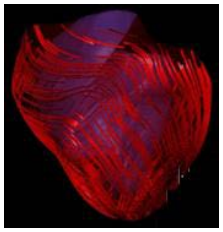
Echo Assessment of LV Function: What Are We Really Trying to Measure)



Jonathan R. Lindner, M.D.
M. Lowell Edwards Professor of Cardiology
Oregon Health & Science University
Portland, Oregon

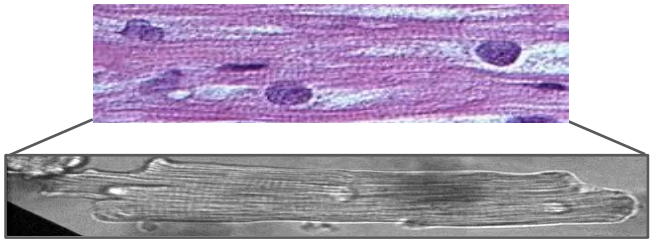
1

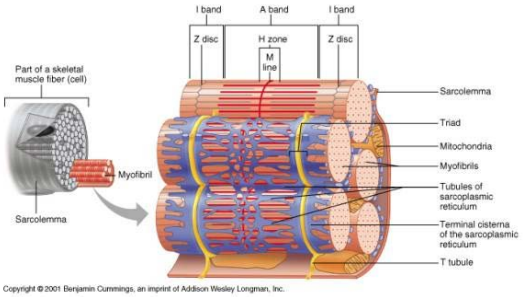
Left Ventricle

Right Ventricle

2

The Cardiomyocyte and LV Function





Dynamic Morphometrics

Myocyte shortening: 15%

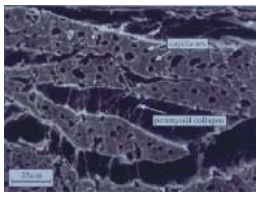
Myocyte thickening: 8%

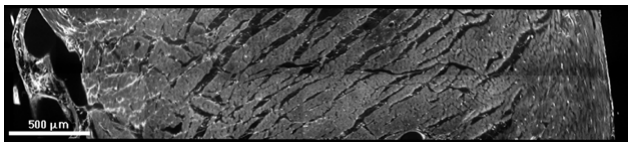
Wall thickening: 40%

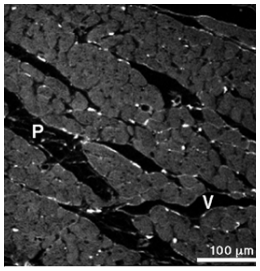
Ejection Fraction: 60-70%

3

Myocardial Sheet Composition



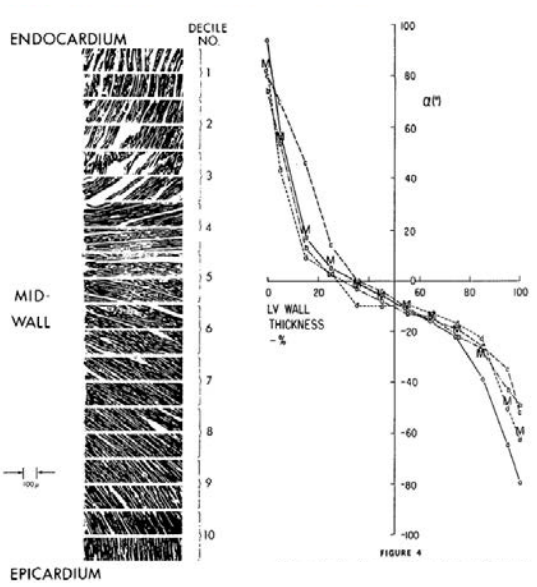


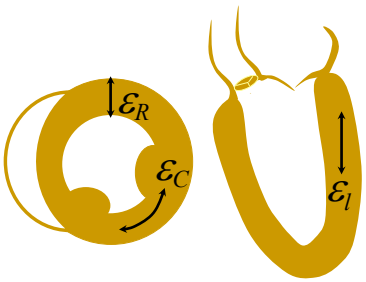


Young AA, et al., J Microsc 1998;191:131

4

Fiber Orientation and Strain

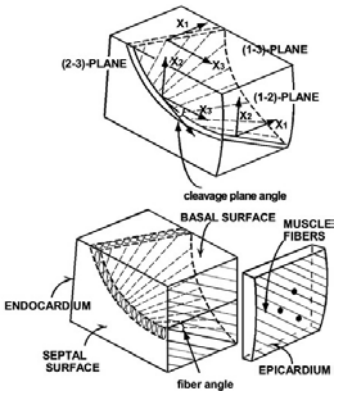


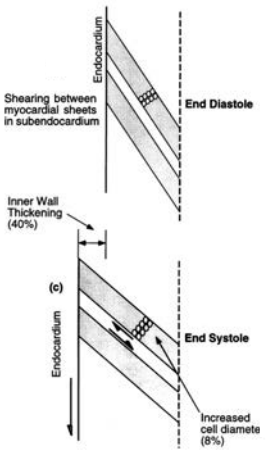


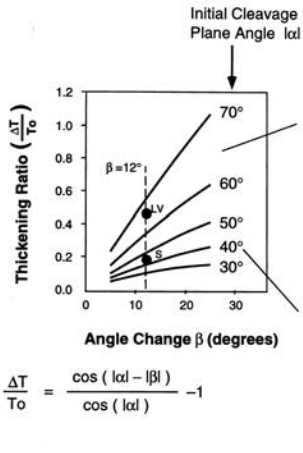
Streeter DD, et al. Circ Res 1969;24:339

