Myocardial Imaging
Tissue Doppler and Strain Imaging

Steven J. Lester MD, FRCP(C), FACC, FASE

DISCLOSURE

Relevant Financial Relationship(s)
None

Off Label Usage
None
Myocardial Imaging

WARNING

CHANGES AHEAD

Doppler:
Doppler Tissue Imaging

1. Turn wall filters off
2. Turn down the gain
Doppler Tissue Imaging
Septal Myocardial Velocity Traces

Velocity: Base to Apex gradient
Strain: Apex to Base gradient
(small)
FORESHORTENED IMAGES!

Curved M-mode : DTI
Goal
To Detect Regional Wall Motion

Tissue Doppler

Pulsed TD
Peak Velocities

Color TD
Mean Velocities
Pitfall (Velocity Analysis)
Translation and Tethering

Strain = deformation resulting from applied force
Stress = force

Strain = deformation
resulting from applied
force

Stress = force

Courtesy of Ted Abraham
Myocardial strain

Used to describe elastic properties of cardiac muscle (Mirsky and Parmley: Circ Res, 1973)

\[ \text{Strain (\(\varepsilon\))} = \frac{L_1 - L_0}{L_0} \]

Strain rate: Rate of deformation

High strain rate

Low strain rate

Equal strain
Strain rate vs. Tissue Doppler

Doppler Feature “Speckle” Tracking

Movement of the myocardium relative to the sample volume fixed in space
Acoustic pattern tracking
Speckle Tracking

Velocity is estimated as a shift of each object divided by time between successive frames (or multiplied by Frame Rate) →

2D vector: \((V_x, V_y) = (dX, dY) \times FR\)

Doppler Independent Techniques (Speckle Tracking)

Potential Advantage?

- Signal noise
- Speckle tracking by principle is angle independent
- Gray scale (standard views)
- Monitor strain in two rather than one dimension
- Minimal user input
- Assessment of rotation: derived from circumferential strain at different levels in the heart (NO fixed sample volume)
Myocardial Mechanics
Rotation/Twist/Torsion

Rotation and Torsion

Rotation
Apex
Torsion
Basal
View from apex
Mitral flow

Normal

Abnormal relaxation

Pseudo-normalization

Restriction

Tissue Doppler

Apical rotation

Basal rotation

LV torsion

Normal

Abnormal relaxation

Positive Values

Negative Values

Routine Practice

Longitudinal

Radial

Circumferential

✔

✖

✖

LV torsion

E

A

E'

A'

EE

E'E'

A'A'

EE

E'E'

A'A'

EE

E'E'

A'A'

EE

E'E'

A'A'

Global Longitudinal Peak Systolic Strain

GLPSS = -24%

Image Arena 2D Speckle Tracking (GE Vivid™ 7)
Echocardiographic Measures of Myocardial Deformation by Speckle-Tracking Technologies: The Need for Standardization?

Matthew R. Nelson, MD, R. Todd Hurst, MD, Serageldin F. Rana, MD, Stephen Chu, MS, Susan Wilinsky, MD, and Steven J. Lester, MD, Scottsdale, Arizona; Rochester, Minnesota

Echocardiographic Measures of Myocardial Deformation by Speckle-Tracking Technologies: The Need for Standardization?

than two left ventricular endocardial segments poorly delineated were excluded. GLS was obtained from the apical four-chamber, three-chamber, and two-chamber views using two independent speckle-tracking echocardiographic software packages (EchoTools version 1.5.0 and Image-Arena version 4.5). Linear regression analysis and paired t-tests were used to compare GLS results. Intraclass correlation coefficients and Bland-Altman plots were used for assessments of reliability.

Results: The "out-of-the-box" mean GLS was -12.99 ± 2.86% using EchoTools and -16.87 ± 2.84% using Image-Arena (mean difference, 3.97 ± 2.47% ; P < .001). Agreement between the software packages was moderate (intraclass correlation coefficient, 0.43; 95% confidence interval, 0.32-0.55). Using uniform variables to derive GLS values consistently assessed in a subset of individual patients, the GLS peak segment was lower by mean difference (0.52-0.70%)

Conclusions: Image-Arena GLS results were consistently different (more negative) than EchoTools measured out of the box but became similar when information used to derive GLS was uniform. The evaluation of measures of myocardial mechanics into routine clinical practice will require vigilance and standardization of the various techniques, reassuring independent validation of commercially available speckle-tracking echocardiographic products.

