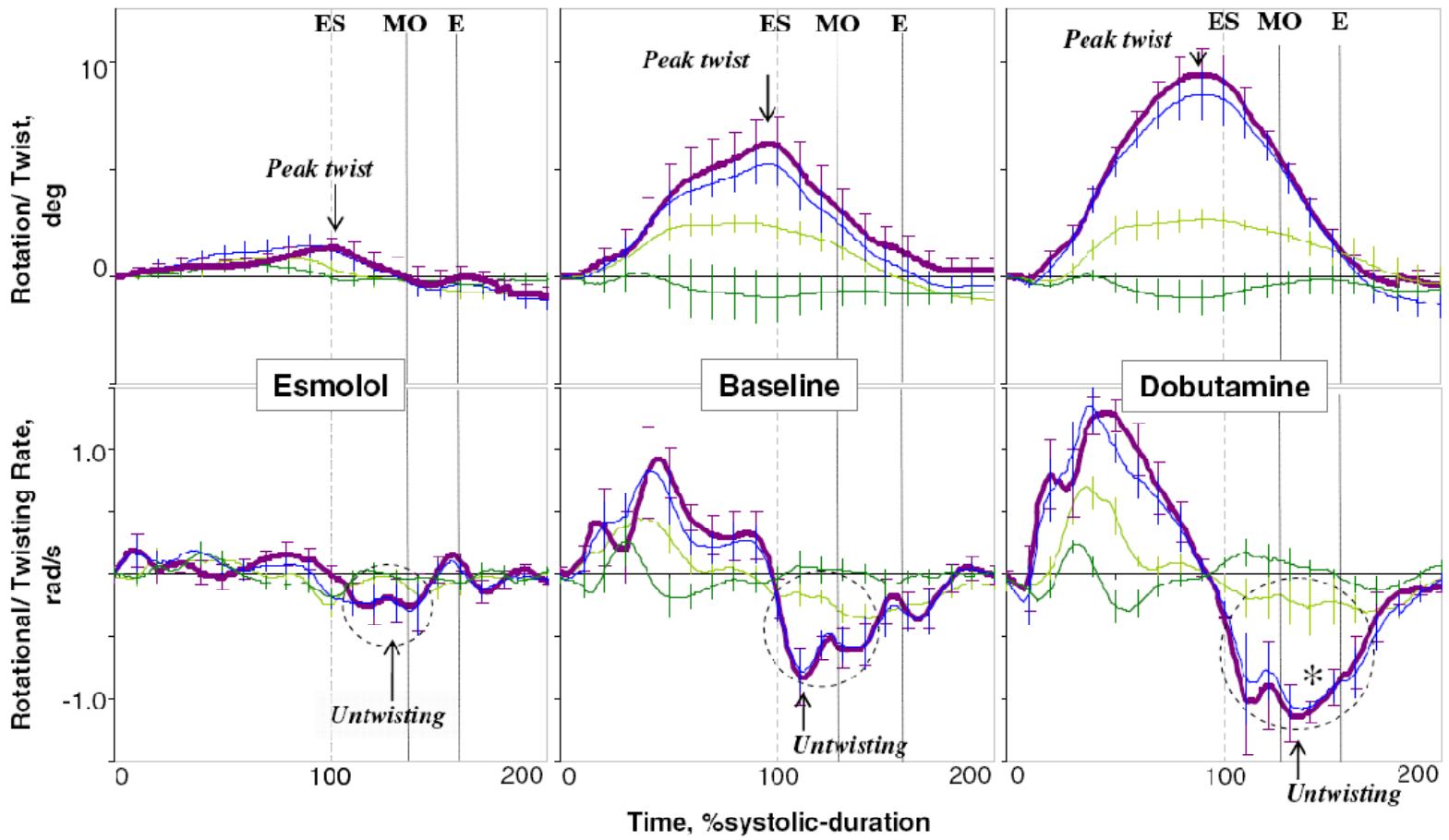
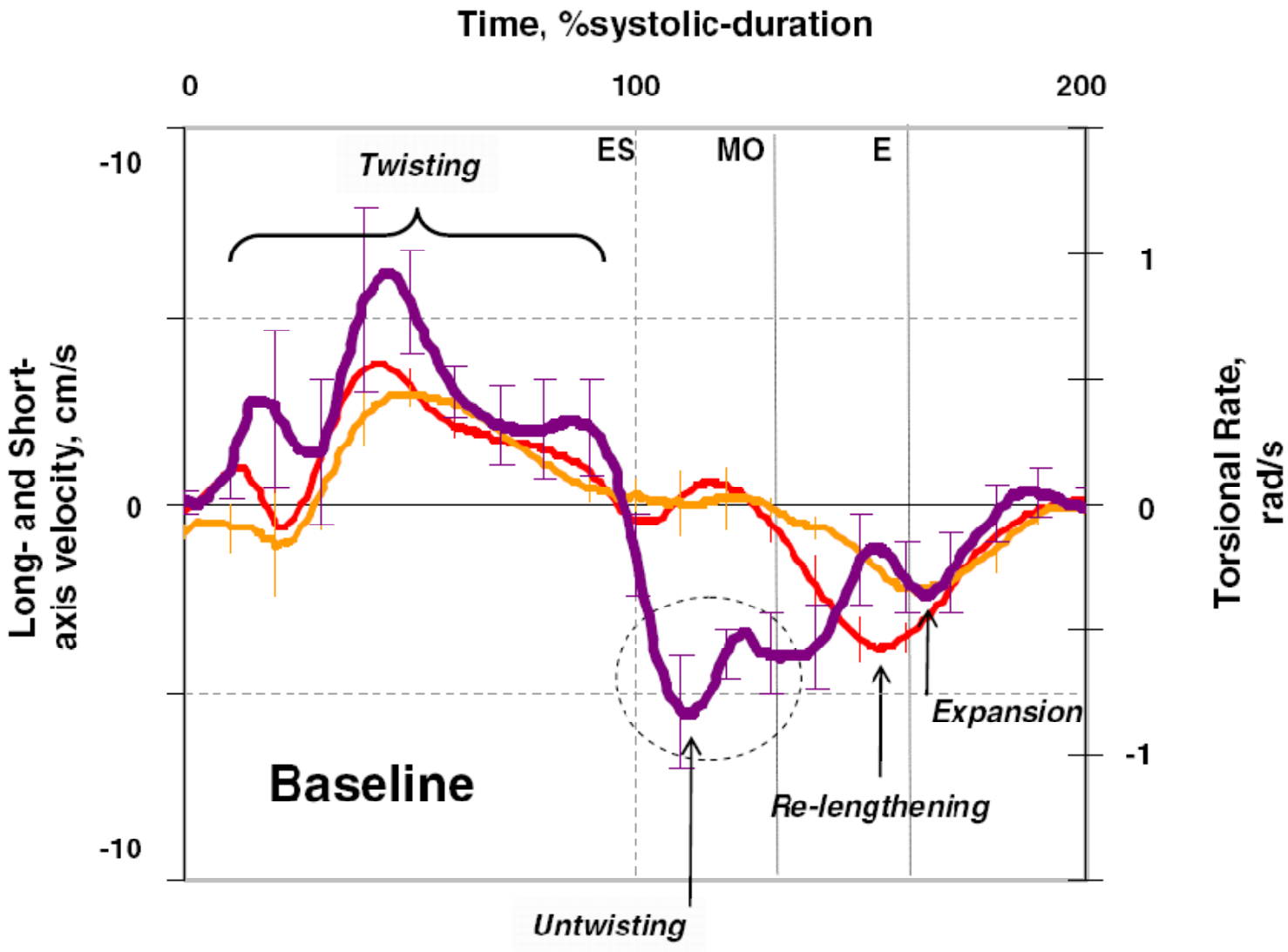


Figure 1-b. *Averaged LV torsion and torsional velocity profile altered by inotropic manipulation.*



Dobutamine enhanced untwisting velocity both during isovolumic relaxation (ES to MO) and early filling (i.e., the suction phase, shown by the asterisk mark). Thus, untwisting occurs over both phases, releasing elastic energy


Time, %systolic-duration
0
100
200
-10
0
-10
1
0
-1
ES
MO
E
Twisting
Long- and Short-axis velocity, cm/s
Torsional Rate, rad/s
Baseline
Untwisting
Re-lengthening
Expansion