5

Sheet Thickening and Interlaminar Shear







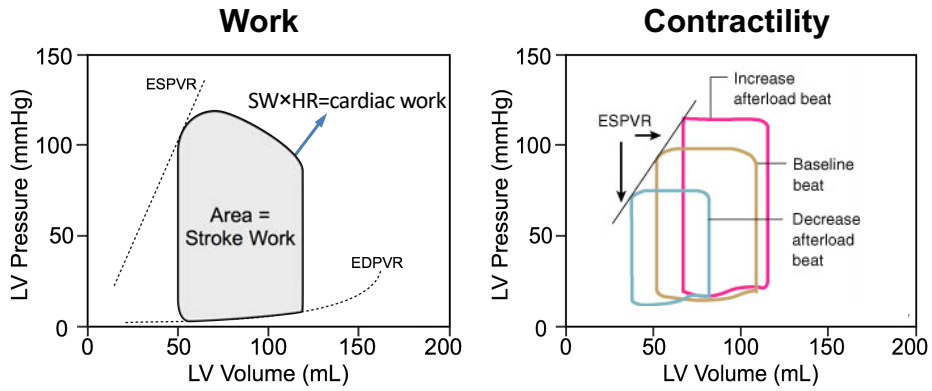
$$\frac{\Delta T}{To} = \frac{\cos(|\alpha| - |\beta|)}{\cos(|\alpha|)} - 1$$

Y Takayama et al. Am J Physiol 2002;282:H1510

IJ LeGrice et al. Circ Res. 1995;77:182

6

Classic Hemodynamic Definitions of Contractility and Myocardial Work



7

Echo Assessment of the Periodic Pump

Muscle Squeeze
dp/dt
Tissue Doppler
VCF
Strain
Strain rate
Isovolumic acceleration
Torsion
Twist

Volume
LVEF
Shortening Fraction
Stroke volume
Stroke work
(ESV-ESP relation)

"Myocardial work"

8

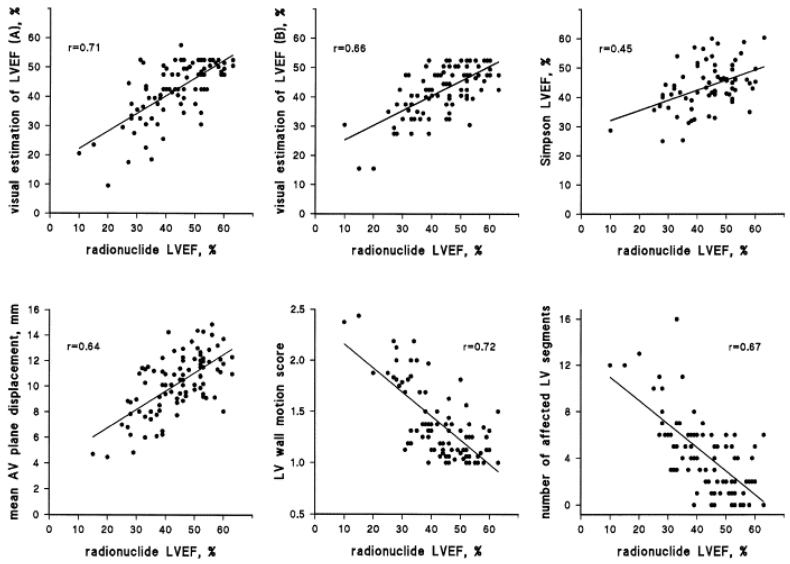
Assessing LV Volumes and LVEF

ISSUES
- Accuracy
- Reproducibility
- Ability to account for geometric distortions

2-D Simpson's Biplane - Limitations
- Two views only
- Foreshortening of the apex
- Endocardial definition
- Dealing with trabeculation

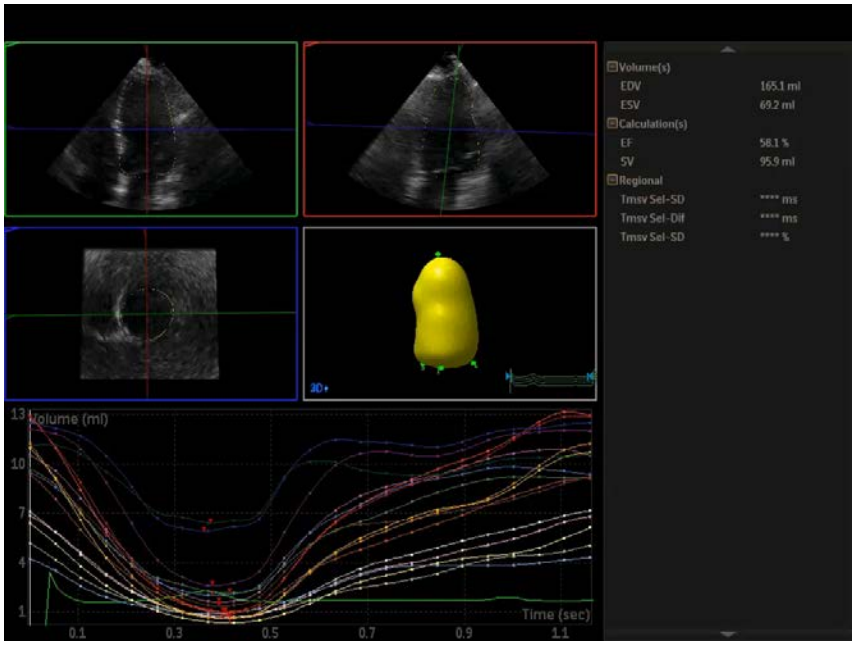
9

LVEF – A Messy Business



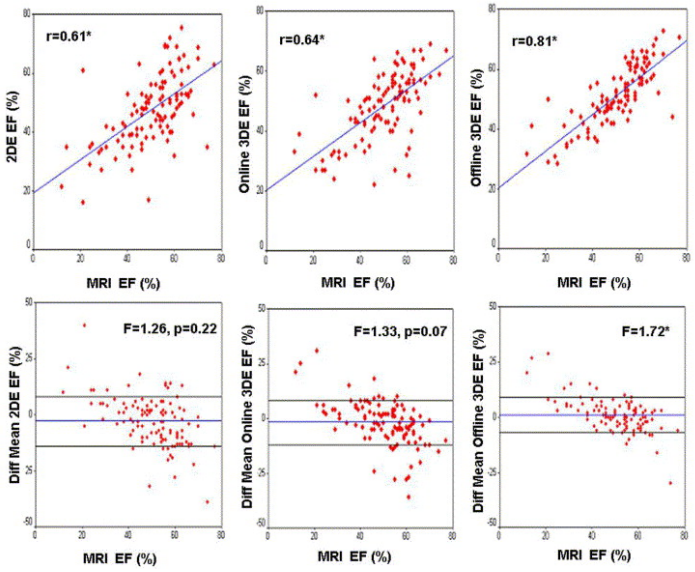
Jensen-Urstad K, et al. Am J Cardiol 1998;81:538