Keywords: Speckle-tracking, Strain, Echocardiography


---

REPRODUCIBILITY OF LEFT VENTRICULAR STRAIN

Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors
The EACVI/ASE Inter-Vendor Comparison Study

Konstantinos X. Fialkow, MD, A&A M. Zaman, MD, Serkan Ünlü, MD, D. James G. Thomas, MD, Luigi P. Radino, MD, PhD, and Jens-Uwe Voigt, MD, PhD, Leuven, Belgium; Chicago, Illinois; and Padua, Italy

Background: This study was planned by the EACVI/ASE Inter-Vendor Task Force to Standardize Deformation Imaging to (1) assess the variability of speckle-tracking global longitudinal strain (GLS) measurements among different vendors and (2) compare GLS measurement variability with conventional echocardiographic parameters.

Methods: Sixty-two volunteers were studied using ultrasound systems from seven manufacturers. Each volunteer was examined by the same sonographer on all machines. Inter- and intraobserver variability was determined in a true test-retest setting. Conventional echocardiographic parameters were acquired for comparison. Using the software packages of the respective manufacturer and of two software-only vendors, endocardial GLS was measured because it was the only GLS parameter that could be provided by all manufacturers. We compared GLS_{max} (the average from the three apical views) and GLS_{min} (measured in the four-chamber view) measurements among vendors and with the conventional echocardiographic parameters.

Results: Absolute values of GLS_{max} ranged from 19.0% to 21.6%, while GLS_{min} ranged from 17.3% to 21.4%. The absolute difference between vendors for GLS_{max} was up to 5.7% in strain units (P < .001). The interobserver relative mean errors were 5.4% to 6.6% for GLS_{max} and 8.2% to 11.0% for GLS_{min}, while the intraobserver relative mean errors were 4.9% to 7.3% and 7.2% to 11.3%, respectively. These errors were lower than for left ventricular ejection fraction and most other conventional echocardiographic parameters.

Conclusion: Reproducibility of GLS measurements was good and in many cases superior to conventional echocardiographic measurements. The small but statistically significant variation among vendors should be considered in performing serial studies and reflects a reference point for ongoing standardization efforts.

Global Longitudinal Strain Among Various Vendors


Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, et al

- “Optimize image quality, maximize frame rate and minimize foreshortening”.
- “When regional tracking is suboptimal in more than two myocardial segments in a single view the calculation of GLS should be avoided”.

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber

Global Longitudinal Peak Systolic Strain (GLS) “in the range of -20%”
Timing: End-Systole?
Pitfall: Avoid The LVOT

**Good**

**Bad**

Pitfall: Avoid The Atrium

**Good**

**Bad**
Pitfall: ROI To Wide

**Good**

-16.6%

**Bad**

-12.6%

24% Difference

Global Longitudinal Peak Systolic Strain

1. Timing of Aortic Valve Closure
2. Avoid LVOT
3. Avoid the Atrium
4. ROI to Wide
5. Foreshortened Images
Mean Error in Measurements

Interobserver Relative Mean Errors
3D LV Volumes and Ejection Fraction

Reproducibility of Echocardiographic Techniques for Sequential Assessment of Left Ventricular Ejection Fraction and Volumes

"Our data suggest that the temporal variability in EF of 0.06 might occur with noncontrast 3DE due to physiological differences and measurement variability, whereas this might be >0.10 with 2D methods. Overall, 3DE also had the best intra- and inter-observer as well as test-retest variability"
3D Strain Analysis
Lower resolution
(spatial and temporal)

Potential Clinical Applications
Case

- 59-year-old male
- Acute Myeloid Leukemia
- No prior history of vascular disease.
- Hypertension treated with Amlodipine.
- About to begin chemotherapy based treatment
Surviving Cancer, But at a Cost