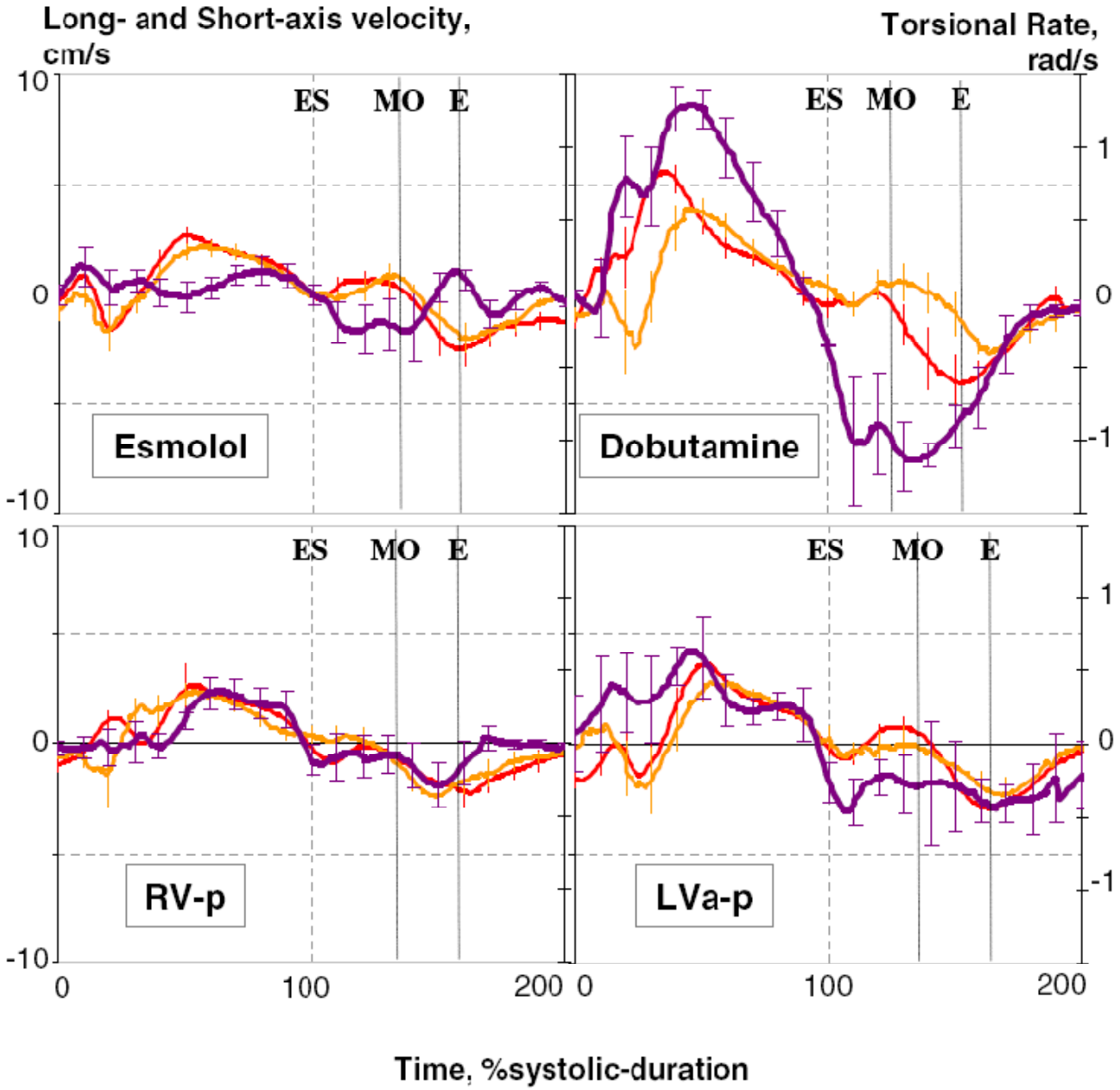
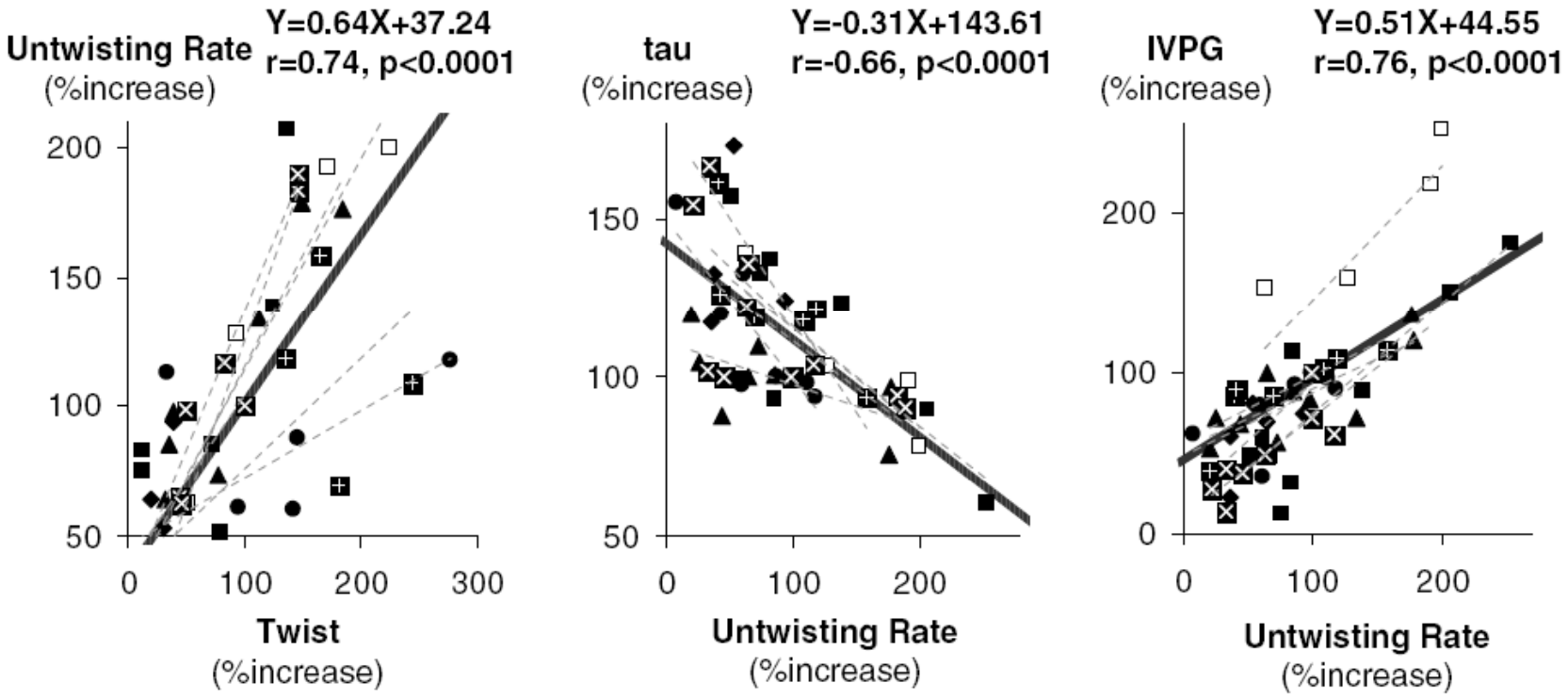
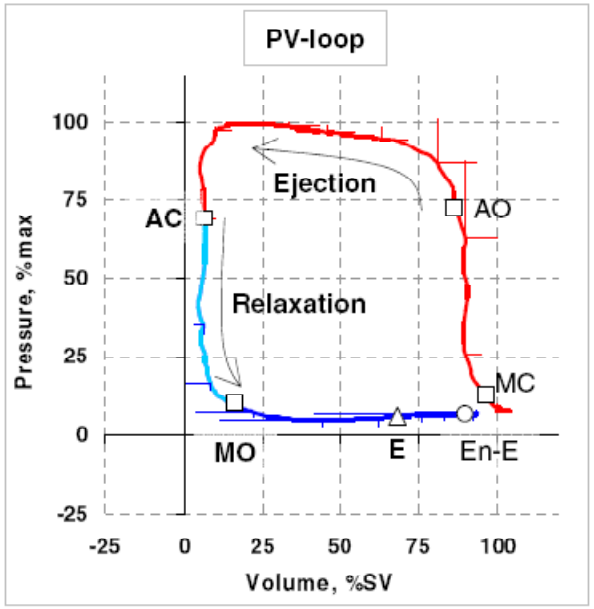
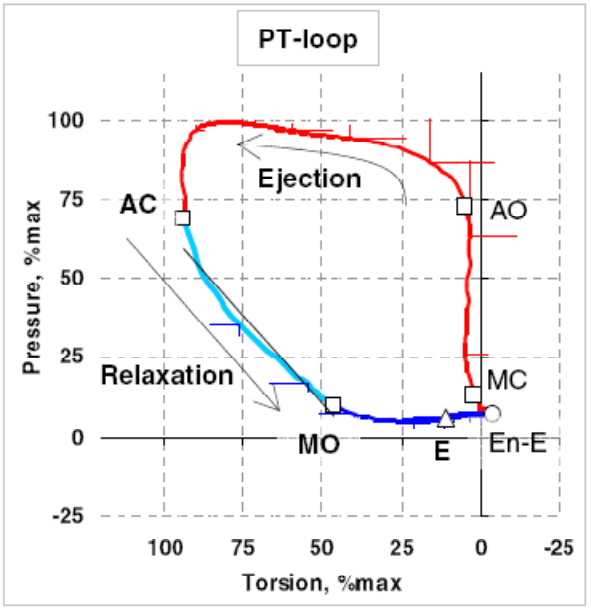

Long- and Short-axis velocity, cm/s
Torsional Rate, rad/s
ES
MO
E
10
0
-10
1
-1
Esmolol
Dobutamine
RV-p
LVa-p
0
100
200
Time, %systolic-duration

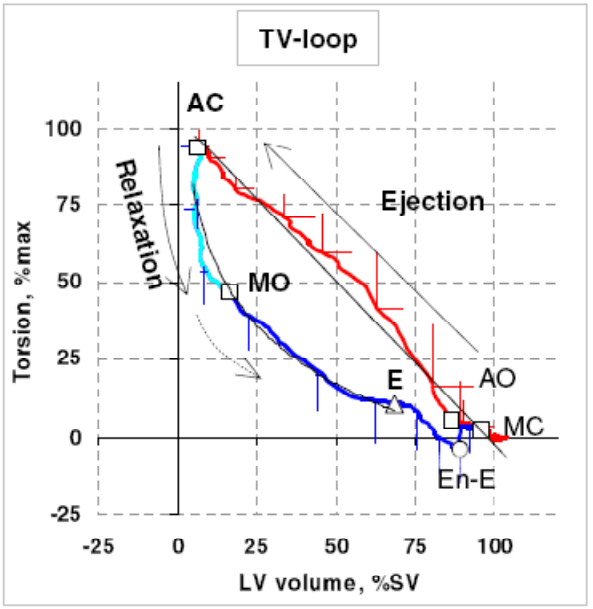
Figure 3. ***Relationship between systolic peak torsion (Torsion) and peak untwisting velocity (Untwisting), peak untwisting velocity and relaxation time constant (tau), and peak untwisting velocity and intra-ventricular pressure gradient (IVPG).***



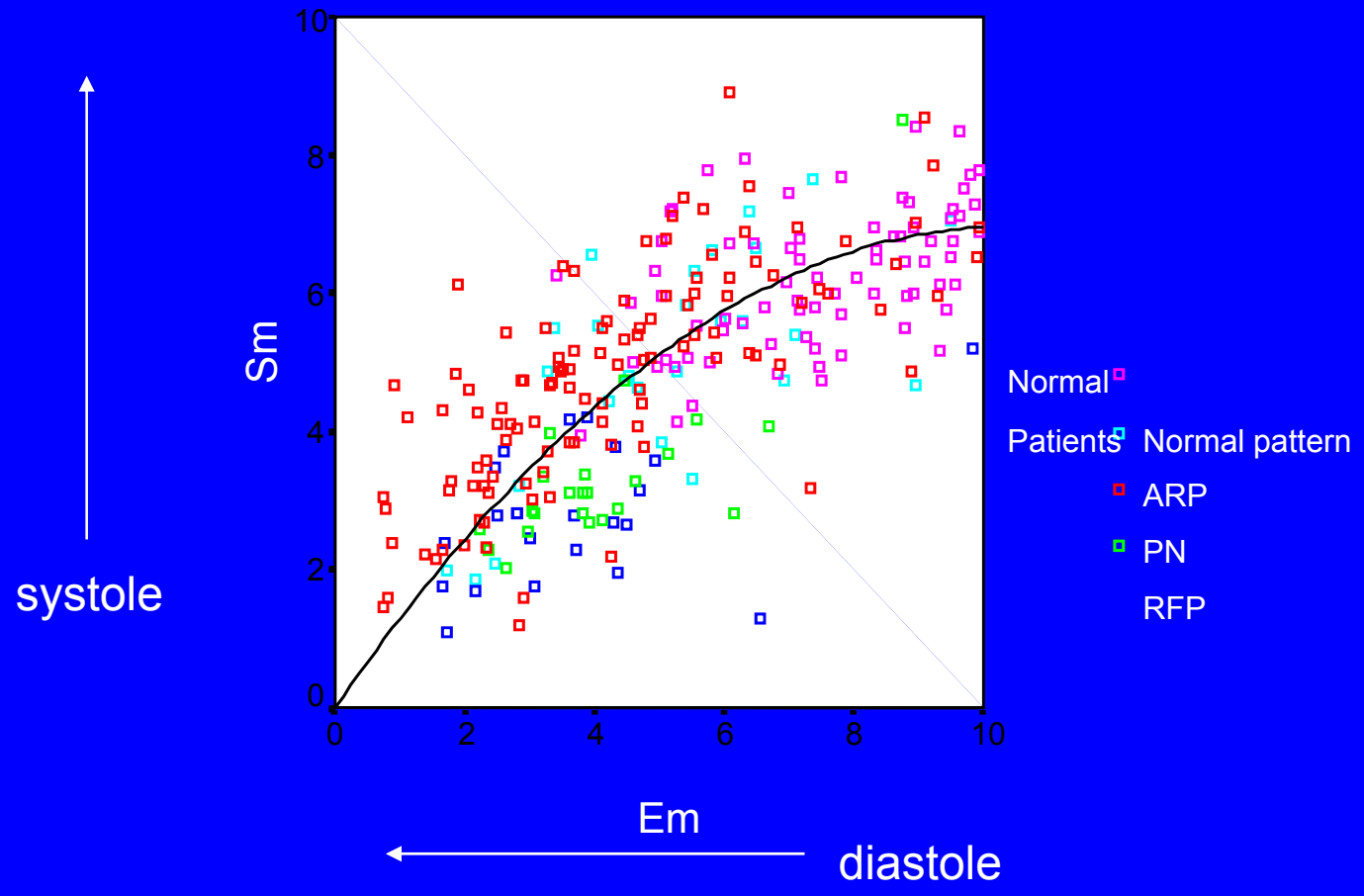
Pressure-volume (PV), Pressure-torsion (PT) and torsion-volume relationships