10



11

Impact of 3D Echo in Patients With Regional WMA

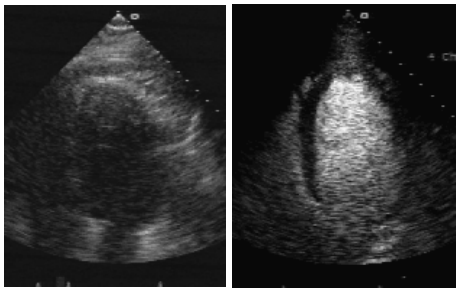


Jenkins C, et al. J Am Soc Echocardiogr 2006;19:1119

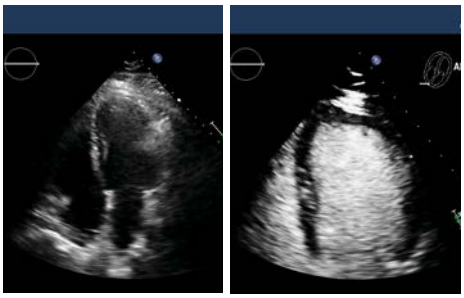
12

Impact on Assessment of LV Size and Function

Bad → Good

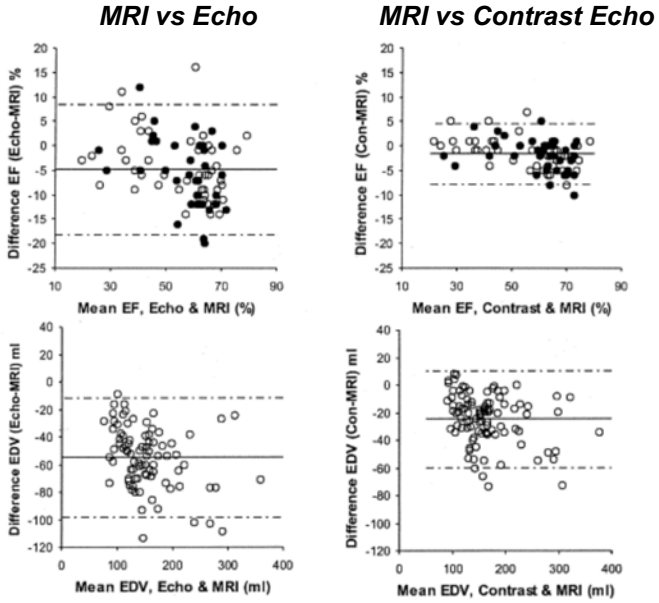


Mediocre → Great



13

Precision and Accuracy



Malm S, et al. JACC 204:44:1030

14

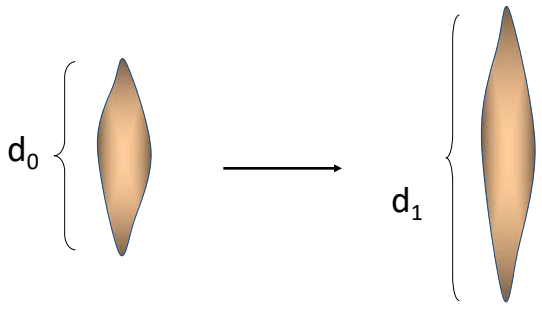
Echo Assessment of the Periodic Pump

Muscle Squeeze	**Volume**
dp/dt	LVEF
Tissue Doppler	Shortening Fraction
VCF	Stroke volume
Strain	Stroke work
Strain rate	(ESV-ESP relation)
Isovolumic acceleration	
Torsion	
Twist	

"Myocardial work"

15

Strain and Strain Rate Imaging

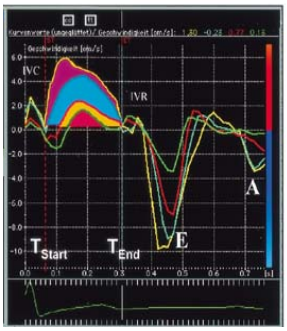


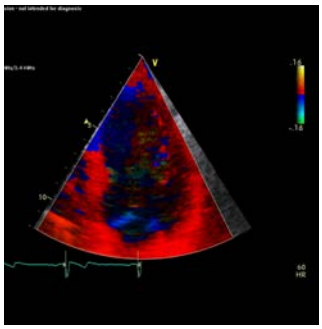
Deformation = $d_1 - d_0$ Strain = $\frac{d_1 - d_0}{d_0}$

