Systolic Function: It’s Not Just EF Anymore

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Which has the worse LV systolic function?
A  
B  
C
How Do We Assess LV Function?

**Qualitative**
- Wall Thickening
- Wall Shortening
- Symmetry of motion
- Excursion

**Limitations**
- Subjective
- Experience dependent
- Lack of standardization
- Large inter- and intra-observer variability

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**ASE American Society of Echocardiography**

**Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging**

Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Alhano, MD, MSc, Anderson Armstrong, MD, MSc, Laura Emanuele, MD, PhD, Frank A. Flachskampf, MD, FESC, Elise Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denis Muraru, MD, PhD, Michael H. Picard, MD, FASE, Ernst R. Rietzschel, MD, PhD, Lawrence Rudski, MD, FASE, Kirk T. Spencer, MD, FASE, Wendy Tsang, MD, and Jens-Uwe Voigt, MD, FESC, Chicago, Illinois; Padua, Italy; Montreal, Quebec and Toronto, Ontario, Canada; Baltimore, Maryland; Créteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts

2D Echo LVEF Underestimates Compared to CMR

Left Ventricular Volume

Mor-Avi V et al. JACC: Cardiovascular Imaging 2012:8:769

2D LVEF has Poor Reproducibility

Kutyifa V. et al. JACC 2013:61:936-44
**3DE LV Assessment is Recommended**

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

*Recommendation.* LV size should be routinely assessed on 2DE by calculating volumes using the biplane method of disks summation technique. In laboratories with experience in 3DE, 3D measurement and reporting of LV volumes is recommended when feasible depending on image quality. When reporting LV

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**3DE LV Measurements Are More Accurate**

- Excellent correlation \((r^2>0.85)\)
- Small biases
- Narrow limits of agreement
Why is 3D more accurate?  
**Volumetric**

- No geometric assumptions
- No image foreshortening


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3DE LV Variability

Thavendiranathan P. JACC. 2013
2DE vs 3DE and Outcomes

Stanton et al. JASE 2014;27:65-73

Why do we need something else?

Marwick TH. Heart 2013;99:15 1078-1086
Deformation Imaging

TISSUE DOPPLER

SPECKLE TRACKING

STRAIN

Doppler Angle

Myocardial Speckle Displacement

No Doppler Angle limitation !!
Speckle tracking strain


Courtesy of Toshiba Medical Systems
Speckle tracking strain

Strain imaging measures tissue deformation.

Lengthen/Shorten

Thickening/Thinning

Speckle tracking strain

Strain is fractional change in length, area or volume.

\[
\text{Strain} = \frac{L_B - L_A}{L_A} = \frac{\Delta L}{L_A}
\]
Principle Strains

- **Longitudinal** – $\varepsilon_L$
  - Myocardial shortening from base to apex
  - Negative value

- **Circumferential** – $\varepsilon_C$
  - Intramural myocardial shortening
  - Negative value

- **Radial** – $\varepsilon_R$
  - Myocardial wall thickening
  - Positive value

2DSTE: Longitudinal Strain
Sources of Variation
1. Acquisition
   • Frame rate (optimal ~60 frames/sec)
   • Temporal vs spatial resolution with high frame rate

2. Physiologic conditions
   • A 10 mmHg change in BP may have more effect than inter-vendor differences

Image: http://blogs.scientificamerican.com
Sources of Variation

3. Post-processing

Algorithm
- Region of interest size
- Number of speckles tracked
- Endocardial, epicardial

Sources of Variation

3. Post-processing

Algorithm
- Contour assumptions
- Direction of contraction
- Smoothing
Sources of Variation
3. Post-processing

- Contour placement

- Lagrangian vs natural strain?
- What is peak global strain?
- Timing?
  - peak systolic, peak ES, peak cardiac cycle
- Measurement?
  - Average regional peak or average of all peaks
Sources of Variation

- Vendor Dependency


Call To Action: Speckle Validation

A Suggested Roadmap for Cardiovascular Ultrasound Research for the Future

within days. The development of standard characterization methods and specialized, well-characterized phantoms would provide an objective approach to estimate the limiting uncertainties of these echocardiographic image based measurements.

Kaul, S. et al. JASE 2011;24:455-64

Courtesy: Scott Settlemeir
LV Global Longitudinal Strain

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

Figure 1 GLS\(_{90}\) (percentage) of all study subjects presented per vendor. Error bars represent SDs of the mean values. Note the significant differences between most vendors (P < .001). The table provides the repeated-measures ANOVA posttest results for differences between individual vendors. A blue dot indicates P < .05.

JASE 2015;28:1171-81
LV Global Longitudinal Strain

Improvement in Strain Concordance between Two Major Vendors after the Strain Standardization Initiative

A. Between Vendors comparison

B. Within Vendors comparison

JASE 2015; 28:642-8

LV Global Longitudinal Strain

AMERICAN SOCIETY OF ECHOCARDIOGRAPHY NEWS
PRESIDENT'S MESSAGE
Even a High Schooler Can Measure Strain

Allan L. Klein, MD.

