Myocardial Imaging
Tissue Doppler and Strain Imaging

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DISCLOSURE
Relevant Financial Relationship(s)
None
Off Label Usage
None
Myocardial Imaging
Objective way with which to quantify the minor amplitude and temporal subtleties in motion
Objectives

1. What is myocardial imaging?
2. Potential Clinical Applications
3. Impediments to widespread clinical adoption?

Doppler: Doppler Tissue Imaging

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

Curved M-mode : TVI

Normal
Goal
To Detect Regional Wall Motion

Tissue Doppler

Peak Velocities
Mean Velocities
Translation and Tethering

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)

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

Strain rate:
Rate of deformation

Courtesy of Andreas Heimdal
Strain rate vs. Tissue Doppler

Movement of the myocardium relative to the sample volume fixed in space
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 \((\text{NO fixed sample volume})\)
Myocardial Mechanics
Rotation/Twist/Torsion

Rotation and Torsion

Basal
Rotation
Apex
Rotation
Torsion
View from apex
Objective #2
Potential Clinical Applications
Impaired Systolic Function by Strain Imaging in Heart Failure With Preserved Ejection Fraction

Strain Imaging detects impaired systolic function despite preserved global LVEF in HFpEF that may contribute to the pathophysiology of the HFpEF syndrome.

Average Longitudinal and Circumferential Systolic Strain

*p<0.0001 compared to controls and between HHD and HFpEF

J Am Coll Cardiol 2014;63:447-56
Association of Longitudinal Systolic Strain and NT-proBNP
Case

• 76 year old male
• CMML/MDS with associated myeloid sarcoma skin lesions
• Experimental Chemotherapy ABT-348
**Baseline**

LVEF = 66%

GLPSS Avg = -17.8%
Troponin T = 0.02

**2 Months**

LVEF = 58%

GLPSS Avg = -14.3%
Troponin T = 0.03
Global Longitudinal Peak Systolic Strain (GLS) “in the range of -20%”

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”.

**Timing: Peak Systole?**
Global Longitudinal Peak Systolic Strain

Early Detection and Prediction of Cardiotoxicity in Chemotherapy-Treated Patients

Heloisa Sawaya, MD, PhD,1 Igael A. Sebag, MD,2 Juan Carlos Plana, MD,3 James L. Januzzi, MD,4 Bonnie Ky, MD,5 Victor Cohen, MD,6 Sucheta Gosavi, MD,7 Joseph R. Carver, MD,7 Susan E. Wiegens, MD,8 Randolph P. Martin, MD,8 Michael H. Picard, MD,8 Robert E. Gerszten, MD,9 Elkan F. Halpern, PhD,10 Jonathan Passeri, MD,10 Irene Kuter, MD,10 and Marielle Scherrer-Crosbie, MD, PhD**

*Academic center survival benefits; cardiotoxicity associated with chemotherapy regimens.

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*Academic center survival benefits; cardiotoxicity associated with chemotherapy regimens.
Anthracyclines and Trastuzumab

Can we predict a later (3 months) decline in LVEF?

- No decrease in GLS > 10% or elevated hsTnI have a 3% probability of a decrease in LVEF.
- If either a decrease in GLS or elevated hsTnI have a 9X increased risk for cardiotoxicity compared to those with no changes in either of these markers.

GLS is the optimal parameter of deformation for the early detection of subclinical LV dysfunction.

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.
Thick Walls, Why?

- Athlete
- HTN
- HCM
- Infiltrative amyloid
- Storage Fabry

HTN or HCM?

The Thinker
Auguste Rodin
Application of a Parametric Display of Two-Dimensional Speckle-Tracking Longitudinal Strain to Improve the Etiologic Diagnosis of Mild to Moderate Left Ventricular Hypertrophy

Dermot Phelan, MB, BCh, PhD, Padalajith Thavendiranathan, MD, MSc; Zoran Popovic, MD, PhD; Patrick Collier, MB, BCh, PhD; Brian Griffin, MD; James D. Thomas, MD; and Thomas H. Marwick, MBBS, PhD, MPH, Cleveland, Ohio; Toronto, Ontario, Canada; Hobart, Australia

Application of a Parametric Display of Two-Dimensional Speckle-Tracking Longitudinal Strain to Improve the Etiologic Diagnosis of Mild to Moderate Left Ventricular Hypertrophy

*J Am Soc Echocardiogr* 2014;27:888-95

**Results:** Baseline concordance among the readers was poor ($r = 0.28$) and improved with the addition of strain data ($r = 0.57$). Accuracy was improved with the addition of polar maps for the entire study cohort ($P < .001$), with 22% of cases reclassified correctly. The largest improvements in sensitivity (from 46% to 86%, $P < .001$), specificity (from 84% to 96%, $P < .001$), and accuracy (from 70% to 92%, $P < .001$) were seen for CA. The strain polar map significantly improved reader confidence in making the correct diagnosis overall ($P < .001$).

**Conclusions:** Regional variations in strain are easily recognizable, accurate, and reproducible means of differentiating causes of LVH. The detection of LVH etiology may be a useful clinical application for strain. (*J Am Soc Echocardiogr* 2014;27:888-95.)

