Introduction to Strain Theory and Applications

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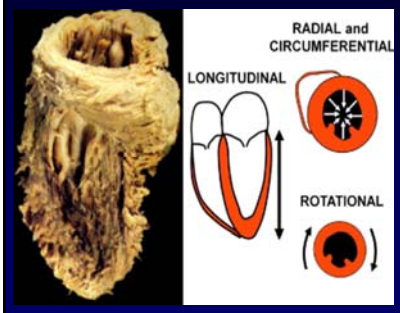
Vectors of Myocardial Strain



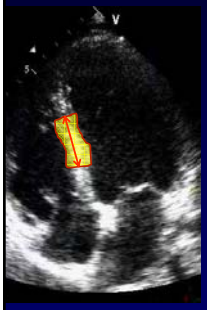
- Shortening
- Thickening
- Twisting

Gorcsan J, JACC 2011;58:1401-13

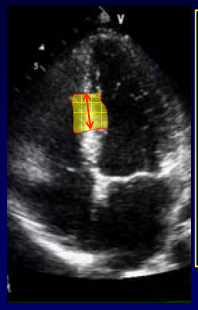
LONGITUDINAL STRAIN IMAGING

Strain = Change in Length / Original Length

Longitudinal Strain LV Shortening



End Diastole



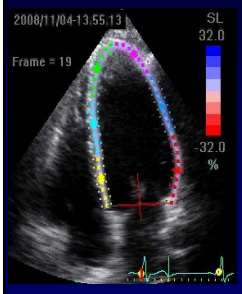
End Systole

End-Diastole End-Systole

%

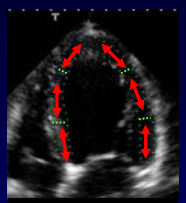
Strain = % Change in Length

Longitudinal Strain

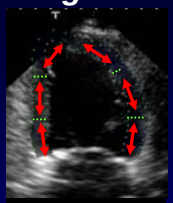


- 23%

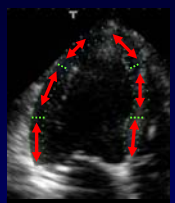
Global Longitudinal Strain (GLS) Average Strain



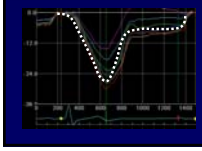
Apical 4-Chamber

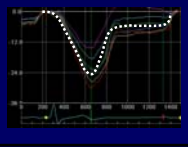


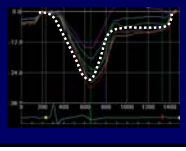
Apical 2-Chamber



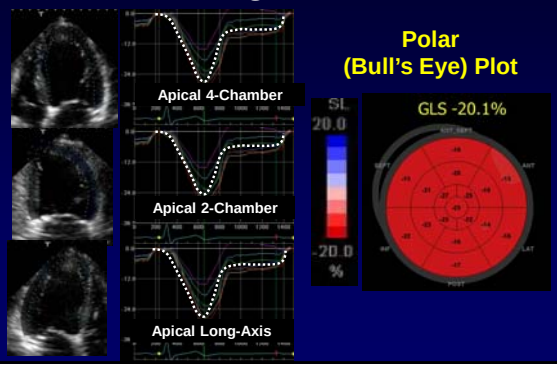
Apical Long-Axis







Global Longitudinal Strain (GLS)
Average Strain



Normal Strain Values

- **Global Longitudinal Strain**

Normal GLS: ≥ -17%

Borderline GLS: between -17% and -15%

Clearly Abnormal GLS: ≤ -15%

Think of GLS in absolute values
(Forget the – sign)

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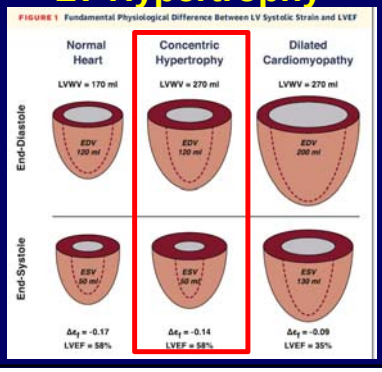
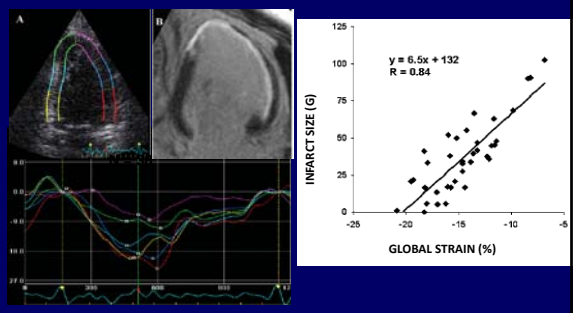
Differences in EF and Strain
LV Hypertrophy