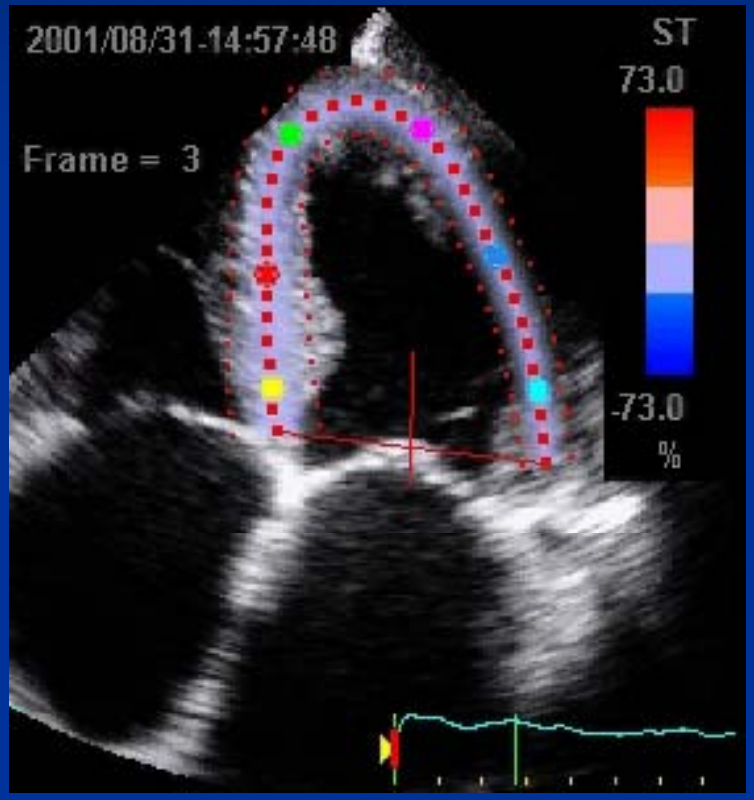


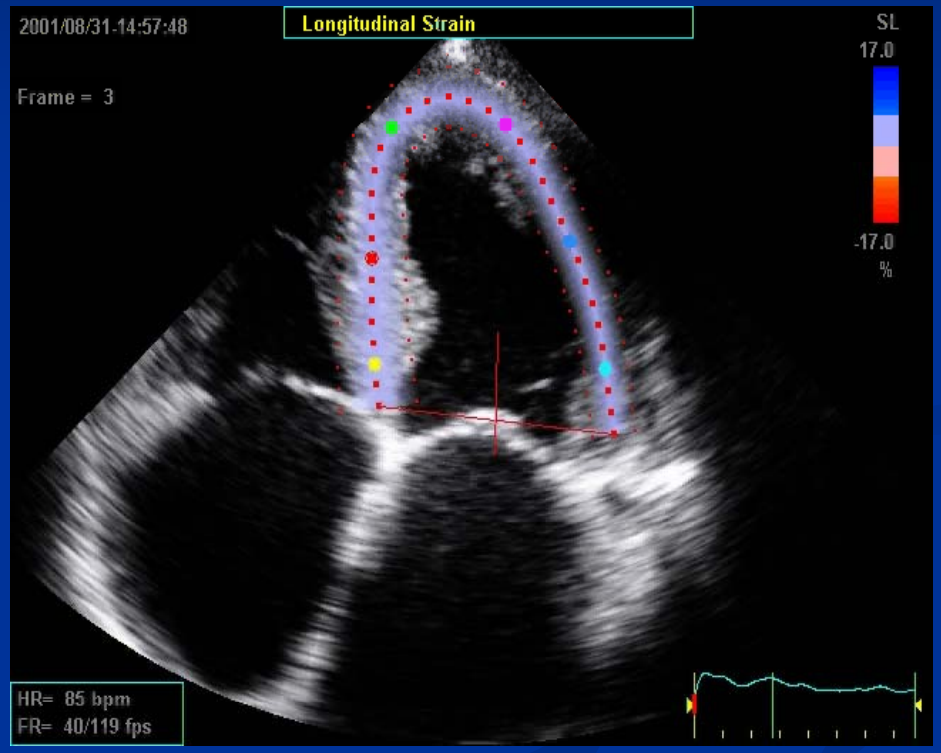
Systole and diastole are linked.



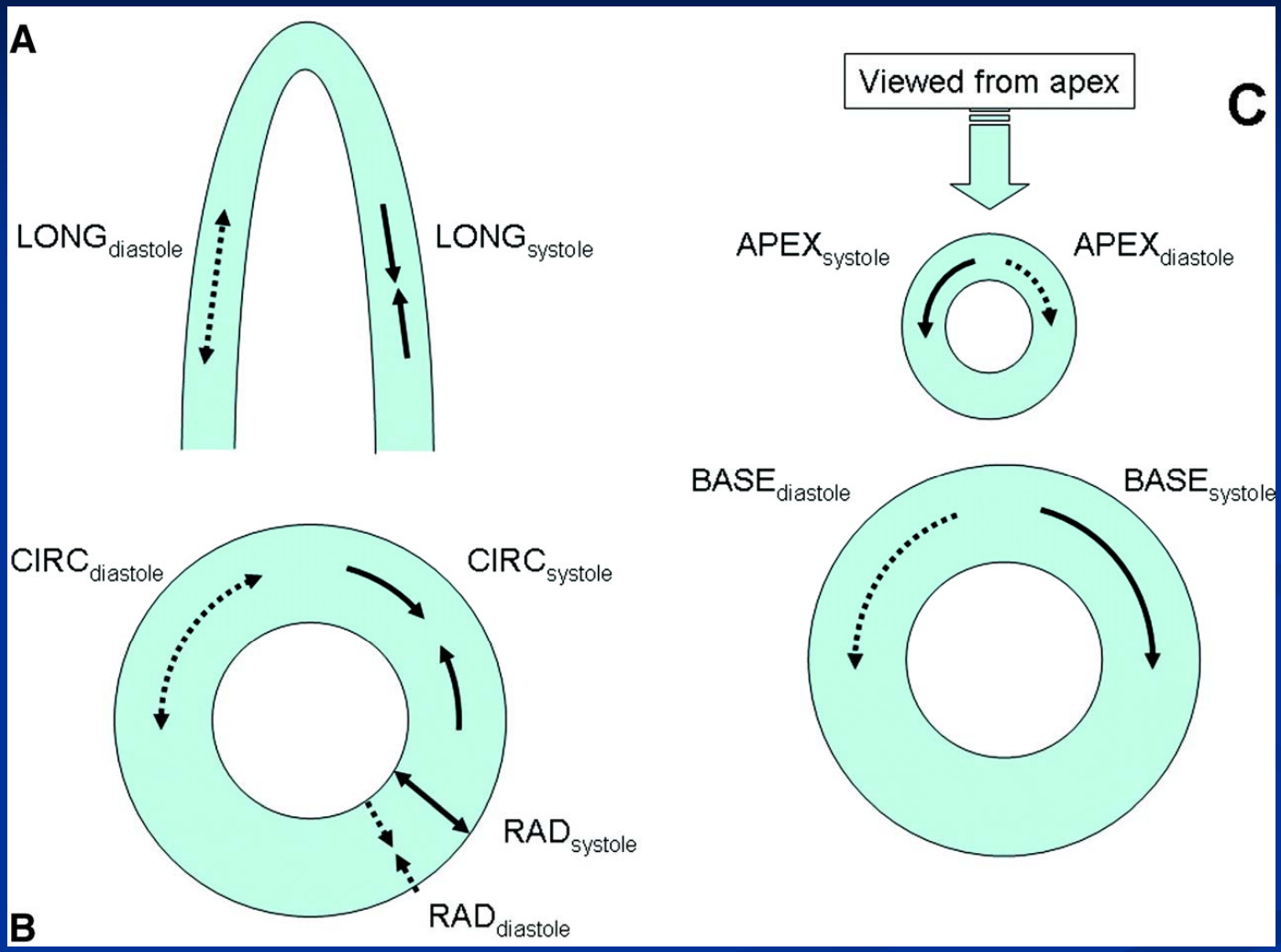
Yip G, Zhang Y, Tan P, Wang M, Ho P, Brodin L-A, Sanderson JE
Clinical Science 2002;102:515-22

2D speckle tracking



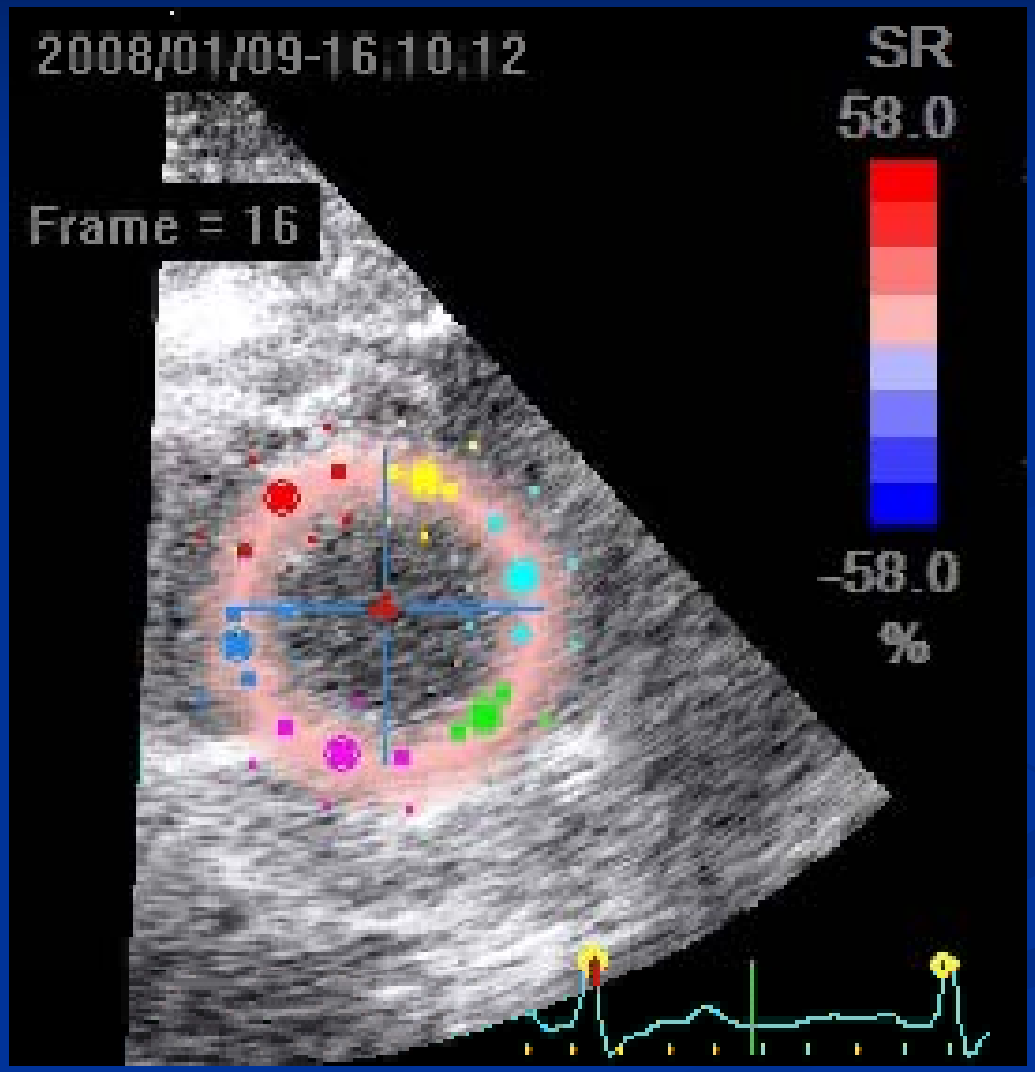


Graphic representation of the principal myocardial deformations: longitudinal (A), radial and circumferential (B), and torsion (C)

