**Strain Imaging: Myocardial Mechanics Simplified and Applied**

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**VECTORS OF CONTRACTION**
- Shortening
- Thickening
- Twisting

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**Calculation of Strain From Speckle Tracking**

Not Dependent on Doppler Angle

\[
\text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}}
\]

Modified from Kawagishi, K

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**LONGITUDINAL STRAIN IMAGING**

\[
\text{Strain} = \frac{\% \text{ Change in Length}}{}
\]

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**Longitudinal Strain**

**LV Shortening**

\[
\begin{align*}
\text{End-Diastole} & \quad \% \text{ End-Systole} \\
\end{align*}
\]

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**Longitudinal Strain**

\[
\text{End-Diastole} \quad \% \quad \text{End-Systole}
\]

- 23%

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Global Longitudinal Strain (GLS)

Average Strain

Apical 4-Chamber
Apical 2-Chamber
Apical Long-Axis

What is Normal? Global Longitudinal Strain

GLS: -15.7 to -21.1%, mean -19.7%

Normal Strain Values
Threshold for Abnormal
- Global Longitudinal Strain

Normal GLS: ≥ -17%
Borderline GLS: between -17% and -15%
Clearly Abnormal GLS: < -15%

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

GLS Values Vary by Vendor, Gender and Age

Global Strain Must Relate to Ejection Fraction

LV Deformation = LV Blood Ejection
Mathematical Linear Relationship of GLS to EF

\[
EF = 1 - \frac{1}{3} = 1 - \left( \frac{1}{3} \right)^2 \text{ (systole)}
\]

\[
GLS = \frac{1}{3} - 1 = \left( \frac{1}{3} \right)^2 - 1.
\]

Linear Fit \( EF = 3 \times |GLS| + 8 \)

Echo vs. Cardiac Magnetic Resonance

Normal Heart Failure Patient

GLS vs. EF

Echo vs. Cardiac Magnetic Resonance

Normal Heart Failure Patient

What Additional Information?

GLS as a Marker for Scar

- Myocardial Scar by Late Gadolinium Enhancement CMR

Differences in EF and Strain

LV Hypertrophy

Differences in EF and Strain

LV Hypertrophy

Differences in EF and Strain

LV Hypertrophy
Strain is Additive to EF

Ejection Fraction
- Blood Displacement

Strain
Wall Properties of Disease
- Hypertrophy
- Fibrosis

More Reproducible than EF

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Global Longitudinal Strain Is a Superior Predictor of All-Cause Mortality in Heart Failure With Reduced Ejection Fraction

N = 1,065 Heart Failure Clinic Patients

Low EF Patients

N = 1,065 Heart Failure Clinic Patients

Mortality by tertiles of GLS

Cardiac Resynchronization Therapy
Treatment for Low EF Wide QRS Heart Failure

Two-site LV Pacing
Baseline Global Strain is Associated with Outcome After CRT

Global Longitudinal Strain

GLS ≤ -9%

Survival probability (%)

N = 205

Routine CRT

Indications

QRS > 120 ms

LVEF < 35%

QRS < 130 ms

Echo Dyssynchrony

Randomized to:

CRT Off

CRT On

N = 809

Baseline Global Strain is Associated with Outcome After CRT

GLS > -9%

p=0.007 vs. other groups, HR=5.70 (95% CI 1.61-20.13),

n = 755

Features of Additive Risk

LOW EF

LOW GLS

Dyssynchrony
GLS and Asymptomatic Severe MR with Preserved EF

- 737 patients
- Severe MR
- LVEF ≥ 60%
- Non-dilated LV
  - ESD < 4.0cm
  - ESDi < 3.3cm/m²

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

- Mortality rate: 20%

Neurocardiac Injury in Subarachnoid Hemorrhage

“Cerebral T Waves”

GLS to Assess Neurocardiac Injury in Subarachnoid Hemorrhage

- 255 patients
  - 52±10 yrs
  - 72% female
  - GLS in ICU (mean 2 days from bleed)
  - Strain feasible on 221

GLS and In-Hospital Mortality with Subarachnoid Hemorrhage

Linear relationship, \( P = 0.013 \)

GLS (%) (absolute values)
Potential Factors in Neurocardiac Injury

- Subarachnoid Hemorrhage
- Catecholamine Surge
- Myocyte Injury
- Impaired Myocardial Perfusion
- Individual Susceptibility

Kagiyama...Gorcsan et al.