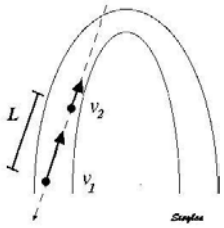
Strain rate = strain/time

16

Strain Calculation Based on Tissue Doppler Data



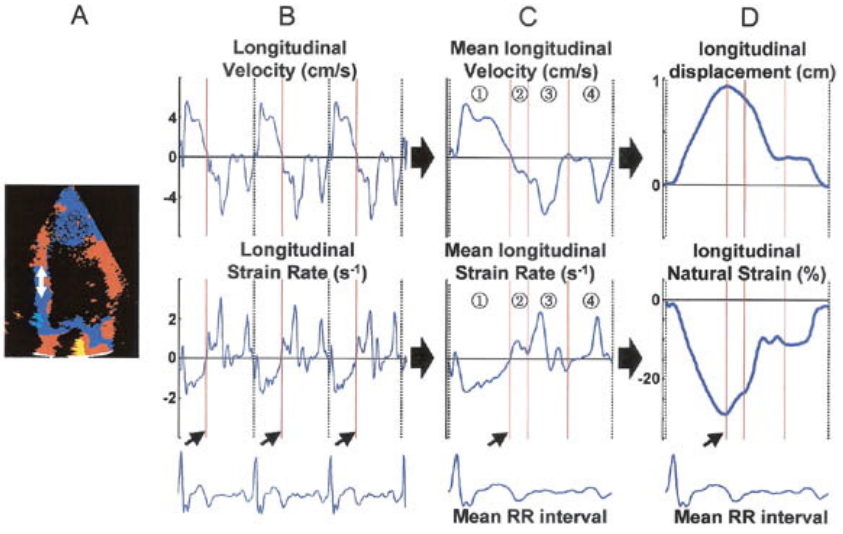




$$SR = \frac{v_1 - v_0}{d}$$

17

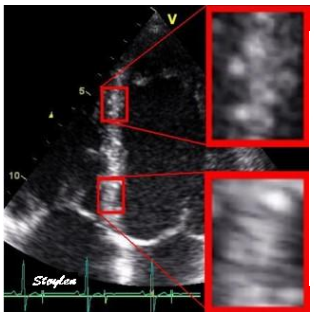
TDI-based Velocities and Strain Calculation

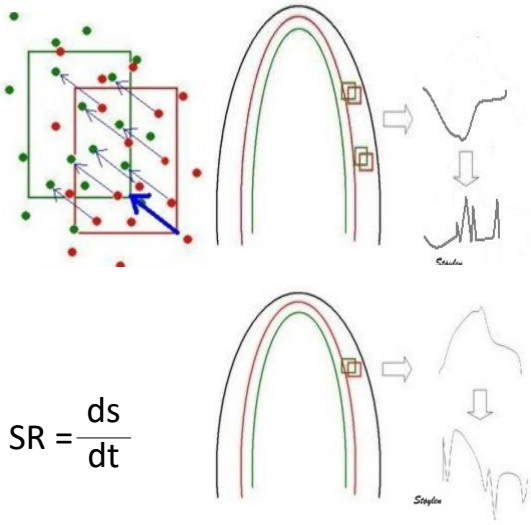


Jamal F, et al. J Am Soc Echocardiogr 2002;15:723

18

Strain Calculation – Speckle Tracking



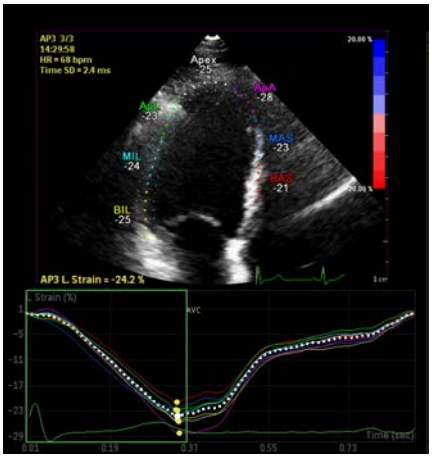


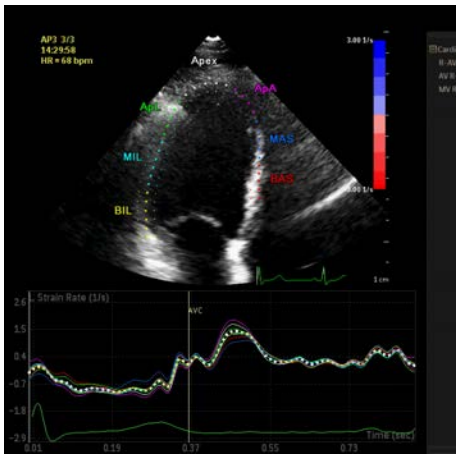
$$\text{Strain} = \frac{d_1 - d_0}{d_0} \qquad \text{SR} = \frac{ds}{dt}$$

19

Speckle-tracking Strain Echocardiography

Strain **Strain Rate**

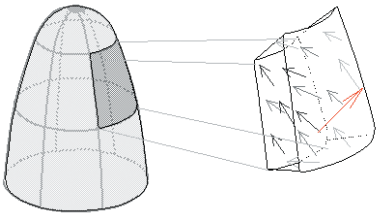




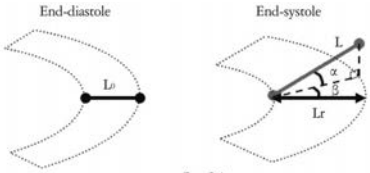
20

3-D and (4-D) Strain

Principal



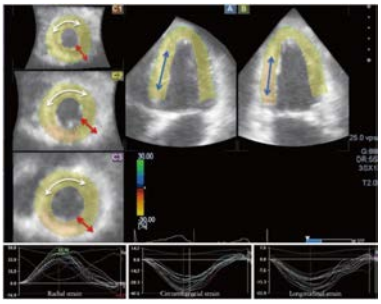
Shear



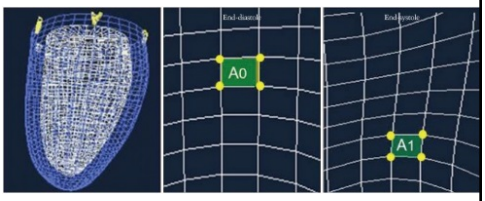
$$\text{Radial strain} = \frac{(Lr - L_0)}{L_0} \times 100\,(\%)$$

$$\text{3D strain} = \frac{(L - L_0)}{L_0} \times 100\,(\%)$$

Component (Langrangian)