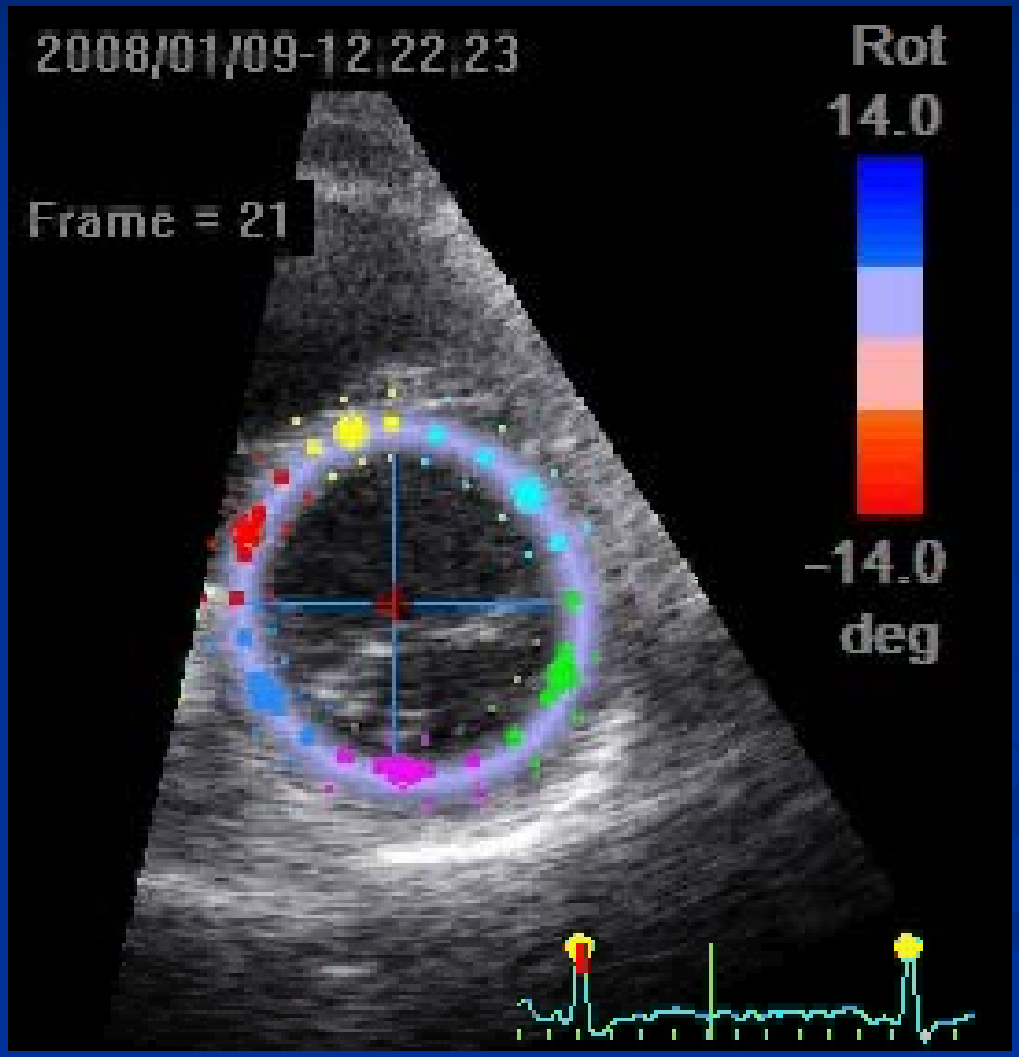


Abraham, T. P. et al. Circulation 2007;116:2597-2609

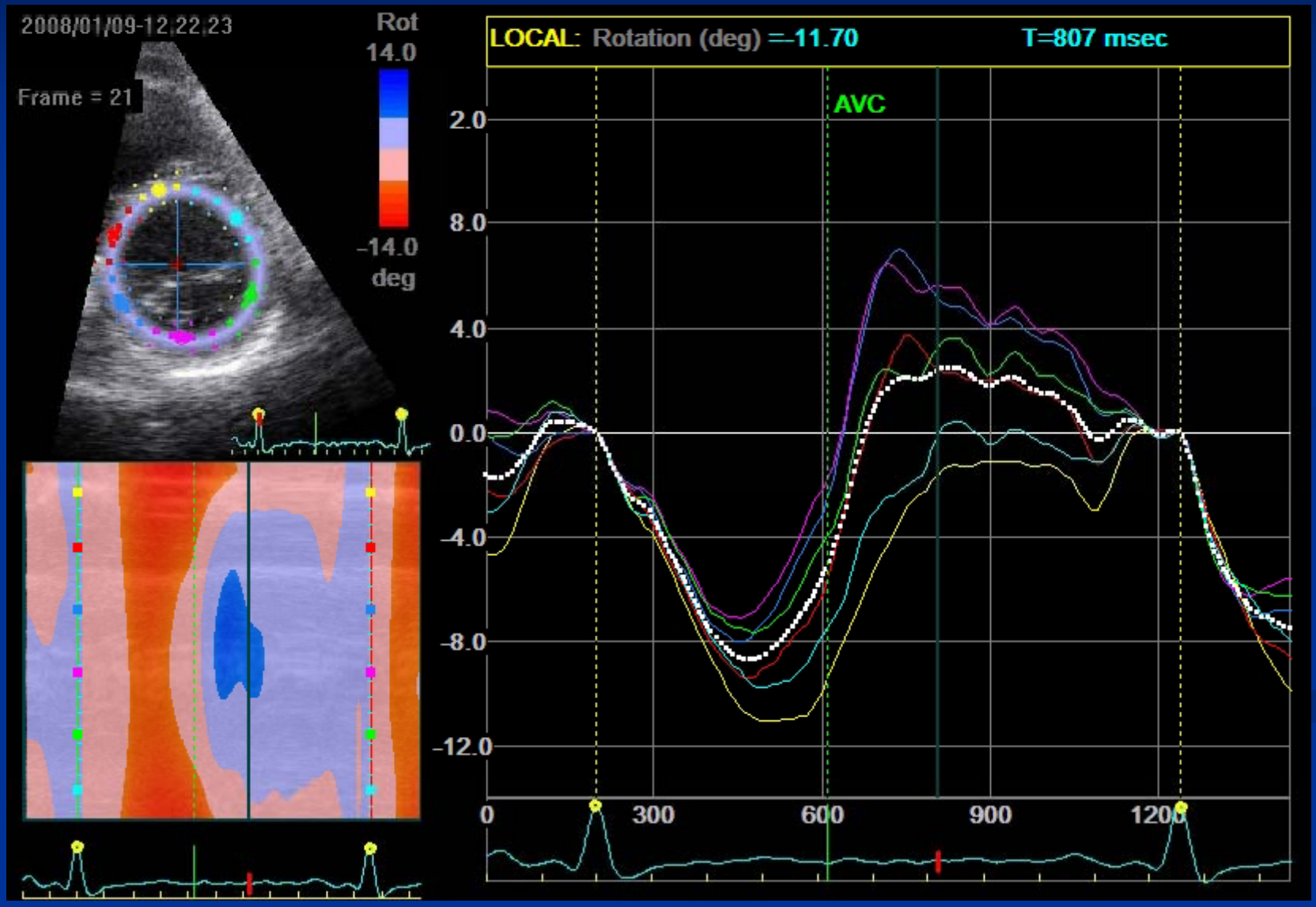
Apical Rotation

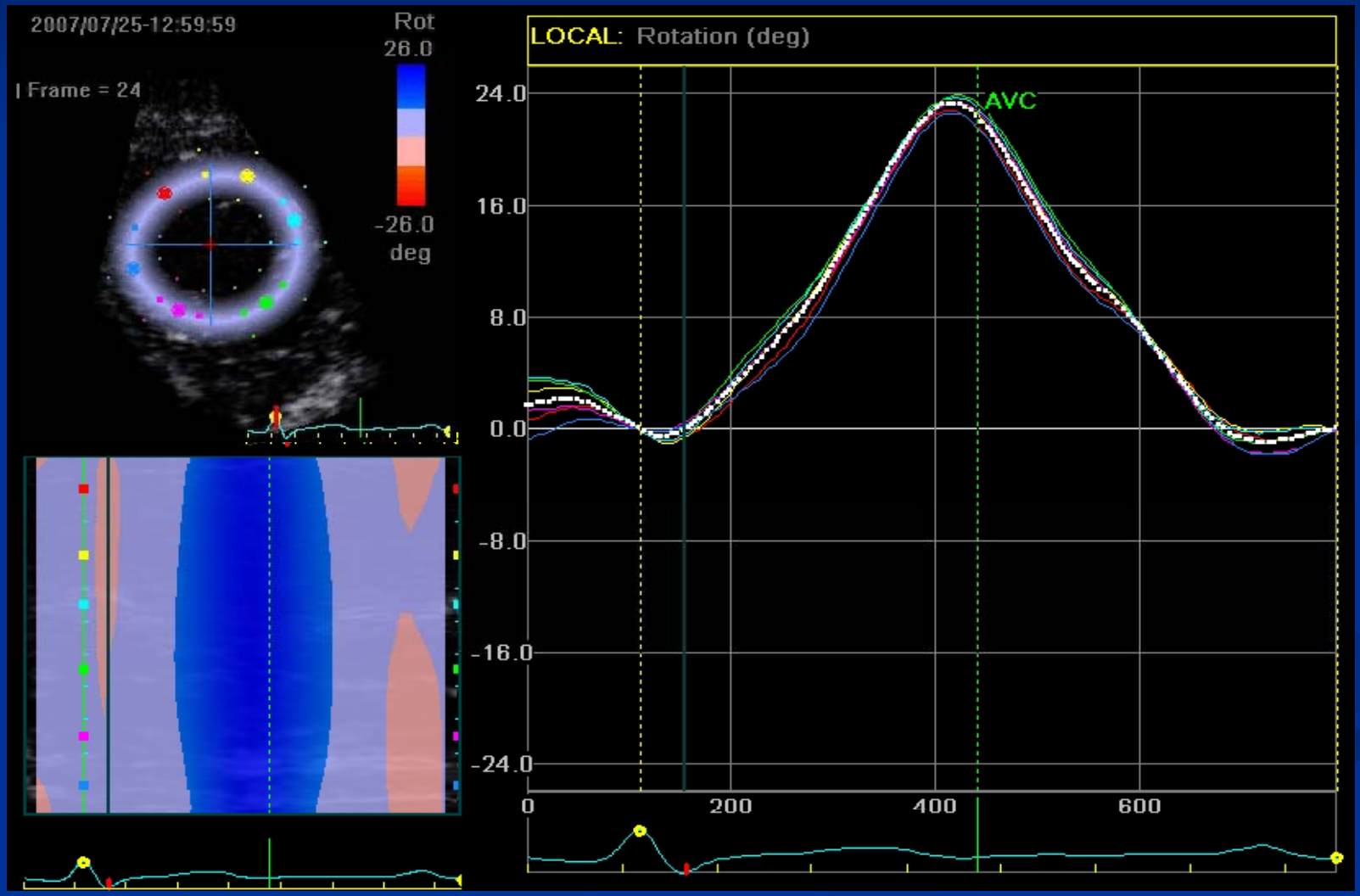


Basal Rotation

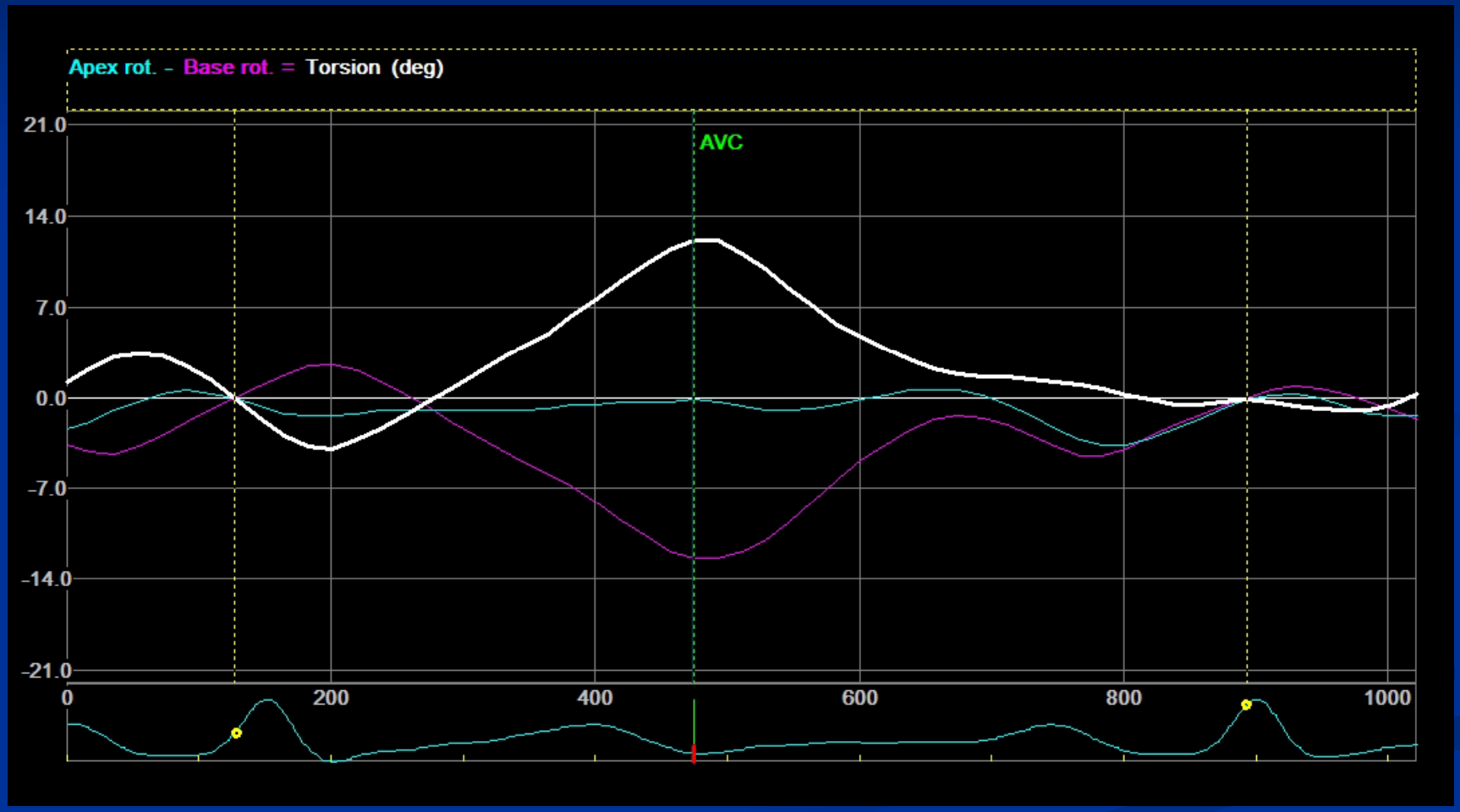


Rotation by STI




2007/07/25-12:59:59
Rot
26.0
-26.0
deg
I Frame = 24
LOCAL: Rotation (deg)
AVC
24.0
16.0
8.0
0.0
-8.0
-16.0
-24.0
0
200
400
600