Lumens et al. 2016

What Additional Information?
GLS as a Marker for Scar

- Myocardial Scar by Late Gadolinium Enhancment CMR



Gjesdal et al.Clinical Science (2007) 113, 287–296

Strain is Additive to EF

Ejection Fraction
- **Blood Displacement**

Strain
Wall Properties of Disease
- **Hypertrophy**
- **Fibrosis**

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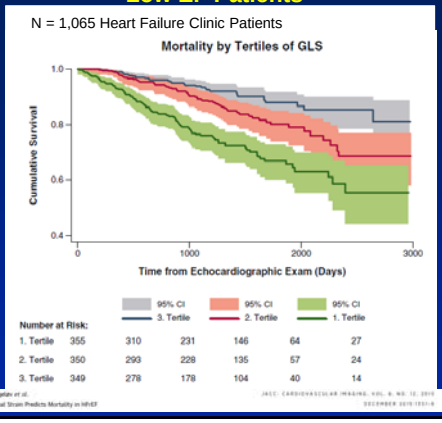
Strain is Additive to EF
Far Ends of Spectrum

Very Low EF ⟷ **High EF**

Low EF Patients

N = 1,065 Heart Failure Clinic Patients



N = 1,065 Heart Failure Clinic Patients

TABLE 3 Univariable and Multivariable Cox Proportional Hazard Models

	Univariable Analysis				Multivariable Analysis*		
	HR	95% CI	p Value	C-Statistic	HR	95% CI	p Value
Age, per 1-yr increase	1.05	1.03-1.06	<0.001		1.05	1.02-1.07	<0.001
MAP, per 1-mm Hg increase	0.97	0.96-0.98	<0.001		0. 97	0.95-0.98	<0.001
Heart rate, per 1-beat/min decrease	1.01	1.00-1.02	0.015				
Ischemic cardiomyopathy	1.14	0.84-153	0.39		1.32	0.78-2.26	0.305
CABG	1.41	1.01-1.96	0.043				
PTCA	0.56	0.38-0.82	0.003				
Cholesterol, per 1-mmol/l increase	0.83	0.72-0.96	0.013				
NIDDM	1.88	1.25-2.81	0.002		2.66	1.55-4.30	<0.001
BMI, per 1-kg/m² increase							
LVEF, per 1% increase	0.95	0.94-0.97	<0.001	0.6533			
LVMI, per 1-g/m² decrease	1.04	1.00-1.01	0.036	0.5641			
LAVI, per ml/m² decrease	1.02	1.01-1.03	<0.001	0.6048			
TAPSE, per 1-cm increase	0.44	0.34-0.58	<0.001	0.6319			
E, per 1-m/s increase	1.88	1.20-2.96	0.006	0.5694			
DT, per 1-ms decrease	0.99	0.99-1.00	0.031	0.5638			
E/A, per 1 increase	1.23	1.08-1.41	0.003	0.5709			
e', per 1-cm/s increase	0.004	0.00-1.96	0.08	0.5502			
E/e', per 1 decrease	1.06	1.02-1.06	0.001	05902			
GCS rate, per 1-s⁻¹ decrease	1.85	0.96-3.60	0.067	0.5833			
GCS, per 1% decrease	1.11	1.06-1.16	<0.001	0.6371			
GLS rate, per 1-s⁻¹ decrease	11.02	4.64-26.20	<0.001	0.6450			
GLS, per 1% decrease	1.20	1.14-1.26	<0.001	0.6735	1.15	1.04-1.27	0.008

Echo Parameters

*Multivariable model includes age, sex, BMI, total cholesterol, MAP, heart rate, ischemic cardiomyopathy, PTCA, CABG, NIDDM, LVEF, LVMI, LAVI, TAPSE, DT, E velocity, E/e' ratio, E/A ratio, and GLS. Only HRs for variables that are significant in the multivariable analysis are shown.
CI = confidence interval; HR = hazard ratio; other abbreviations as in Tables 1 and 2.

Sengelov et al. Global Strain Predicts Mortality in HFrEF JACC: CARDIOVASCULAR IMAGING, VOL. 9, NO. 12, 2016 DECEMBER 2016:1351–9

Strain Echocardiography and Functional Capacity in Asymptomatic Primary Mitral Regurgitation With Preserved Ejection Fraction

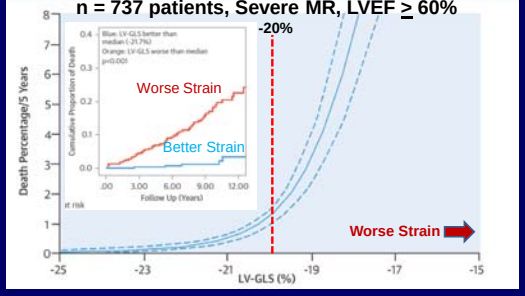
J Am Coll Cardiol. 2016;68(18):1974-86.

