Myocardial Imaging

Tissue Doppler and Strain Imaging

Steven J. Lester MD, FRCP(C), FACC, FASE
Relevant Financial Relationship(s): None

Off Label Usage: None
When obtaining a pulsed wave tissue Doppler signal you should?

a. Turn the wall filters on and turn down the receiver gain.

b. Turn the wall filters off and turn up the receiver gain.

c. Turn the wall filters off and turn down the receiver gain.

d. Turn the wall filters on and turn up the receiver gain.
With “speckle tracking” myocardial imaging:

a. You measure strain along the axis of the ultrasound beam.

b. Velocity and strain measurements are measured from standard gray-scale images.

c. Myocardial velocity measurements are not influenced by translational or tethering motion as they are when obtained by pulsed wave tissue Doppler imaging.

d. You can measure longitudinal but not circumferential or radial strain.
Compared to pulsed wave tissue Doppler the myocardial velocities obtained by color tissue Doppler are?

a. Higher
b. Lower
c. The same
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.
How Do We Obtain a Velocity?

Christian Andreas Doppler
1803 - 1853

Positive Frequency Shift

\[(fr - fo) = 2fo \frac{v (\cos \theta)}{c}\]

C = average speed of sound in tissue (1540m/sec)
Doppler:  
Doppler Tissue Imaging

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

Velocity (TV'), range: -8.24 - +8.24 cm/s
Trace no: 1 2 3
Curved M-mode : TVI

Normal
Goal
To Detect Regional Wall Motion
Peak Velocities

Mean Velocities
Pitfall (Velocity Analysis)
Translation and Tethering

Translation
- Transducer
- Chest wall
- Ventricular wall

Tethering
- Transducer
- Chest wall
- Normal myocardium
- Akinetic myocardium
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)

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

- Strain rate
  - 10 cm to 8 cm: -20%
  - 10 cm to 12 cm: +20%
  - 10 cm to 0 cm: 0%
Strain rate: Rate of deformation

- High strain rate
- Low strain rate
- Equal strain

Courtesy of Andreas Heimdal
Strain rate vs. Tissue Doppler
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

Basal

Rotation

Apex

Torsion

View from apex
Mitral flow

Tissue Doppler

Apical rotation

Basal rotation

LV torsion

Normal relaxation

Pseudo-normalization

Restriction

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

Controls | Hypertensive Heart Disease | HFpEF
---|---|---
Longitudinal | * | *
Circumferential

*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
Surviving Cancer, But at a Cost

Radiation & Chemo-induced Cardiovascular Diseases
Cardio-Oncology

“The difficulty when dealing with cardiology side effects is that they can often mask themselves as normal effects from the cancer treatment itself...”
Case

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

LVEF = 66%

2 Months

LVEF = 58%
Baseline

LVEF = 66%

GLPSS Avg = -17.8%
Troponin T = 0.02

2 Months

LVEF = 58%

GLPSS Avg = -14.3%
Troponin T = 0.03
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”.

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

Aortic Valve closure

Peak Systolic Strain

Longitudinal Strain
Global Longitudinal Peak Systolic Strain

Peak Systolic Strain

ANT_SEPT

SEPT

ANT

INF

LAT

POST

Click here for tips

| GLPSS_LAX  | -17.5 % |
| GLPSS_A4C  | -20.2 % |
| GLPSS_A2C  | -24.6 % |
| GLPSS_Avg  | -20.8 % |
| HR_ApLAX   | 68.0 bpm |
| AVC_CALC   | 0.308 sec |
Early Detection and Prediction of Cardiotoxicity in Chemotherapy-Treated Patients

Heloisa Sawaya, MD, PhD,†, Igal A. Sebag, MD,‡, Juan Carlos Plana, MD,§, James L. Januzzi, MD,∥, Bonnie Ky, MD,§, Victor Cohen, MD,∥, Sucheta Gosavi, MD,¶, Joseph R. Carver, MD,∥, Susan E. Wiegars, MD,§, Randolph P. Martin, MD,∥, Michael H. Picard, MD,∥, Robert E. Gerszten, MD,∥, Elkan F. Halpern, PhD,∥, Jonathan Passeri, MD,∥, Irene Kuter, MD,¶, and Marielle Scherrer-Crosbie, MD, PhD,∥,∥,§,*

As breast cancer survival increases, cardiotoxicity associated with chemotherapeutic regimens such as anthracyclines and trastuzumab becomes a more significant issue. Development of early detection and biomarkers (high-sensitivity troponin I [hsTnI] and N-terminal pro-B-type natriuretic peptide [NT-proBNP]) could predict the development of chemotherapy-induced cardiotoxicity in patients treated with anthracyclines and trastuzumab. Cardiotoxicity was defined according to recent guidelines (Cardiac Review and Evaluation Committee of trastuzumab-associated cardiotoxicity) as a reduction of the left ventricular ejection fraction (LVEF) of ≥35% to <55% with symptoms of heart failure or an asymptomatic reduction of the LVEF of ≥15% to <20%.