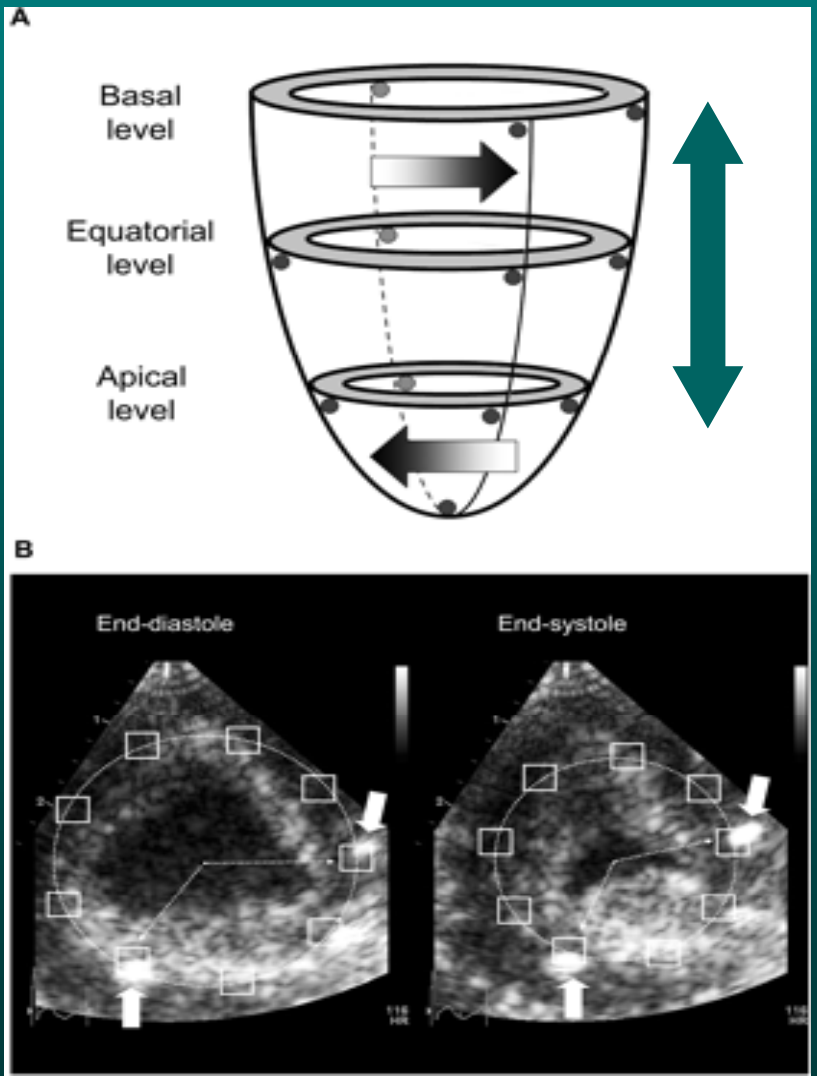
Torsion

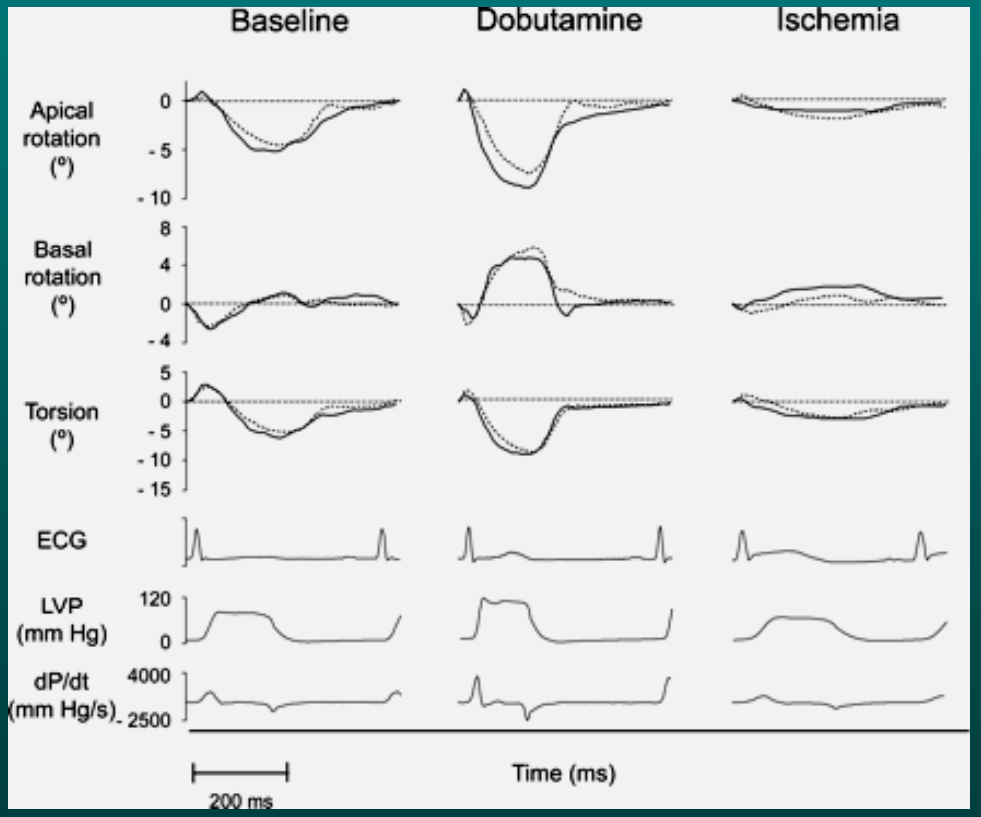

Apex rot. - Base rot. = Torsion (deg)
21.0
14.0
7.0
0.0
-7.0
-14.0
-21.0
AVC
0
200
400
600
800
1000

New Noninvasive Method for Assessment of Left Ventricular Rotation

Speckle Tracking Echocardiography

Thomas Helle-Valle, MD; Jonas Crosby, MSc; Thor Edvardsen, MD, PhD; Erik Lyseggen, MD; Brage H. Amundsen, MD; Hans-Jørgen Smith, MD, PhD; Boaz D. Rosen, MD; João A.C. Lima, MD; Hans Torp, DrTechn; Halfdan Ihlen, MD, PhD; Otto A. Smiseth, MD, PhD