Amgad Mentias, MD, Peyman Naji, MD, A. Marc Gillinov, MD, L. Leonardo Rodriguez, MD, Grant Reed, MD, Tomislav Mihaljevic, MD, Rakesh M. Suri, MD, DPhil, Joseph F. Sabik, MD, Lars G. Svensson, MD, PhD, Richard A. Grimm, DO, Brian P. Griffin, MD, Milind Y. Desai, MD

GLS and Asymptomatic Severe MR with Preserved EF: Risk of Death

A. Estimated Risk of Death at 5 Years for Resting Left Ventricular Global Longitudinal Strain (LV-GLS)

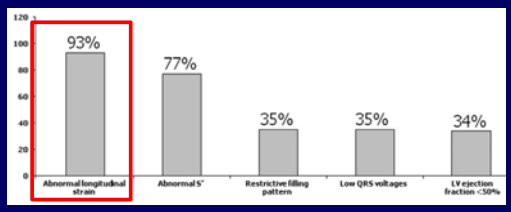
n = 737 patients, Severe MR, LVEF ≥ 60%



Mentias, A. et al. J Am Coll Cardiol. 2016;68(18):1974-86.

Prevalence of Abnormal Echo Indices in Cardiac Amyloidosis

n = 172 patients with Cardiac Amyloidosis



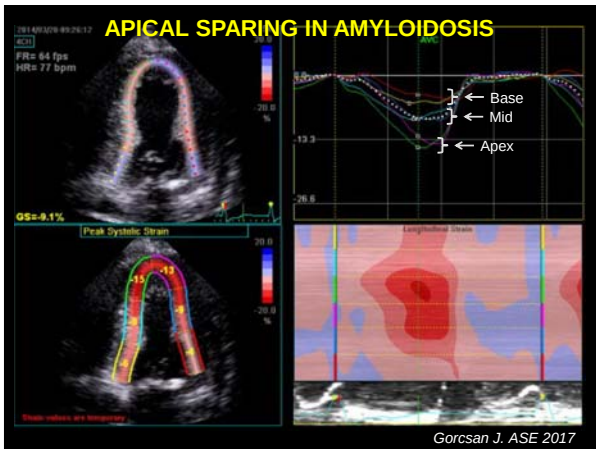
Quarta, Solomon et al. Circulation. 2014;129:18 1840-1849

GLS Predicts Survival in Cardiac Amyloidosis

Table 6. Multivariable Analysis of Risk of Death Resulting from Any Cause and Incident Heart Failure

	HR	95% CI	P
Death resulting from any cause			
Pathogenesis of ATTRm versus AL	0.39	1.66–0.92	0.032
Pathogenesis of ATTRwt versus AL	0.36	0.18–0.71	0.003
NYHA class III–IV	1.92	1.00–3.65	0.047
eGFR, each incremental 1 mL/min	0.98	0.97–0.99	0.001
Global LV longitudinal strain, each incremental 1%	1.1	1.01–1.19	0.026

Quarta, Solomon et al. Circulation. 2014;129:18 1840-1849


APICAL SPARING IN AMYLOIDOSIS
Base
Mid
Apex
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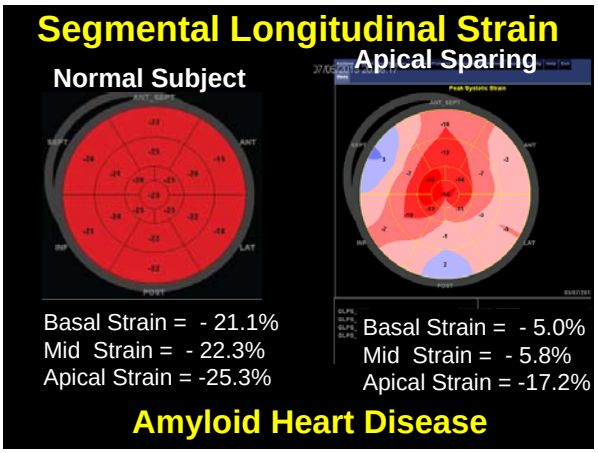
Segmental Longitudinal Strain
Normal Subject
Apical Sparing
Basal Strain = - 21.1%
Mid Strain = - 22.3%
Apical Strain = -25.3%
Basal Strain = - 5.0%
Mid Strain = - 5.8%
Apical Strain = -17.2%
Amyloid Heart Disease