Methods

Patients >18 years of age diagnosed with HER-2-overexpressing breast cancer and either scheduled to receive treatment including anthracyclines and trastuzumab or scheduled to receive trastuzumab after previous anthracycline treatment were eligible. Patients with LVEFs <50% were excluded.

Patients were enrolled at 4 institutions. All patients signed informed consent forms, which were approved by the institutional review board of the participating institutions.

Patients were studied before chemotherapy (except 10 patients who had previously been treated with anthracy-
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.
CRTCD if decrease in LVEF > 10% to a value < 53%  
- Reversible: to within 5 percentage points of baseline  
- Partially reversible: improved by > 10 percentage points from the nadir but remaining > 5 percentage points below baseline  
- Irreversible: improved by < 10 percentage points from the nadir and remaining > 5 percentage points below baseline  

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
Are They Really The Same?
Patients with HCM have significantly limited systolic function reserve and more dynamic dyssynchrony with exercise compared with those with HTN...
## HTN or HCM?

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>HTN</th>
<th>HCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest Strain (%)</td>
<td>-18.5 ± 2.0</td>
<td>-15.5 ± 3.7*</td>
<td>-13.5 ± 5.6**</td>
</tr>
<tr>
<td>Exercise Strain (%)</td>
<td>-23.1± 2.7</td>
<td>-17.7 ± 2.4*</td>
<td>-11.8 ± 4.9**</td>
</tr>
<tr>
<td>Rest TTP-SD (msec)</td>
<td>28 ± 7.5</td>
<td>28 ± 12.7</td>
<td>52 ± 28.9**</td>
</tr>
<tr>
<td>Exercise TTP-SD (msec)</td>
<td>20.9 ± 12</td>
<td>30 ± 20*</td>
<td>60 ± 37**</td>
</tr>
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</table>
## HTN or HCM?

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>HTN</th>
<th>HCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rest Circumferential Strain (%)</strong></td>
<td>-19.3 ± 2.5</td>
<td>-23.9 ± 2.9*</td>
<td>-22.8 ± 3.4**</td>
</tr>
<tr>
<td>▲Circumferential Strain Exercise (%)</td>
<td>5.3± 1.2</td>
<td>1.7 ± 2.1*</td>
<td>2.3± 3.0**</td>
</tr>
<tr>
<td><strong>Septal Thickness (mm)</strong></td>
<td>9.6 ± 2.0</td>
<td>17.8 ± 4.4*</td>
<td>26.0 ± 6.0**</td>
</tr>
</tbody>
</table>
Identify “Regionality” of Myocardial Motion

Apical HCM

Septal HCM
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, Paaladinesh 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

Results: Baseline concordance among the readers was poor (κ = 0.28) and improved with the addition of strain data (κ = 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 40% to 86%, P < .001), specificity (from 84% to 95%, 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.)
Cardiac Amyloidosis

Hypertensive Heart Disease

Hypertrophic Cardiomyopathy

Mean Wall Left Ventricular Thickness

14mm

14mm

13mm
Pattern Recognition
Constrictive Pericarditis

Longitudinal Strain (%)

Longitudinal Velocity cm/sec

AVC
Torsion (degrees)

7°
Amyloidosis

Longitudinal Strain (%)

Longitudinal Velocity cm/sec
Torsion (degrees)

16°
LV dysfunction is frequently subclinical despite a normal ejection fraction. It may precede 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”. 

The clinical identification of early abnormalities in LV function. This review gathers and summarizes current evidence 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.
Objective #3
Impediments to Clinical Adoption?

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

Matthew R. Nelson, MD, R. Todd Hurst, MD, Serageldin F. Raslan, MD, Stephen Cha, MS, Susan Wilansky, MD, and Steven J. Lester, MD, Scottsdale, Arizona; Rochester, Minnesota

Methods: A convenience sample of 100 prospectively collected patients was evaluated. Subjects with more 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 (EcholInsight 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 $-12.99 \pm 2.38\%$ using EcholInsight and $-16.87 \pm 2.84\%$ using Image-Arena (mean difference, 3.87 ± 2.42%; $P = .0001$). 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 (Lagrangian strain measured in systole and diastole at the endocardium and averaging the peak segmental strain curves), EcholInsight GLS was $-16.17 \pm 2.90\%$ and Image-Arena GLS was $-16.87 \pm 2.84\%$ (mean difference, 0.70 ± 2.75%; $P = .02$), with an intraclass correlation coefficient of 0.70 (95% confidence interval, 0.52–0.79).