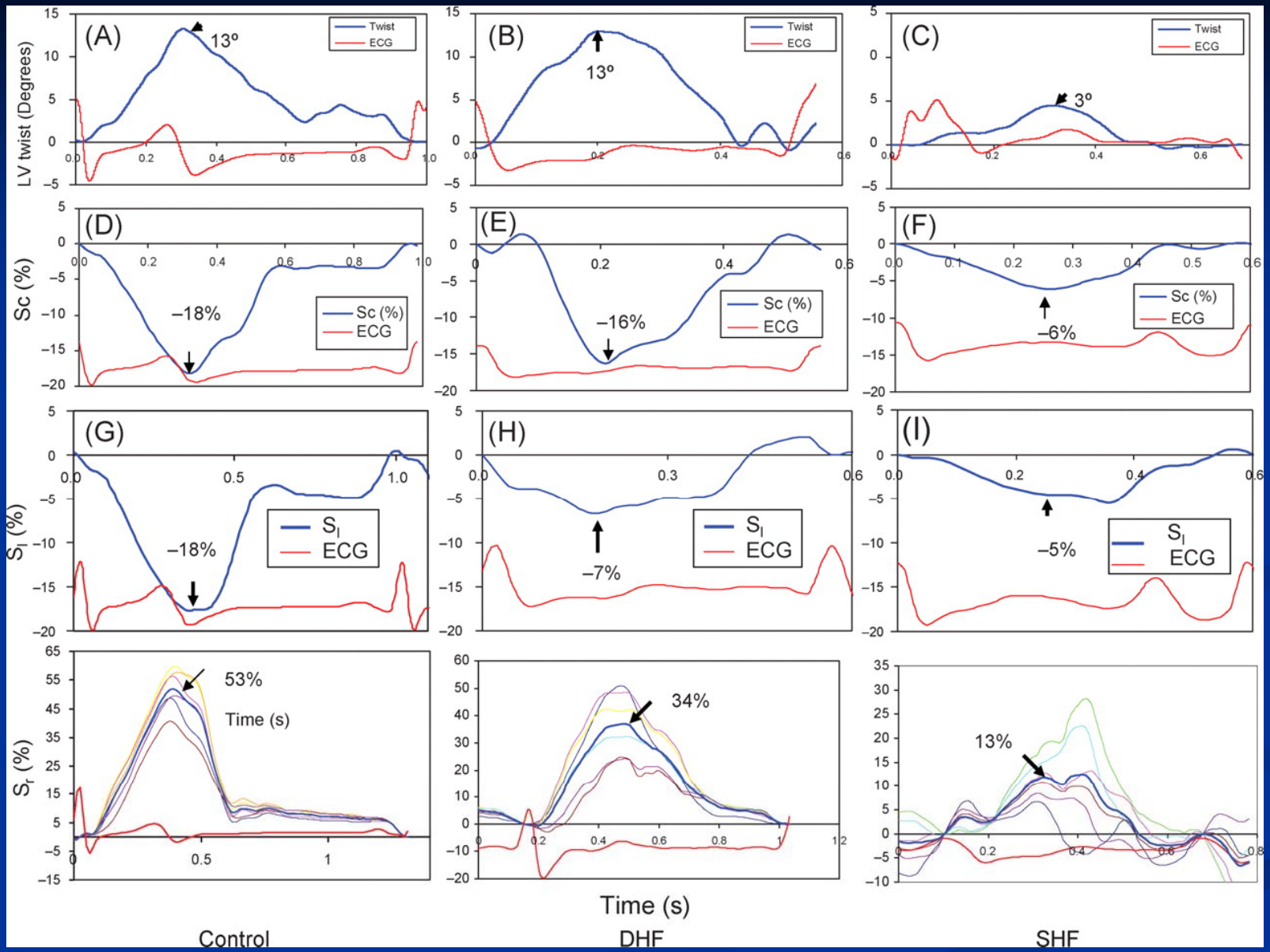
Circulation 2005;112:3149-3156

European Heart Journal Advance Access published April 2, 2008

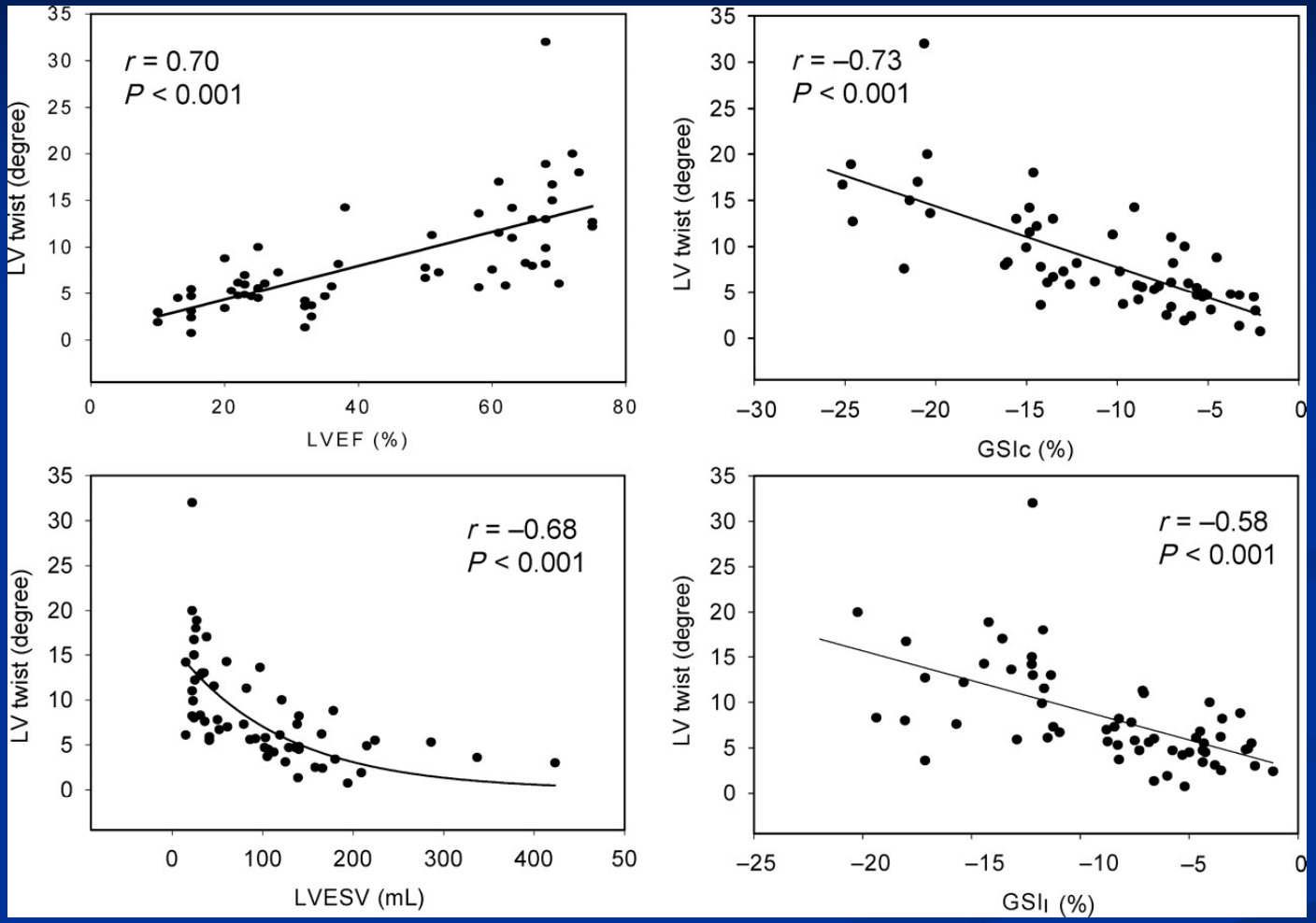
Preserved left ventricular twist and circumferential deformation, but depressed longitudinal and radial deformation in patients with diastolic heart failure

Jianwen Wang, Dirar S. Khoury, Yong Yue, Guillermo Torre-Amione, and Sherif F. Nagueh*

Conclusion LV longitudinal and radial strains are reduced, but circumferential deformation and twist are normal in DHF patients. On the other hand, in patients with SHF, longitudinal, radial, and circumferential deformation, and twist are all reduced. Multivariable regression analysis suggests that preserved LV twist and circumferential strain may contribute to normal EF in patients with DHF.



Wang, J. et al. Eur Heart J 2008 0:ehn141v1-7; doi:10.1093/eurheartj/ehn141



Wang, J. et al. Eur Heart J 2008 0:ehn141v1-7; doi:10.1093/eurheartj/ehn141

Longitudinal Strain and Torsion Assessed by Two-dimensional Speckle Tracking Correlate with the Serum Level of Tissue Inhibitor of Matrix Metalloproteinase-1, a Marker of Myocardial Fibrosis, in Patients with Hypertension

Soo-Jin Kang MD, PhD, Hong-Seok Lim MD, Byoung-Joo Choi MD, So-Yeon Choi MD, PhD, Gyo-Seung Hwang MD, PhD, Myeong-Ho Yoon MD, PhD, Seung-Jea Tahk MD, PhD and Joon-Han Shin MD

Division of Cardiology, Ajou University Hospital, Suwon, South Korea

JASE Available online 6 March 2008.

Background

We hypothesized that the alterations of myocardial collagen turnover in patients with hypertension may be involved in the early changes of regional contractile function assessed by a new speckle tracking method.

Methods

In 56 patients with untreated hypertension (48 ± 11 years, ejection fraction > 55%) and 20 age-matched control subjects, the serum levels of aminoterminal propeptide of procollagen I/III and tissue inhibitor of matrix metalloproteinase (TIMP)-1 were measured by radioimmunoassay and enzyme immunoassay. To assess the regional contractile function, the average of negative longitudinal strain of 6 segments at apical 4-chamber view (longitudinal ε), the average of radial strain (radial ε) and the average of circumferential strain (circumferential ε) of 6 mid-left ventricular (LV) segments, and basal-to-apical torsion were obtained by 2-dimensional speckle tracking imaging.

Results

Compared with control group, longitudinal ε was significantly decreased (−20.4 ± 3.0% vs −22.1 ± 2.2%, $P = .030$) and basal-to-apical torsion was increased (20.5 ± 5.7 degrees vs 17.4 ± 3.7 degrees, $P = .013$) in patient group. The serum level of log TIMP-1 was higher in the patients (3.6 ± 0.6 vs 3.0 ± 0.5, $P < .001$). The serum log TIMP-1 significantly correlated with longitudinal ε ($r = 0.405$, $P = .015$), basal-to-apical torsion ($r = 0.331$, $P = .017$), and the LV mass ($r = 0.266$, $P = .047$). In multivariate analysis, longitudinal ε (β = 0.326, $P = .015$) and basal-to-apical torsion (β = 0.402, $P = .003$) independently correlated with the serum TIMP-1 level.

Conclusion

In patients who are hypertensive with normal ejection fraction, impaired longitudinal ε and increased LV torsion correlated with serum TIMP-1, which suggests that the change in collagen turnover and the myocardial fibrotic process may affect the early contractile dysfunction of LV.

Assessment of left ventricular rotation and torsion with two-dimensional speckle tracking echocardiography.

Kim HK, Sohn DW, Lee SE, Choi SY, Park JS, Kim YJ, Oh BH, Park YB, Choi YS.

Division of Cardiology, Department of Internal Medicine, Seoul National University College of Medicine, Cardiovascular Center, Seoul National University Hospital, Seoul, Korea.

BACKGROUND: Speckle tracking echocardiography (STE) has a unique feature of angle independence and, thus, may provide a powerful means of assessing left ventricular (LV) torsion (LVtor). The aims of this study were to assess: (1) the feasibility of 2-dimensional STE in the measurement of LVtor; and (2) the relationship of LVtor with age and conventional echocardiographic parameters. METHODS: We consecutively recruited 160 healthy volunteers. After obtaining conventional echocardiographic parameters, apical and basal short-axis rotations were assessed with STE. LVtor was defined as the net difference between rotation angles in the two short-axis planes normalized for LV longitudinal length. RESULTS: Reliable LVtor measurement was possible only in 56 volunteers (35%). This low feasibility was largely a result of the failure to obtain reliable basal rotation values. In 56 volunteers who were finally enrolled in this study, a significant correlation was found between LV ejection fraction and LVtor ($r = 0.56$, $P < .001$) and this correlation was attributed to apical ($r = 0.47$, $P < .001$) but not basal ($P = .14$) rotation. There was no significant change in LVtor with aging. However, initial counterclockwise motion ($r = -0.51$, $P = .001$) and its interval ($r = -0.44$, $P = .001$) in the basal rotation gradually decreased with aging, and correlated with early transmitral inflow velocity ($r = 0.44$ and 0.49, respectively) and its deceleration time ($r = -0.43$ and -0.48, respectively) (all $P < .001$). In contrast, such correlations were not found for initial clockwise motion and its interval in the apical rotation.

CONCLUSIONS: Currently, STE has limited feasibility in the measurement of LVtor. There was no significant age-related change in LVtor. In LV rotations, basal rotation was affected by the age-related changes in the LV early diastolic filling, whereas apical rotation was mainly related to LV systolic performance.

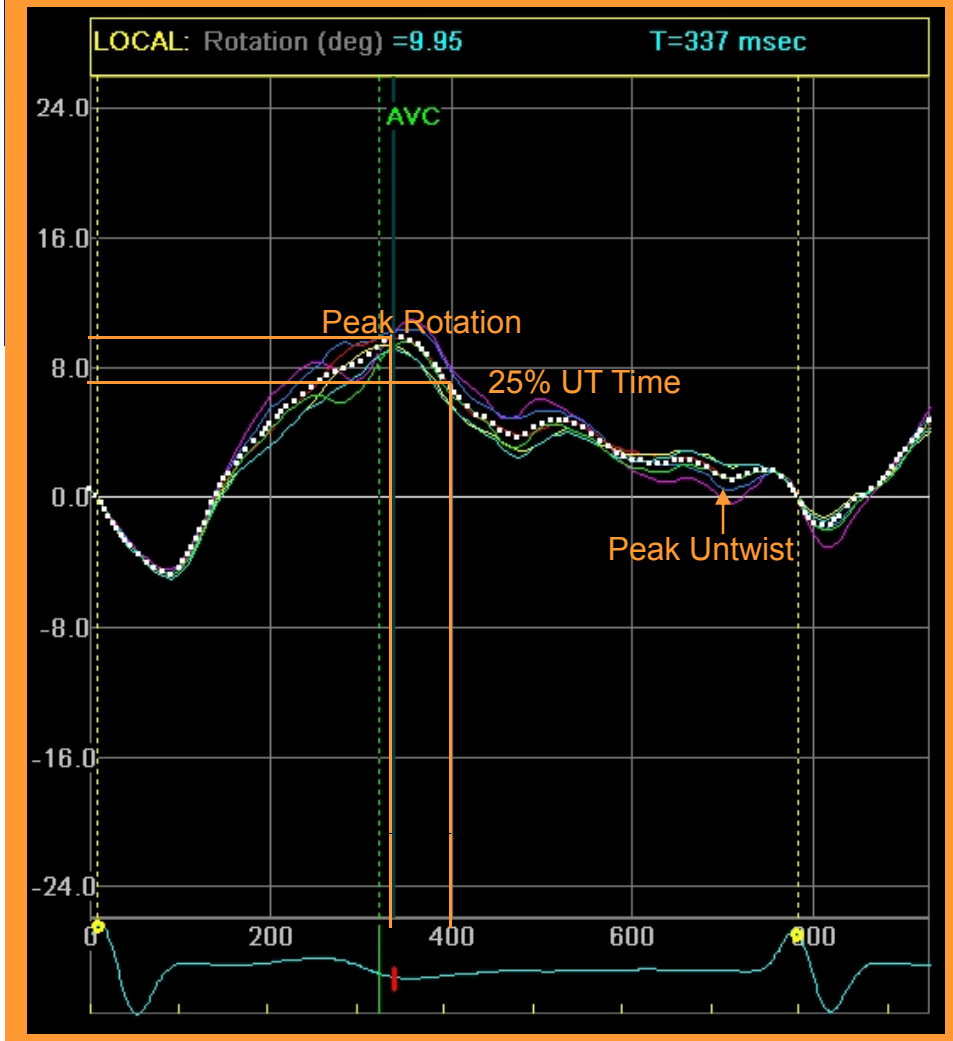
JASE 2007;20:45-53

Hypothesis:
Reduced ventricular twist and long axis function (AV plane displacement) leads to:

- Reduced ventricular suction
- Reduced and delayed early diastolic filling
- Shortened time for filling of the heart
- Increased filling pressure
- Breathlessness on exercise.