Impaired Systolic Function by Strain Imaging in Heart Failure With Preserved Ejection Fraction

Global Longitudinal Strain (%) absolute values

- Controls (n=50)
- Hypertensive Heart Disease (n=44)
- HFpEF (n=219)

Kraigher-Krainer...Solomon et al. JACC 2014;63:447-56

* p<0.001 vs. Controls and Hypertensive Heart Disease

Kraigher-Krainer...Solomon et al. JACC 2014;63:447-56

Impaired Systolic Function by Strain Imaging in Heart Failure With Preserved Ejection Fraction

Association of GLS with Biomarkers for Heart Failure (NT-proBNP)

GLS Predictive of Survival in Patients with ESRD and Preserved EF

- 468 African Americans with ESRD on Hemodialysis
- LV EF > 50%
- Baseline GLS - Prospectively enrolled and followed 1.9 years
- GLS was predictive of All Cause Mortality
- GLS Cut-Off < 16% (absolute values)
- Hazard ratio 1.15, 95% confidence interval 1.02 to 1.30, p = 0.02,


CASE STUDY

- 62 year old man with weight loss, gastroparesis, dyspnea and edema.

Gorcsan J. MSE 2017
Segmental Longitudinal Strain

Normal Subject

Basal Strain = -21.1%
Mid Strain = -22.3%
Apical Strain = -25.3%

Our Patient

Basal Strain = -5.0%
Mid Strain = -5.8%
Apical Strain = -17.2%

Amyloid Heart Disease

Apical Longitudinal Strain

Sparing in Amyloidosis

Examples of Increase Wall Thickness No Amyloidosis

Examples of Cardiac Amyloidosis

Prevalence of Abnormal Echo Indices in Cardiac Amyloidosis

\[ n = 172 \] patients with Cardiac Amyloidosis

- \[ n=80 \] with Light Chain Immunoglobulins
- \[ n=36 \] transthyretin-related mutant form
- \[ n=56 \] Nonmutant transthyretin-related amyloidosis


GLS Predicts Survival in Cardiac Amyloidosis

An 85 year woman with progressive shortness of breath and syncope

Severe Aortic Stenosis

Peak Velocity 5 m/sec
Peak Gradient 100 mmHg, Mean Gradient 69 mmHg
AVA = 0.6 cm²

n = 125 patients with Severe AS

Preop GLS

GLS Quartile 1 and 2
GLS Quartile 3
GLS Quartile 4
GLS was Additive to Clinical Features and EF

*Substantial improvements in cancer patient survival.*

*14.5 million cancer survivors in the US*

*Leads to a higher prevalence of patients with cancer and cardiovascular disease*


GLS was Additive to EF to Predict Chemo Cardiotoxicity

GLS < 11%

Nigishi…Marwick et al. JASE 2013

Strain New Directions: Fusion imaging

Ultrasound system

Fluoroscopy Angiographic System

Fusion imaging

RV 3D SPECKLE TRACKING

RAO View

LAO View
Strain Imaging into the Future

Definitions for a Common Standard for 2D Speckle Tracking Echocardiography: Consensus Document of the EACVI/ASE Industry Task Force to Standardize Deformation Imaging

ASE Announcement:
Myocardial Strain Imaging
- Acceptance of New CPT Category III code, 039X9T
- Introduced January, 2016
- Category III codes are not yet reimbursed: Often lead to the adoption of payable codes by CMS and other payers.

Take Home Messages

- Speckle Tracking Strain has emerged as the most useful new echocardiographic tool to assess myocardial function.
- Global Longitudinal Strain is best represented in the literature as being a sensitive measure additive to EF.
- Most Promising New Clinical Applications:
  - Adding to EF in Heart Failure to Enhance Prognosis
  - Cardiac Amyloidosis
  - Valvular Heart Disease
  - Neurocardiac Injury
  - Cardio-oncology
  - 3D Strain has promise for the future!