Radiation & Chemo-induced Cardiovascular Diseases

Oncologist
“Killer”

Cardiologist
“Protector”
Niccolo Machiavelli (1469-1527)

“...at the beginning a disease is *easy to cure but difficult to diagnose*; but as time passes, not having been recognized or treated at the outset, *it becomes easy to diagnose but difficult to cure*.”
Percentage of Responders To Heart Failure Therapies

ACEI & Beta Blockers

Cardinale et al: J Am Coll Cardiol 55:213, 2010

Subclinical Change

Overt Heart Failure

Echocardiography

Biomarker Elevation (Troponin)

Asymptomatic Subclinical Δ in LV function (Strain)

Asymptomatic Reduced LV Function (LVEF)

Symptomatic LV Dysfunction
Case

- 59-year-old male
- Acute Myeloid Leukemia
- No prior history of vascular disease.
- Hypertension treated with Amlodipine.
- About to begin chemotherapy based treatment

Baseline Echocardiogram

LVEF = 66%, EDVI = 53 ml/m²
Baseline Echocardiogram
Global Longitudinal Peak Systolic Strain

LVEF = 66%
GLPSS Avg = -17.3%

1. CTRCD if decrease in LVEF >10% to a value <53%
2. In patients with available baseline strain measurements, a relative percentage reduction of GLS of <8% from baseline appears not to be meaningful, and those >15% from baseline are very likely to be abnormal.

(© 2017 MFMER | 3682262-55)

EXPERT CONSENSUS STATEMENT

Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy: A Report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

© 2017 MFMER | 3682262-56

(© 2017 MFMER | 3682262-57)
LVEF = 66%  

CTRCD if decrease in LVEF >10% to a value <53%  

\[
\frac{(66-58)}{66} = 0.12 \text{ (12%)}
\]

GLPSS Avg = -14.3%  
Troponin T = 0.02  

GLS of <8% from baseline appears not to be meaningful, and those >15% from baseline are very likely to be abnormal  

Change In Strain: \[
\frac{(17.3 - 14.3)}{17.3} = 17.3\%
\]

GLPSS Avg = -14.3%  
Troponin T = 0.03
Cardio-Oncology Screening Strategy

Baseline Evaluation of Patient, LVEF, GLS, Troponin

LVEF < 53%
GLS (+) -18%**
Troponin +

Cardiology Consultation

LVEF > 53%
GLS (+) -18%**
Troponin -

Follow-Up Every 3-6 months*

Drop of LVEF by > 10% point To LVEF <53%

Relative drop of GLS as Compared to baseline

<8%
No evidence of Subclinical LV dysfunction

>15%
Subclinical LV dysfunction (Initiate Cardioprotection)

Case

- 64 year old woman
- HER2 positive infiltrating lobular carcinoma of the right breast
- HER2 positive ductal carcinoma insitu of the left breast.
- Preoperative chemotherapy with paclitaxel (80mg/m²) and trastuzumab. Paclitaxel discontinued after 8 infusions due to toxicity (neuropathy).
- Then preoperatively started Q3weekly doxorubicin/cyclophosphamide (discontinued after 2 cycles due fatigue and anorexia).
Pre-Treatment Echocardiogram

LVEF = 65%

Pre-Treatment: Strain Imaging

GLPSS = -24%
3 Months Into Treatment: Echocardiogram

LVEF = 65-59/65 = 9%

CTRCD if decrease in LVEF >10% to a value <53%

3 Months Into Treatment: Strain Imaging

GLPSS = -17%

GLS of <8% from baseline appears not to be meaningful, and those >15% from baseline are very likely to be abnormal
What should we do now?

- LVEF dropped from 65% to 59% (9% RRR)
- GLPSS dropped from -24% to -17% (29% RRR)
- Started treatment with Coreg and Enalapril
- Initiated adjuvant trastuzumab and anastrozole
- Serial echocardiograms Q2-3 months

Completion of 1 year of adjuvant trastuzumab

LVEF = 59%
Completion of 1 year of adjuvant trastuzumab

GLPSS = -18%

Thick Walls Why?