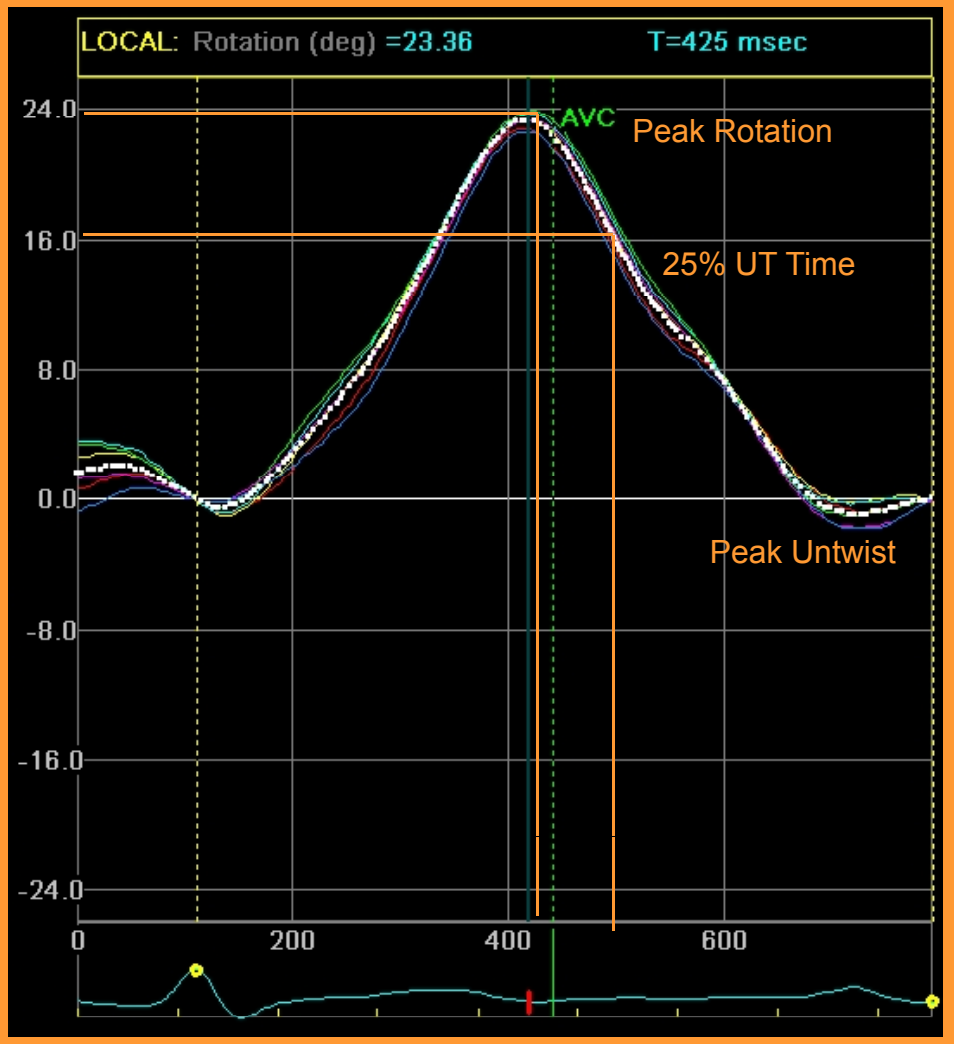
Rotation and Untwist

Patient, ♂ 62 years



Peak Rotation: 9.95deg (337ms)
Untwist at 25% of Untwist Duration: 9.25deg = 7% (378ms)

Control, ♀ 61 years



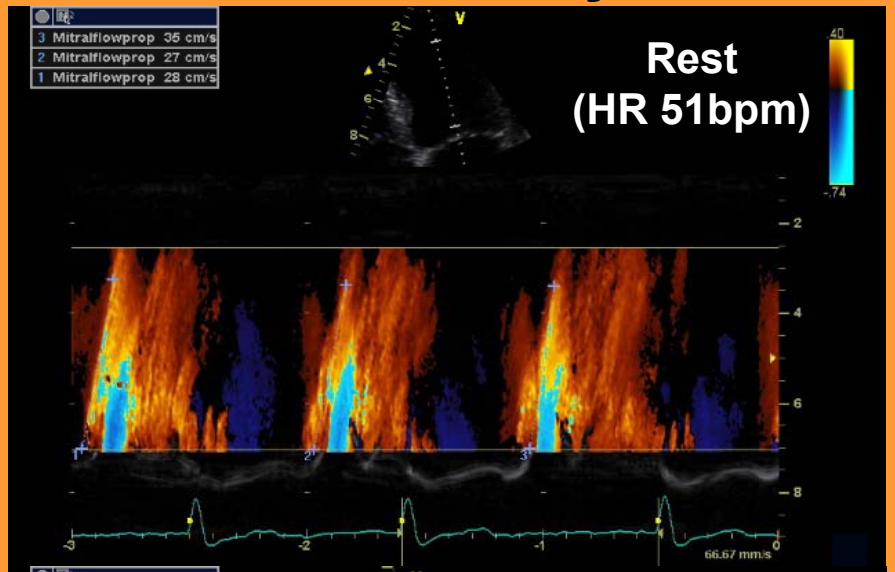
Peak Rotation: 23.36deg (at 425ms)
Untwist at 25% of Untwist Duration: 16.88deg = 28% (491ms)

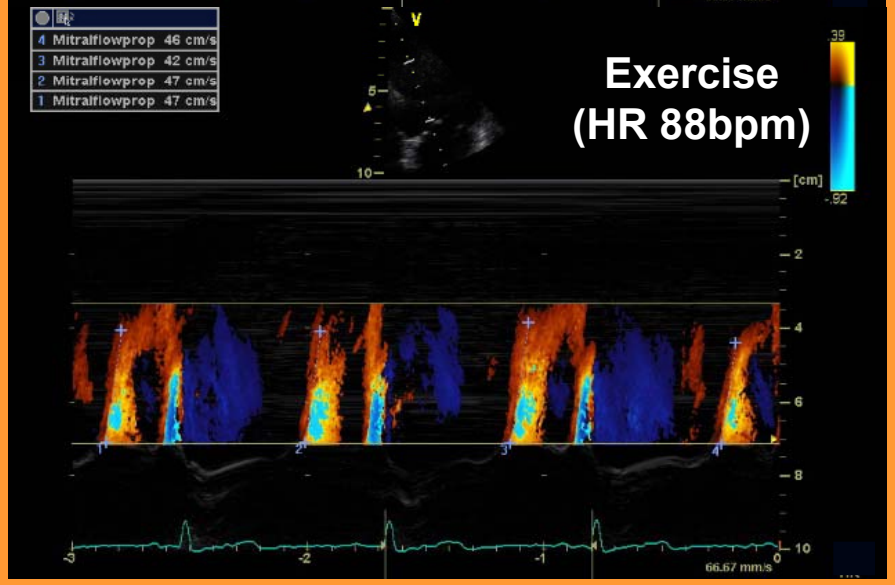
Rotation and Untwist at Rest

Echo Results	Patients (n=32)	Controls (n=22)
Heartrate at Rest (bpm)	66±12	66±10
Apical Rotation at Rest (Degree)	9.5±3.7 p=0.004	12.7±4.1
Basal Rotation at Rest (Degree)	-9.5±3.3	-10.7±3.3
Torsion at Rest (Degree/cm)	2.6±0.5 p=0.01	3.2±0.6
Percent of Untwist at 25% of	22.3±10.4 p=0.012	30.0±10.2
Untwist Duration		

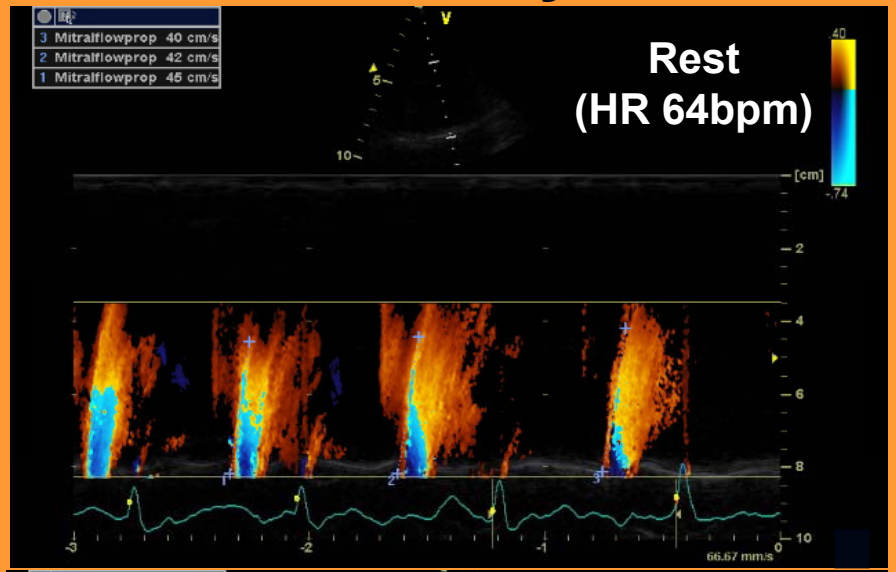
Mitral Flow Propagation Velocity at Rest and Exercise

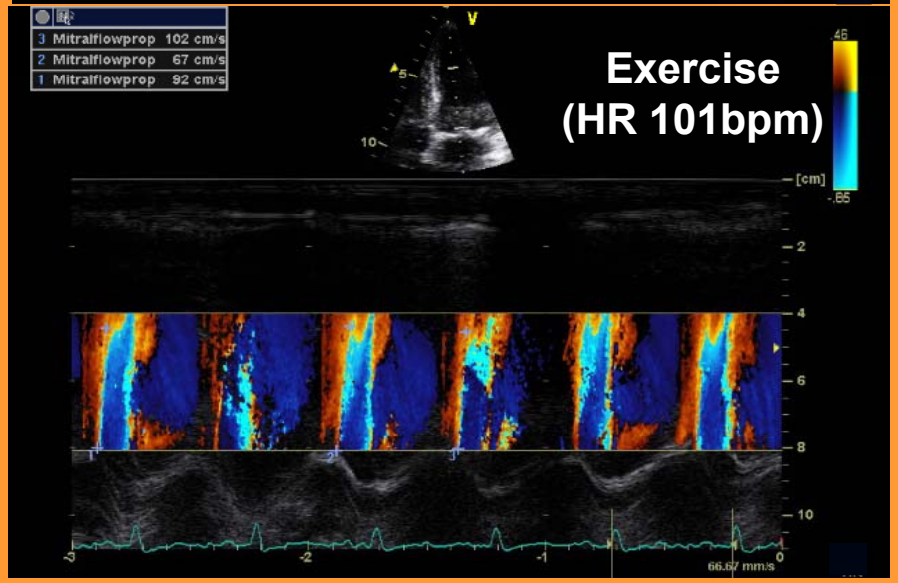
Patient, ♀ 77 years





Control, ♀ 72 years

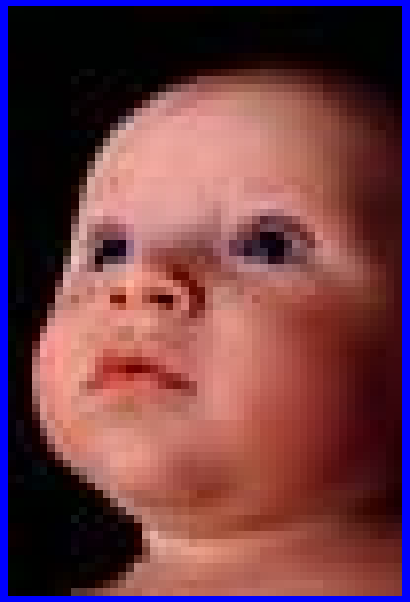




Mitral Flow Propagation Velocity (MFPV)

Results	Patients (n=37)	Controls (n=20)
Heartrate at Rest (bpm)	68±12	68±10
Heartrate at Exercise (bpm)	91±9	93±7
MFPV Rest (cm/s)	38.6±9.9	36.9±5.4
MFPV Exercise (cm/s)	48.8±12.7 p=0.025	57.0±13.2
MFPV Increase (cm/s)	10.8±10.8(32%) p=0.003	20.6±12.3(58%)

Effects of Ageing on Diastolic function and Collagen.