**Are They Really The Same?**

Dermot Phelan, MB, BCh, PhD, Padalajith Thavendiranathan, MD, MSc; Zoran Popovic, MD, PhD; Patrick Collier, MB, BCh, PhD; Brian Griffin, MD; James D. Thomas, MD; and Thomas H. Marwick, MBBS, PhD, MPH, Cleveland, Ohio; Toronto, Ontario, Canada; Hobart, Australia

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Cardiac Amyloidosis

Hypertensive Heart Disease

Hypertrophic Cardiomyopathy

14mm

14mm

13mm

Mean Wall Left Ventricular Thickness

Pattern Recognition
• Up to 50% with asymptomatic severe AS and preserved LVEF will have subclinical LV dysfunction as noted by reduced longitudinal strain.

Low longitudinal strain
• Independent predictor of symptom development
• More likely to have an abnormal BP response to exercise
• Higher rates of cardiac events at follow up

Severe Valve Disease
Asymptomatic (Stage C)

Positive Stress Test
Rest LV GLS (<=) -18%

Valve Replacement / Repair?

*ACC/AHA NOT ESC guidelines
Objective #3
Impediments to Clinical Adoption?

1. Standardization
2. Workflow

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 E. Faralinos, MD, Ana M. Daraban, MD, Sekas Űnija, MD, James D. Thomas, MD, Luigi P. Badano, MD, PhD, and Jens-Uwe Voigt, MD, PhD, Lausen, Belgium; Chicago, Illinois; and Padua, Italy

Background: This study was planned by the EACVI/ASE Industry Task Force to Standardize Deformation Imaging to (1) test 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 GLSaw (the average from the three apical views) and GLSawx (measured in the four-chamber view) measurements among vendors and with the conventional echocardiographic parameters.

Results: Absolute values of GLSaw ranged from 18.0% to 21.5%, while GLSawx ranged from 17.9% to 21.4%. The absolute difference between vendors for GLSaw was up to 3.7% strain units (P < .001). The interobserver relative mean errors were 5.4% to 8.6% for GLSaw and 8.2% to 11.0% for GLSawx, 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. (J Am Soc Echocardiogr 2015;28:1171-81.)
Any innovation in imaging must be paralleled or exceeded by an innovation in workflow.
Fully Automated Versus Standard Tracking of Left Ventricular Ejection Fraction and Longitudinal Strain
The Fast-EFs Multicenter Study

**Abstract**

**Background:**

Recent advances in echocardiography have led to the development of automated methods for quantifying left ventricular function. However, the accuracy and reproducibility of these methods have not been fully evaluated.

**Objectives:**

The primary objective of this study was to compare the accuracy and reproducibility of fully automated versus standard manual methods for quantifying left ventricular ejection fraction (EF) and longitudinal strain (LS).

**Methods:**

We performed a multicenter study involving 100 patients with a wide range of left ventricular function. Automated and manual methods were compared in terms of EF and LS measurements.

**Results:**

Automated methods provided highly accurate EF and LS measurements, with coefficients of correlation exceeding 0.99. Interobserver variability was lower for automated than for manual methods, with smaller differences seen between automated and reference manual determinations. However, automated methods required significantly less time to complete.

**Conclusions:**

Fully automated methods for quantifying left ventricular function are highly accurate and reproducible, and offer significant time savings compared to manual methods. These findings support the widespread adoption of automated methods for clinical use.

*J Am Coll Cardiol 2015;66:1456-66*
1. AutoLV measurements were feasible in 98% of studies.
2. Average analysis time was 8±1 sec/patient.
3. Interobserver variability was higher for both visual and manual EF, but not different for LS.
Evaluation of Global Left Ventricular Systolic Function Using Three-Dimensional Echocardiography Speckle-Tracking Strain Parameters

Patricia Reant, MD, PhD, Laurence Barbot, MD, Cécile Touche, MD, Marin Dijon, MD, Florence Arcas, MD, Xavier Pibiris, PhD, Mathieu Landelle, MD, Raymond Roudaut, MD, and Stéphane Lafitte, MD, PhD, Poitiers, France

Background: The aim of this study was to evaluate the capacity and reproducibility of three-dimensional echocardiographic (3DE) strain parameters in the assessment of global left ventricular (LV) systolic function.

Methods: A total of 128 subjects with differing LV ejection fractions were investigated using two-dimensional echocardiographic (2DE) and 3DE strains. Three-dimensional echocardiographic strain allows obtaining “a promising approach”

Results: After excluding 21 patients for insufficient image quality, four for arrhythmia, two for severe valvular disease, and one for severe dyspnea, the final population consisted of 100 patients. Comparison between 2DE and 3DE GLS revealed high correspondence (r = 0.94, y = 0.94x - 0.7%) and mean error measurement of −1.3% (95% confidence interval, −5.7 to 3.2). Among strain parameters, global area strain exhibited the highest correlation with LV ejection fraction (r = −1.60−13.4, r = −0.92, P < .001). Interobserver measurement variability proved acceptable: 8% for GLS (vs 6% on 2DE analysis), 7% for circumferential strain (vs 15% on 2DE analysis), 7% for radial strain (vs 33% on 2DE analysis), and 5% for global area strain. The mean error between two measurements was lower but similar for GLS. The mean time of J Am Soc Echocardiogr 2012;25:68-79

Conclusions: Of all strain parameters, new 3DE area strain correlated best with common LV systolic function parameters and is thus the most promising approach, while all 3DE strain markers exhibited good reproducibility.

Myocardial Imaging

“What’s Next Starts Soon”

Standardization Workflow Efficiency
“It doesn’t matter how slowly you go as long as you do not stop”

Confucius