Area



Seo Y, et al., J Cardiovasc Ultrasound 2014;22:490

21

Velocity and Strain Echo Techniques

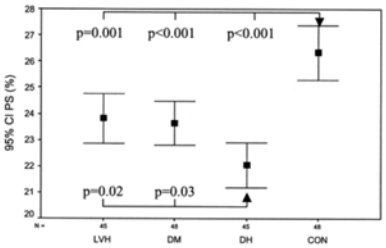
Features	DTI	2-D STE	3-D STE
Feasibility	+++	++	+
Temporal resolution	+++	++	+
Angle independency	-	+	++
Affected by through-plane motion	+++	+	+++
Defined values (normal and dz)	+++	+++	+
Segmental uniformity	-	++	++
Vendor variability	++	+	+

- poor, + reasonable, ++ good, +++ very good

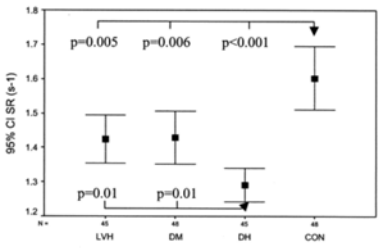
22

Detecting Underlying Disease

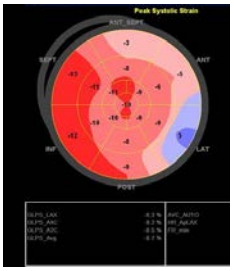
Strain

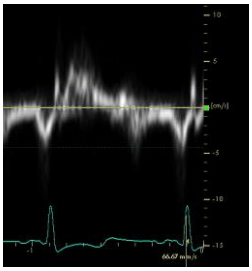


Strain Rate



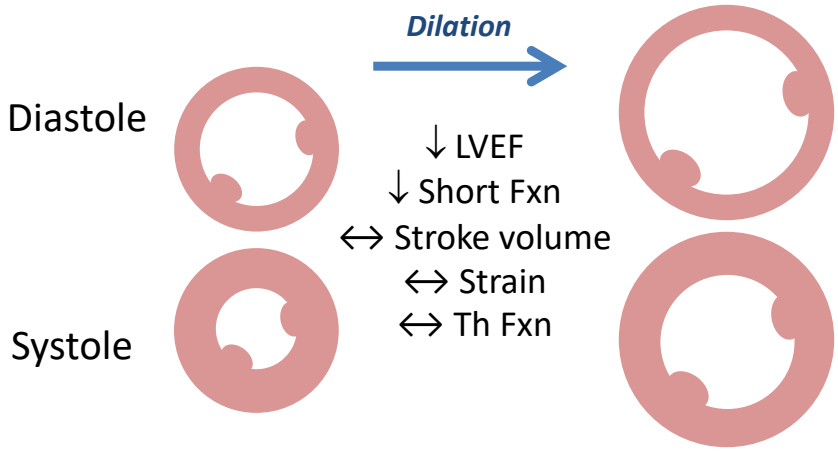
Fang ZY, et al. J Am Coll Cardiol 2003;41:611





23

Expect Incongruent Data with Echo Data



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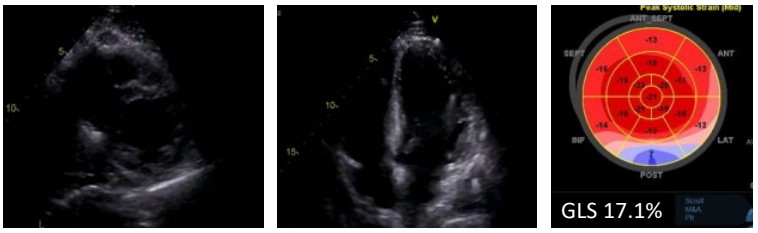
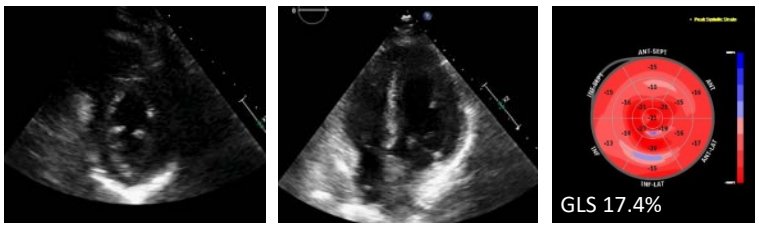
Concentric Remodeling

Normal



LVEF 66%
SV=81 mL

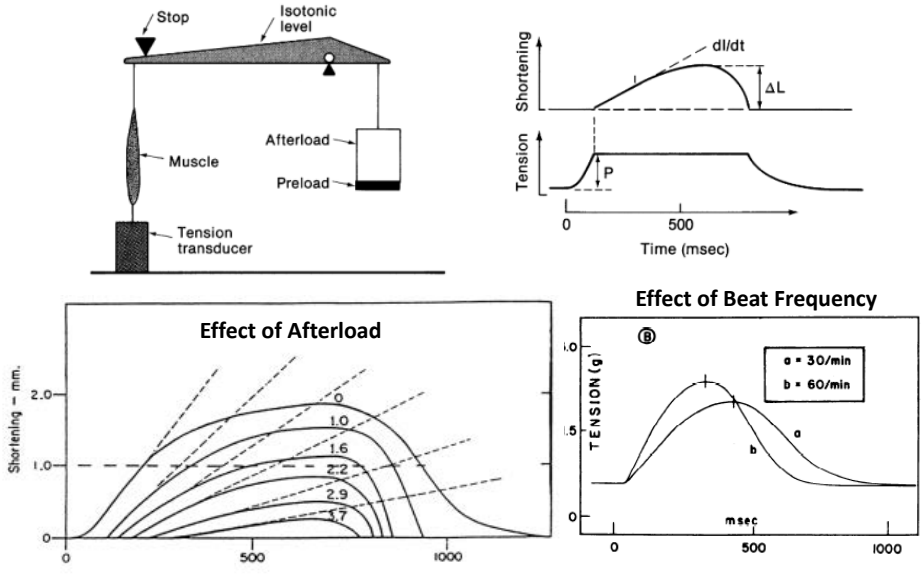
Concentrically remodeled



LVEF 69%
SV =51 mL

25

Afterload and Force-velocity Relations



Sonnenblick EH, et al. Am J Physiol 1962;205:931
Sonnenblick EH, et al. Circ Res 1966;19:980