Hypertrophy

- Genetic
- Hemodynamic, Endocrine

Infiltrative

- Amyloidosis

Storage

- Glycogen Storage – Pompe, Danon
- Mucopolysaccharidoses
- Sphingolipidoses
  - Gaucher
  - Anderson-Fabry
Are They Really The Same?

Cardiac Amyloidosis
Hypertensive Heart Disease
Hypertrophic Cardiomyopathy

14mm 14mm 13mm

Mean Wall Left Ventricular Thickness
“LV dysfunction is frequently subclinical despite a normal ejection fraction. It may preceded the onset of symptoms and portend a poor outcome…”

“The advent of novel tissue-tracking echo techniques has unleashed new opportunities for the clinical identification of early abnormalities in LV function”.

regarding the use of these techniques to assess myocardial deformation in patients with valvular heart disease. J Am Coll Cardiol Img 2014;7:1151-66 © 2014 by the American College of Cardiology Foundation.
Asymptomatic Severe Aortic Stenosis and LVEF > 50%
Survival from MACE

![Graph showing survival from MACE](image)

Nagata et al. J Am Coll Cardiol Img 2015;8:235–45

2D Global Longitudinal Strain
All Cause Mortality

![Graph showing cumulative survival](image)

Ng et al. European Heart Journal - Cardiovascular Imaging (2017) 0, 1–9
Echocardiographic Evaluation of Aortic Stenosis

Rule #7:
The evaluation of left ventricular function should include not only a measure of ejection fraction but also global longitudinal strain.
Severe Valve Disease
Asymptomatic (Stage C)

LVEF ≥ 50%
Vmax <5m/s
ΔPmean <60mmHg
Normal ETT
ΔVmax <0.3m/s/yr

Valve Replacement

Positive Stress Test

Very Severe MVA<1cm² T1/2 ≥ 220
- Unfavorable morphology,
  LA clot, > mild MR
Severe MVA<1.5cm² T1/2 ≥ 150
- Sinus rhythm
  -Afib with unfavorable morphology,
  LA clot, > mild MR

Global Longitudinal Strain and Primary MR
Normal LV Size, LVEF ≥ 60%

Estimated Risk of Death at 5 years for Resting LV GLS


©2017 MFMER  |  3682262-124

*ACC/AHA NOT ESC guidelines
Severe Valve Disease
Asymptomatic (Stage C)

LVEF > 50%
LVESD < 50mm
LVEDD < 65mm
LVEF > 50%
Vmax < 5 m/s
ΔPmean < 60 mmHg
Normal ETT
ΔVmax < 0.3 m/s/yr
LVEF > 60%
LVESD < 40mm
Sinus Rhythm
PASP < 50 mmHg
Successful Repair < 95%
Or Mortality > 1%

Very Severe MVA < 1 cm² T1/2 > 220
- Unfavorable morphology,
  LA clot, > mild MR
Severe MVA < 1.5 cm² T1/2 > 150
-Sinus rhythm
-Afib with Unfavorable morphology,
LA clot, > mild MR

Positive Stress Test
? Rest LV GLS (> - 18% or Δ from baseline

Valve Replacement / Repair?

Indications for Surgery For MR
Primary MR (Stage C)

LVEF 30-60%
or LVESD ≥ 40mm
(stage C2)

LVEF > 60% and
or LVESD < 40mm
(stage C1)

New onset AF
or PASP > 50 mmHg
(stage C1)

Relative Reduction In
GLS > 15%
???

Likelihood of successful repair
> 95% and
expected mortality < 1%

Yes
No

MV Surgery*
(I)
MV Surgery
(IIa)
MV Repair
(IIa)
Periodic
Monitoring

Nishimura et al: J Am Coll Cardiol; Valve Focused Update, 2017
Myocardial Imaging
Proven Utility & Potential
A Masterpiece in Echocardiography?

1. Subclinical LV dysfunction
2. HCM Phenocopies
3. Valve Disease
4. ...
5. ...

MAYO CLINIC