Effect of Aging on Twist-Displacement Loop by 2-Dimensional Speckle Tracking Imaging

Hiromi Nakai, BS, Masaaki Takeuchi, MD, Tomoko Nishikage, BS, Michiko Kokumai, MS, Shinichiro Otani, MD, and Roberto M. Lang, MD, *Osaka, Japan, and Chicago, Illinois*

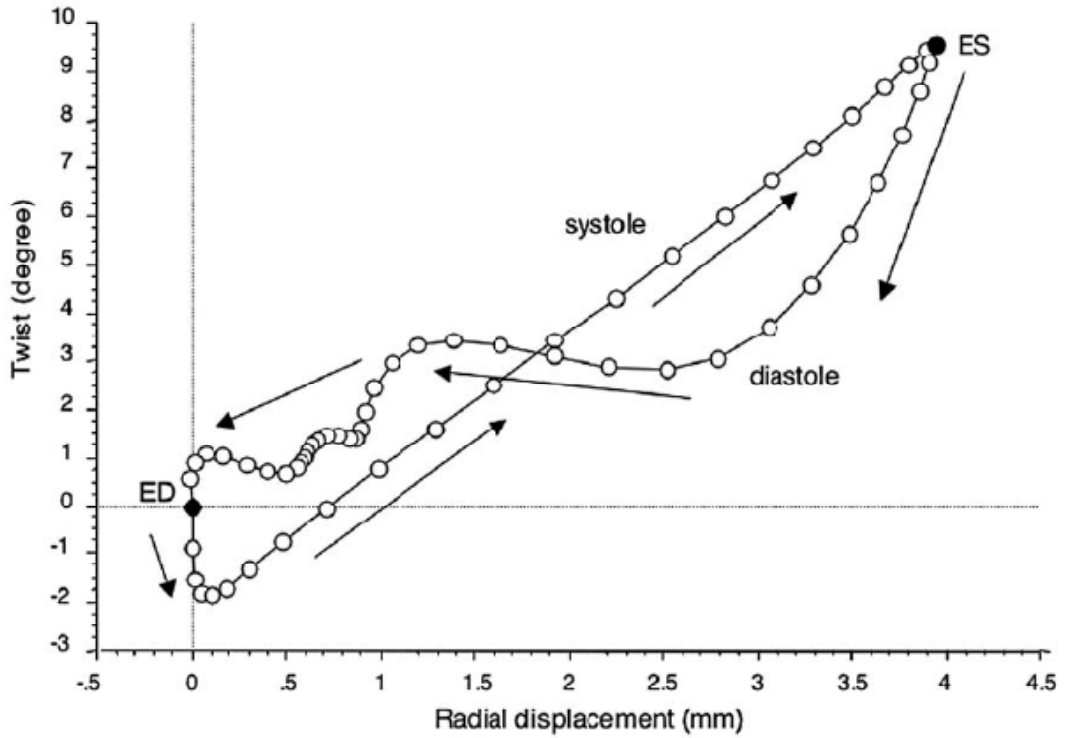
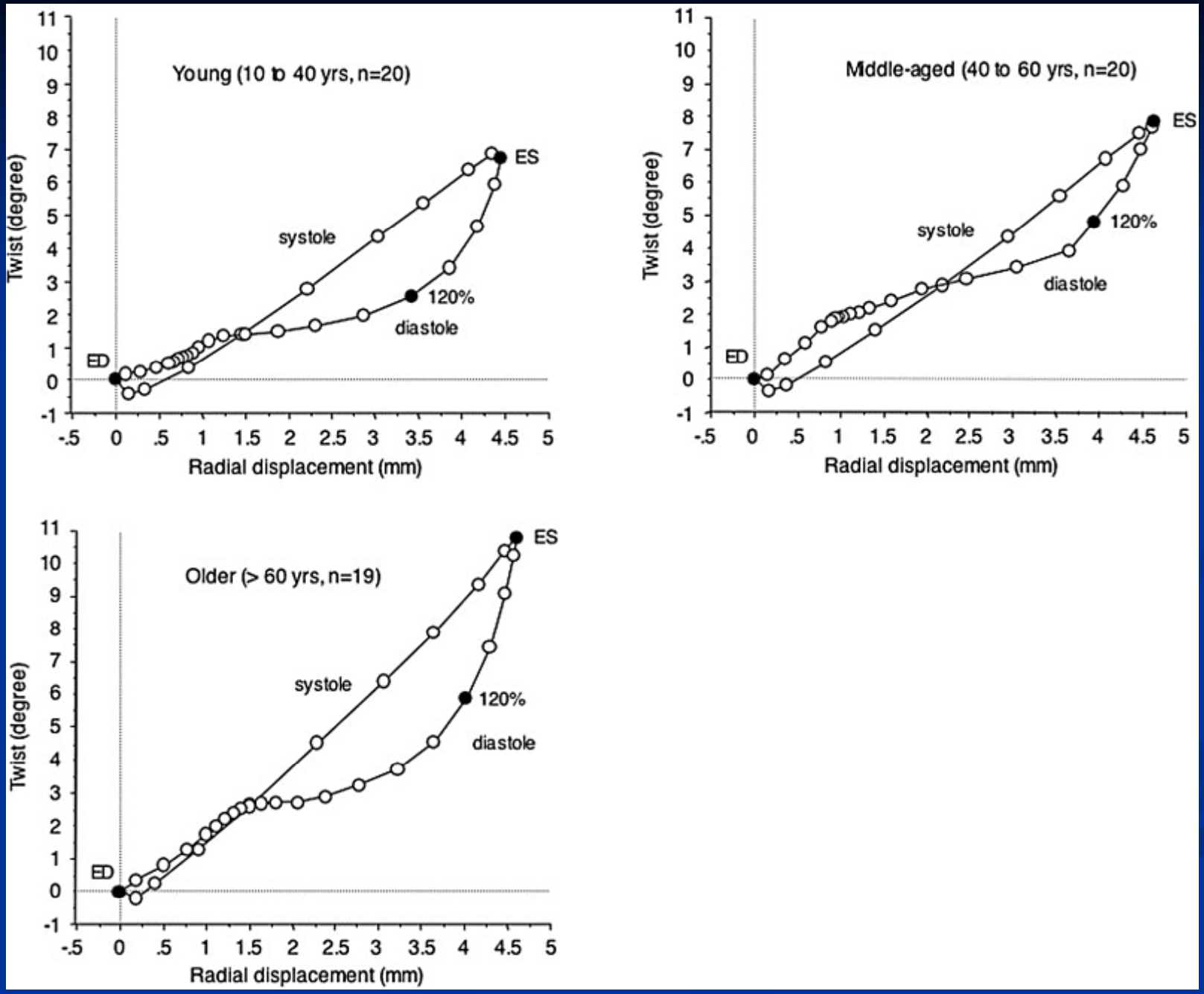
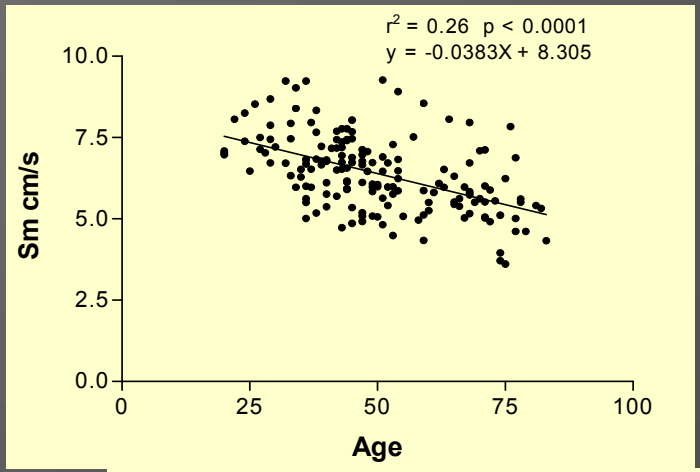
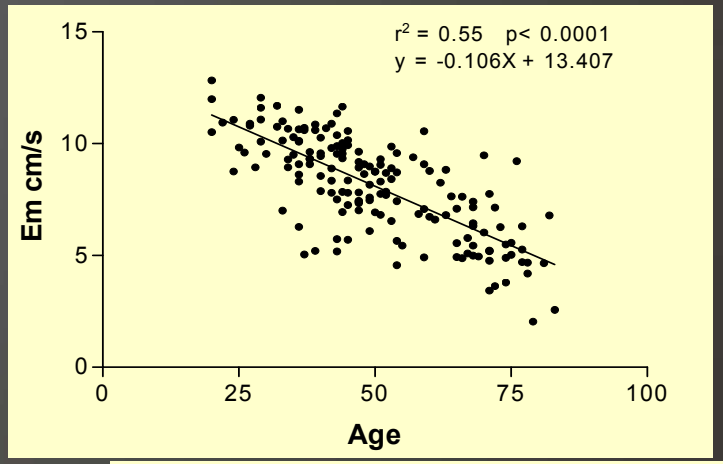


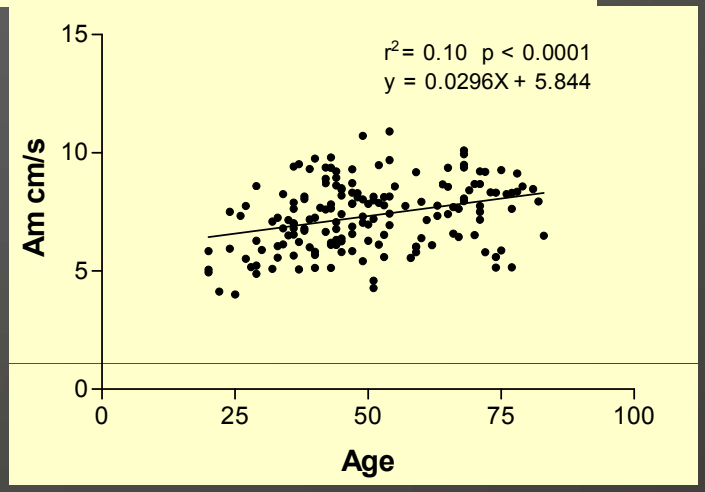
Figure 1 Twist-displacement loop in healthy 26-year-old man. Twist is plotted against radial displacement during one cardiac cycle. Number of dots reflects frame rate (69 Hz in this case). X-axis denotes radial displacement and y-axis denotes twist. Dot point of 0 means at end diastole (*ED*). After initial transient clockwise twist, left ventricle shows persistent counterclockwise twist that peaks at end systole (*ES*). Note that curve during systole looks almost linear and that there is tight relationship between twist and displacement ($r = 0.99$). During early diastole, rapid untwisting occurs despite small reversal of systolic radial displacement. During remainder of mid to late diastole, less untwisting develops with large change in radial displacement.

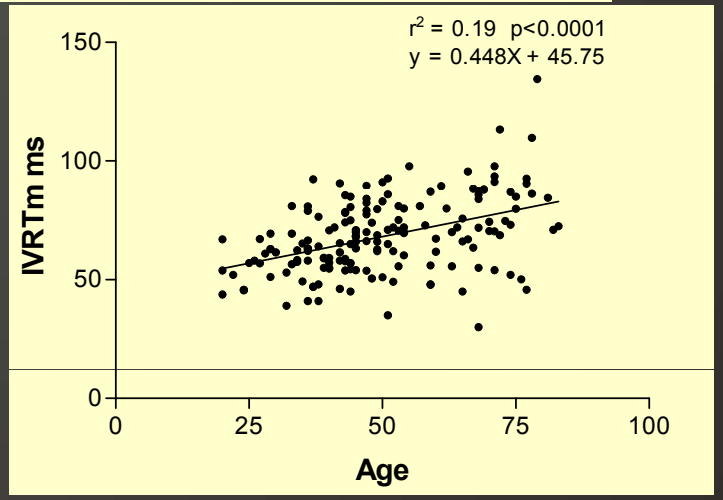

Young (10 to 40 yrs, n=20)
Middle-aged (40 to 60 yrs, n=20)
Older (> 60 yrs, n=19)
Twist (degree)
Radial displacement (mm)
ED
ES
systole
diastole
120%
11
10
9
8
7
6
5
4
3
2
1
0
-1
-.5
0
.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Influence of Age on LV long axis changes in velocities (TDI) in normal subjects









Yip et al 2001

Age changes (20-84 years) of mitral annular excursion (LAX) and velocity (m) in systole and diastole

	Expected at age 20	Expected at age 84	Changes from age 20 to 84 years	Changes in %	Linear correlation to age	Level of significance
S_{LAX}	1.49	1.22	-0.28	-18%	r = -0.44	p<0.001
Sm	7.48	5.22	-2.26	-30%	r = -0.49	p<0.001
E_{LAX}	1.09	0.56	-0.53	-49%	r = -0.67	p<0.001
Em	10.99	4.82	-6.17	-56%	r = -0.67	p<0.001
A_{LAX}	0.48	0.60	0.12	25%	r = 0.35	p<0.001
Am	6.57	8.53	1.96	30%	r = 0.31	p=0.002

Yip GW, Zhang Y, Tan PY, Wang M, Ho PY, Sanderson JE 1999

Conclusions

- Rotation or twist is a fundamental property of ventricular function and its disturbance may be a major factor in the development of impaired ejection and filling.


THANK YOU
13 6 2003