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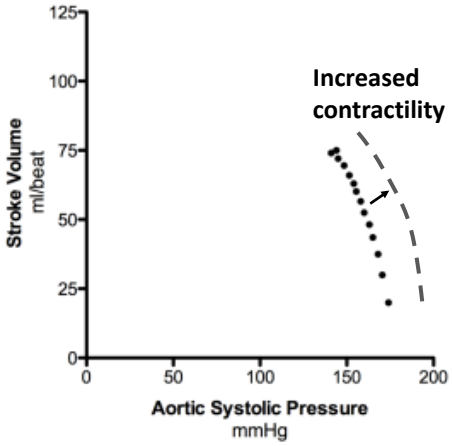
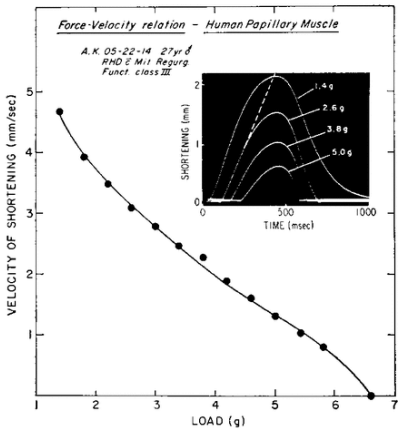
Afterload and LV Function





Sonnenblick EH, et al., J Clin Invest 1965;44:966

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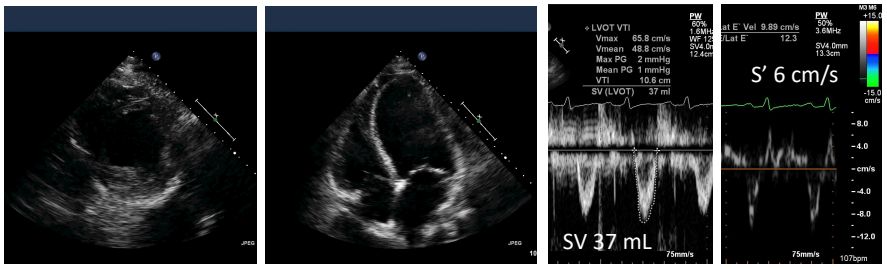
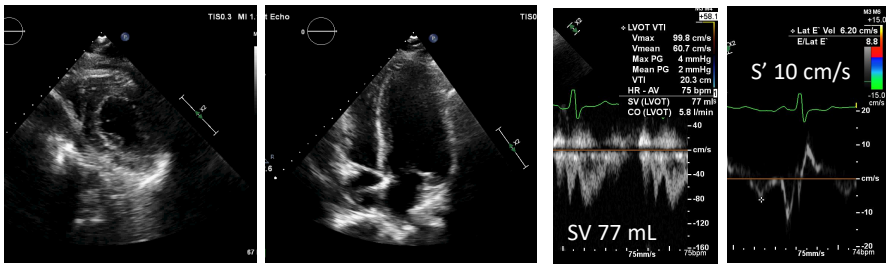
BP 220/114



BP 132/84



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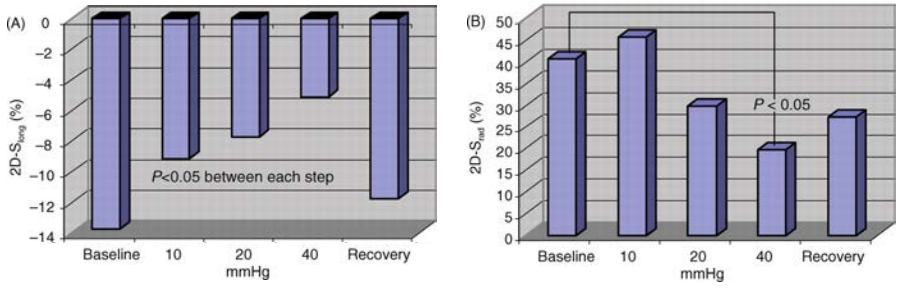
Effect of Afterload on Strain
Acute Changes in BP in Pigs

Longitudinal Strain **Radial Strain**



Donal E. et. al. Eur Heart J CVI 2009;10:914

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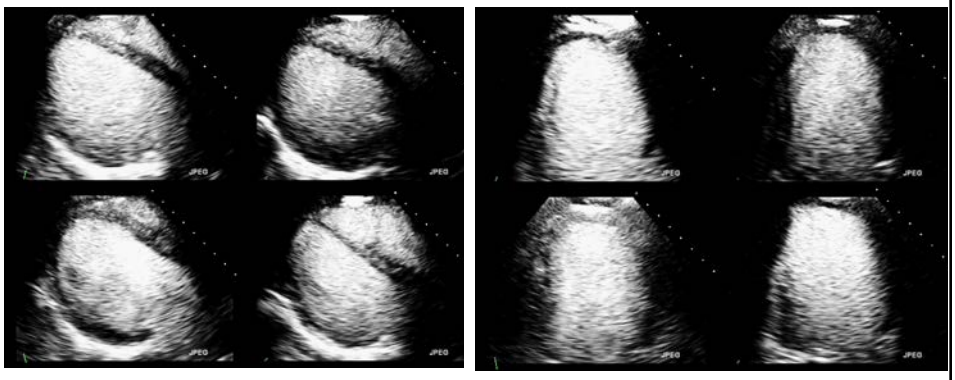
Hypertensive Response to Exercise
Systolic BP at Peak 218/74