Conclusions: Image-Arena GLS results were consistent out of the box but became similar when information used to compute GLS was normalized. The application of measures of myocardial mechanics into routine clinical practice will require vigilance and standardization of the various techniques, necessitating independent validation of commercially available speckle-tracking echocardiographic products.

Keywords: Speckle-tracking, Strain, Echocardiography

Image Area

GLS -16.87 ± 2.84% vs -12.99 ± 2.38%; p=0.0001

EcholInsight
### Need For Standardization

<table>
<thead>
<tr>
<th></th>
<th>Endocardium</th>
<th></th>
<th>Endocardium/Epicardium</th>
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<tr>
<td></td>
<td>Natural</td>
<td>Lagrangian</td>
<td>Natural</td>
<td>Lagrangian</td>
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<tr>
<td>Average of peaks</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Systole</td>
<td>-14.63±2.48∗</td>
<td>-15.79±2.86†</td>
<td>-13.42±2.22†</td>
<td>-14.39±2.53†</td>
</tr>
<tr>
<td>Systole/diastole</td>
<td>-14.96±2.50†</td>
<td>-16.17±2.90∗</td>
<td>-13.70±2.24†</td>
<td>-14.71±2.57†</td>
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<tr>
<td>Peak of average</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systole</td>
<td>-15.95±2.66†</td>
<td>-14.99±2.84†</td>
<td>-12.96±2.43†</td>
<td>-13.58±2.75†</td>
</tr>
<tr>
<td>Systole/diastole</td>
<td>-13.99±2.61†</td>
<td>-15.05±2.99†</td>
<td>-12.99±2.38†</td>
<td>-13.91±2.69†</td>
</tr>
</tbody>
</table>

*Significant difference (P<.05) compared with Image-Arena GLS
†Significant difference (P<.001) compared with Image-Arena GLS

-16.17 vs -16.87; p=0.02

Average of Peaks or Peak of the Average?

-16.17 vs -16.87; p=0.02
Scaling and Adaptive Scaling?
Head-to-Head Comparison of Global Longitudinal Strain Measurements among Nine Different Vendors 

The EACVI/ASE Inter-Vendor Comparison Study

Konstantinos E. Farsalinos, MD, Ana M. Daraban, MD, Serkan Ünlü, MD, James D. Thomas, MD, Luigi P. Badano, MD, PhD, and Jens-Uwe Voigt, MD, PhD, Leuven, 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 GLS_{AV} (the average from the three apical views) and GLS_{4CH} (measured in the four-chamber view) measurements among vendors and with the conventional echocardiographic parameters.

Results: Absolute values of GLS_{AV} ranged from 18.0% to 21.5%, while GLS_{4CH} ranged from 17.9% to 21.4%. The absolute difference between vendors for GLS_{AV} was up to 3.7% strain units (P < .001). The interobserver relative mean errors were 5.4% to 8.6% for GLS_{AV} and 6.2% to 11.0% for GLS_{4CH}, 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.)
Global Longitudinal Strain Among Various Vendors

\[ \text{GLS}_{\text{AV}, \%} \]

- Hitachi-A: -18.8 ± 3.4
- Esaote: -20.2 ± 3.6
- GE: -21.0 ± 3.9
- Philips: -18.0 ± 3.6
- Samsung: -18.2 ± 3.6
- Siemens: -20.0 ± 3.6
- Toshiba: -18.5 ± 3.2
- Epsilon: -18.5 ± 3.1
- Tomtec: -19.4 ± 3.3
- Mean of All: -21.5 ± 4.0

Mean Error in Measurements

Mean Error, %

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<tr>
<th></th>
<th>E</th>
<th>E/A</th>
<th>IVS</th>
<th>LVEDD</th>
<th>PW</th>
<th>GLS_{AV}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.2</td>
<td>19.7</td>
<td>11.6</td>
<td>8.2</td>
<td>17.0</td>
<td>6.9</td>
</tr>
</tbody>
</table>

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

Jens-Uwe Voigt,‡ Gianni Pedrizzetti,‡ Peter Lysyansky,‡ Tom H. Marwick, Hélène Houle, Rolf Baumann,

Cross vendor variability in peak systolic global longitudinal strain may now be less than that of measures of left ventricular ejection fraction

Recognizing the critical need for standardization in strain imaging, in 2010, the European Association of Echocardiography (now the European Association of Cardiovascular Imaging, EACVI) and the American Society of Echocardiography (ASE) initiated a concerted effort to reduce intervendor variability. The EACVI/ASE/Industry initiative to standardize deformation imaging, we prepared this technical document which is intended to provide definitions, names, abbreviations, formulas, and procedures for calculation of physical quantities derived from speckle tracking echocardiography and thus create a common standard.