PSAX **Ap 2 Ch**



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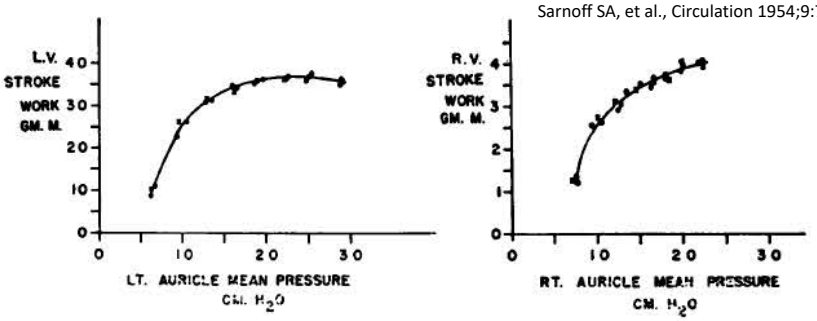
Frank-Starling Principles

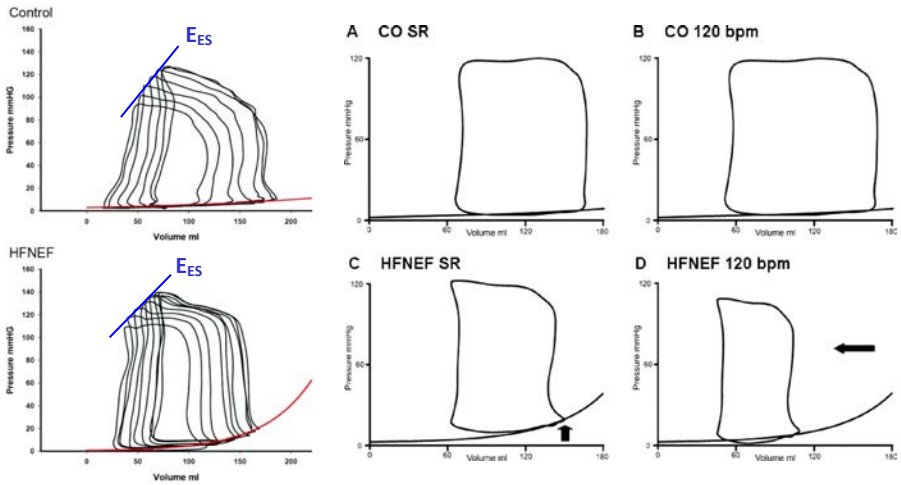
Sarnoff SA, et al., Circulation 1954;9:706



Intravascular volume status
Mitral/tricuspid stenosis
Tamponade physiology
Tachycardia
PEEP
RV infarct/Pulmonary embolus

31

LV Stiffness in Moderate-Severely Symptomatic Pts.



Westermann D, et al, Circulation 2008;117:2051

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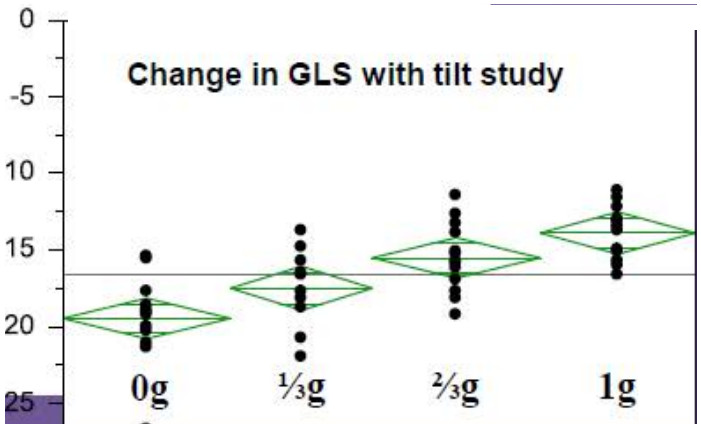
Strain During Tilt Table Testing



Shi , et al., Circulation 2017;30:1180

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Incremental Value of Global Strain Assessment

1. Hypertensive CM
2. Amyloid
3. Infiltrative
4. Transplant rejection
5. HCM
6. Muscular dystrophy
7. Valvular CM
8. Cardiotoxic effects of drugs
9. Etc.

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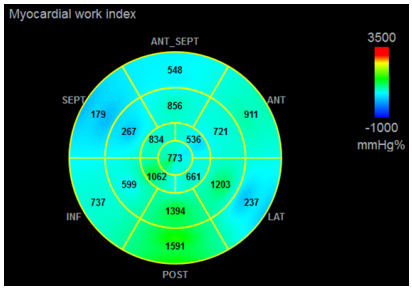
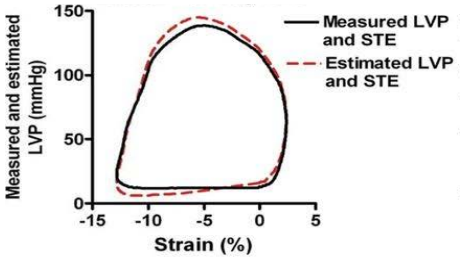
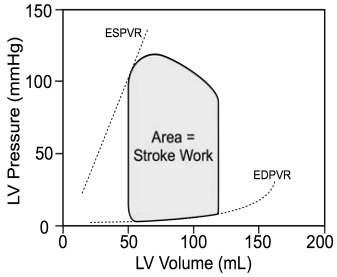
Myocardial "Work"







Russell, et al. Am J Physiol 2013;305:H996

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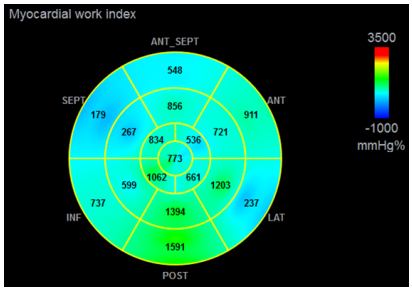
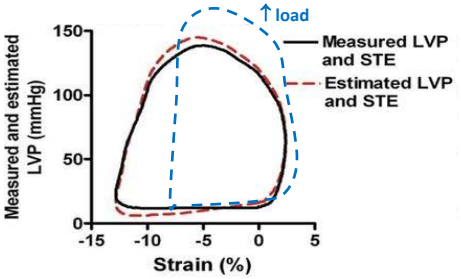
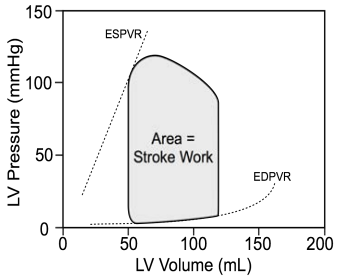
Myocardial "Work"