J Am Soc Echocardiogr 2015;28:183-93

Keywords: Echocardiography, Two-dimensional, Deformation imaging, Strain, Strain rate, Speckle tracking, Left ventricle, Myocardial, Standard, Definitions
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

Christian Knackstedt, MD,* Sebastiaan C.A.M. Bekkers, MD, PhD,* Georg Schummers,† Marcus Schreckenberg,*
Denisa Muraru, MD, PhD,‡ Luigi P. Badano, MD, PhD,‡ Andreas Franke, MD,§ Chirag Bavishe, MD, MPH,*
Alaa Mabrouk Salem Omar, MD, PhD,** Partho P. Sengupta, MD, DM

Fully Automated Versus Standard Tracking of Left Ventricular Ejection Fraction and Longitudinal Strain

The Fast-EFs Multicenter Study

were saved in a centralized database, and machine learning-enabled software (AutoLV, TomTec-Arena 1.2, TomTec Imaging Systems, Unterschleissheim, Germany) was applied for fully automated EF and LS measurements. A reference center reanalyzed all datasets (by visual estimation and manual tracking), along with manual LS determinations.

RESULTS AutoLV measurements were feasible in 98% of studies, and the average analysis time was 8 ± 1 s/patient. Interclass correlation coefficients and Bland-Altman analysis revealed good agreements among automated EF, local center manual tracking, and reference center manual tracking, but not for visual EF assessments. Similarly, automated and manual LS measurements obtained at the reference center showed good agreement. Intraobserver variability was higher for visual EF than for manual EF or manual LS, but not different for LS. Automated EF and LS were higher than manual EF and LS, but also higher than visual EF and LS. Automated LS was lower than visual LS.

CONCLUSIONS Fully automated analysis of echocardiography images provides rapid and reproducible assessment of left ventricular EF and LS. (J Am Coll Cardiol 2015;66:1456-66) © 2015 by the American College of Cardiology Foundation.
Fully Automated Versus Standard Tracking of Left Ventricular Ejection Fraction and Longitudinal Strain

The FAST-EFs Multicenter Study

Abstract

Background

Objective

Methods

Results

Conclusion
AutoLV measurements were feasible in 98% of studies.

Average analysis time was 8±1 sec/patient.

Interobserver variability was higher for both visual and manual EF, but not different for LS.
Simultaneous measurement of Strain and Ejection Fraction

- **Longitudinal Strain**
  - Measures *systolic shortening*
  - Sensitive measure of myocardium function

- **Regional Ejection Fraction**
  - Measures *fractional change in volume*
  - Established, commonly used metric

Images courtesy of J. D’Hooge et. al.
Cardio-Oncology Analysis

- OCTOBER:
  - Ejection Fraction (EF): 0.62
  - Longitudinal Strain: 0.20

- JANUARY:
  - EF: 0.70
  - Longitudinal Strain: 0.13

Strain values and EF comparison between October and January.
3D Strain Analysis (spatial and temporal)
Evaluation of Global Left Ventricular Systolic Function Using Three-Dimensional Echocardiography Speckle-Tracking Strain Parameters

Patricia Reant, MD, PhD, Laurence Barbot, MD, Cecile Touche, MD, Marina Dijos, MD, Florence Arsac, MD, Xavier Pillois, PhD, Mathieu Landelle, MD, Raymond Roudaut, MD, and Stephane Lafitte, MD, PhD, Pessac, 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 ($r = 0.91$, $y = 1.04x - 0.71$) 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 ($y = -1.65 + 10.4, r = -0.92, P < .001$). Intraobserver 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 with 3DE than 2DE analysis for circumferential, radial, and global area strain but similar for GLS. The mean time of analysis was less than for 2DE analysis ($P < .001$).

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. (J Am Soc Echocardiogr 2012;25:68-79.)
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
1. DTI characterizes the low velocity, high intensity signals that come from the wall.

2. DTI is limited to movement relative to the sample volume fixed in space.

4. Local parameters of deformation (strain and strain rate) are not influenced by tethering or translational motion.

5. Feature or Speckle tracking can evaluate velocity, strain and strain rate from standard gray scale images.

6. Feature tracking permits assessment of strain in the axis of movement rather than the axis of the ultrasound beam.
When obtaining a pulsed wave tissue Doppler signal you should?

a. Turn the wall filters on and turn down the receiver gain.

b. Turn the wall filters off and turn up the receiver gain.

c. Turn the wall filters off and turn down the receiver gain.

d. Turn the wall filters on and turn up the receiver gain.
With “speckle tracking” myocardial imaging:

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