Russell, et al. Am J Physiol 2013;305:H996

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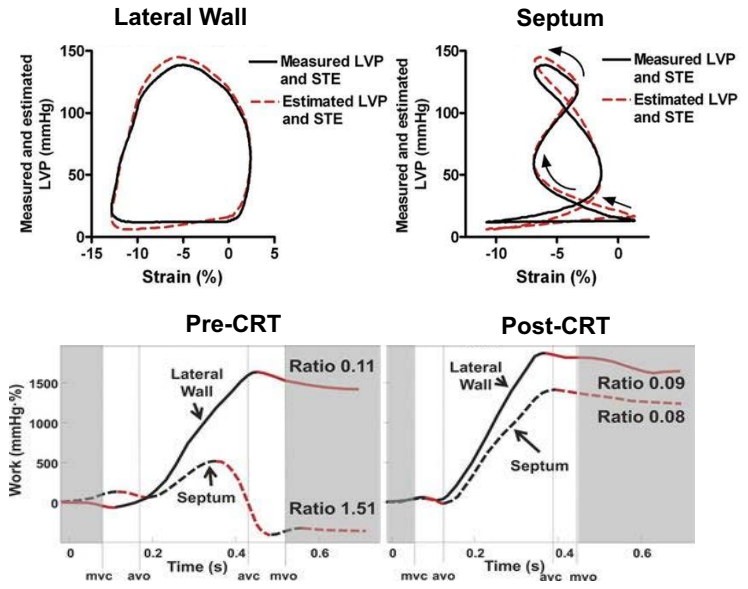
Myocardial "Work" in Dyssynchrony



Russell, et al. Am J Physiol 2013;305:H996

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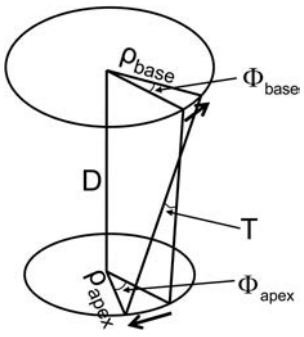
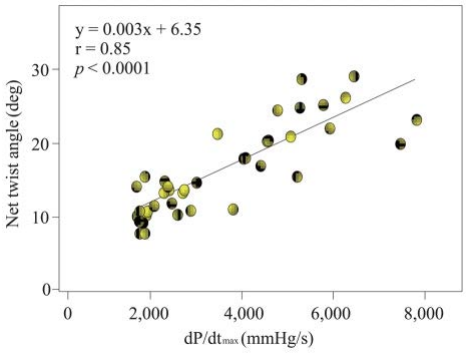
LV Rotation, Twist, and Torsion



Russel IK, JACC Cardiovasc Imag 2009;2:648



Nakatani S, J Cardiovasc Ultrasound 2011;19:1

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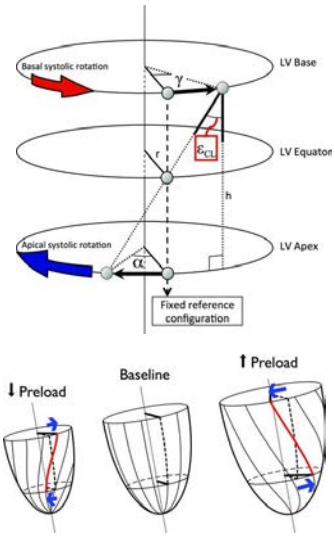
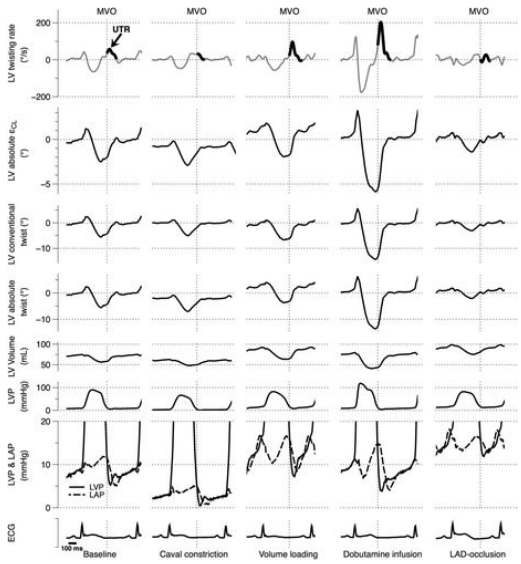
Conditional Determinants of Twist/Untwist





Opdahl A, et al. Circulation 2012;126:1441

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LV Twist for Systolic Function

Degree of Twist/Torsion

↓

Degree of Untwist

↓

Early diastolic suction

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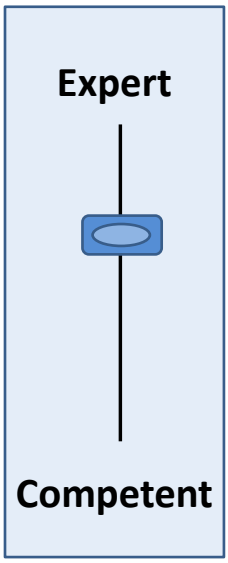
Summary



Understands applications *and* limitations of new echo technology and the physiologic influences of function

Knowledge and reporting of new technologies 2D/3D strain, dp/dt

Knowledge, reporting, and problem solving for LVEF, SV, and TDI

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