JASE 2016;21:A19-21
Regional Deformation

- Quantitative assessment of the magnitude of regional LV deformation is not recommended
  - lack of reference values
  - suboptimal reproducibility
  - considerable inter-vendor measurement variability

Reference Ranges and Regional Patterns of Left Ventricular Strain and Strain Rate Using Two-Dimensional Speckle-Tracking Echocardiography in a Healthy Middle-Aged Black and White Population: The CARDIA Study

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal</td>
<td>n = 243</td>
<td>n = 98</td>
<td>n = 142</td>
<td>n = 69</td>
<td></td>
</tr>
<tr>
<td>Four-chamber</td>
<td>-16.4 ± 2.2 [-20.8 to -12.0]</td>
<td>-15.9 ± 1.9 [-19.9 to -12.0]</td>
<td>-15.6 ± 2.0 [-19.7 to -11.5]</td>
<td>-14.7 ± 2.2 [-19.1 to -11.3]</td>
<td>1 vs 3, 1 vs 4, 2 vs 4, 3 vs 4</td>
</tr>
<tr>
<td>Two-chamber</td>
<td>-17.3 ± 2.3 [-22.0 to -12.6]</td>
<td>-16.7 ± 2.1 [-21.0 to -12.5]</td>
<td>-16.5 ± 2.2 [-21.0 to -11.9]</td>
<td>-14.9 ± 1.8 [-18.7 to -11.1]</td>
<td>1 vs 3, 1 vs 4, 2 vs 4, 3 vs 4</td>
</tr>
<tr>
<td>Combined</td>
<td>-17.0 ± 2.0 [-21.0 to -15.0]</td>
<td>-16.5 ± 1.8 [-20.1 to -12.9]</td>
<td>-16.1 ± 1.8 [-19.7 to -12.5]</td>
<td>-14.8 ± 1.9 [16.6 to 11.0]</td>
<td>1 vs 3, 1 vs 4, 2 vs 4, 3 vs 4</td>
</tr>
<tr>
<td>Circumferential</td>
<td>-16.2 ± 2.6 [-21.4 to -10.9]</td>
<td>-15.9 ± 2.7 [-21.4 to -10.4]</td>
<td>-15.4 ± 2.3 [-20.0 to -10.7]</td>
<td>-14.7 ± 2.6 [-20.0 to -9.5]</td>
<td>1 vs 3, 1 vs 4, 2 vs 4</td>
</tr>
<tr>
<td>Radial</td>
<td>35.5 ± 11.3 [12.8-58.2]</td>
<td>38.4 ± 10.5 [17.2-59.6]</td>
<td>37.6 ± 10.3 [16.8-58.3]</td>
<td>36.0 ± 10.4 [15.1-56.8]</td>
<td>--</td>
</tr>
</tbody>
</table>

- Sex and race differences

Relation Between Global Left Ventricular Longitudinal Strain Assessed with Novel Automated Function Imaging and Biplane Left Ventricular Ejection Fraction in Patients with Coronary Artery Disease

<table>
<thead>
<tr>
<th></th>
<th>Overall (n = 242)</th>
<th>Controls (n = 218)</th>
<th>STEMI (n = 98)</th>
<th>Heart failure (n = 125)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left ventricular end-systolic volume (mL)</td>
<td>118 ± 75</td>
<td>56 ± 12</td>
<td>68 ± 21</td>
<td>173 ± 68</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Left ventricular end-diastolic volume (mL)</td>
<td>175 ± 80</td>
<td>86 ± 22</td>
<td>128 ± 34</td>
<td>220 ± 78</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>37 ± 14</td>
<td>68 ± 6</td>
<td>47 ± 7</td>
<td>24 ± 2</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>GLPSS Avg (%)</td>
<td>11.1 ± 4.8</td>
<td>16.3 ± 1.7</td>
<td>14.0 ± 3.4</td>
<td>7.6 ± 3.0</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

GLPSS Avg, Averaged global longitudinal peak systolic strain; LVEF, left ventricular ejection fraction; STEMI, ST-segment elevation myocardial infarction.


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

J Am Coll Cardiol 2014;63:447-56
Geometry as a Confounder When Assessing Ventricular Systolic Function
Comparison Between Ejection Fraction and Strain

| TABLE 1: Characteristics of the 5 Subject Groups |
|----------------|----------------|----------------|----------------|----------------|----------------|
|                | CAD (n = 200) | nCAD (n = 200) | BDM (n = 200) | HCM (n = 200) | Control (n = 200) |
| Age, yrs       | 63 ± 7        | 59 ± 10        | 51 ± 20       | 40 ± 15       | 35 ± 8          |
| BMI, kg/m²     | 21 ± 3        | 26 ± 4         | 25 ± 3        | 25 ± 3        | 25 ± 3          |
| Heart rate, beats/min | 64 ± 10   | 67 ± 12        | 69 ± 15       | 63 ± 12       | 62 ± 12         |
| SBP, mm Hg     | 146 ± 16      | 132 ± 17       | 110 ± 24      | 129 ± 24      | 129 ± 23        |


Geometry as a Confounder When Assessing Ventricular Systolic Function
Comparison Between Ejection Fraction and Strain

GLS and Outcomes

![Graph showing GLS and outcomes with statistical analysis]

**Circ Cardiovasc Imaging 2009;2;356-36**

**2D and 3D imaging comparisons**
3D Speckle Tracking

(Gorcsan J., J Am Coll Cardiol 2011;58:1401–13)
Case CA1

- Presented in 2012 to the heart failure clinic
- 58 y.o. M with progressive shortness of breath and exertional chest pain
- PMHx: HTN, atrial flutter
- Fam Hx: lymphoma in both parents and 1 sibling
- Cardiac catheterization: normal coronaries
Case CA1
Case CA1
Case CA1

- Serum protein electrophoresis
  - IgG lambda paraprotein
- Bone marrow aspiration and biopsy
  - Plasma cell aggregate which stands for lambda chains
- Cardiac biopsy
  - Positive for amyloid

→ Amyloidosis with plasma cell dyscrasia.
→ Cardiac and renal involvement.
- Started on chemotherapy

Strain


Left ventricular fluid dynamics in heart failure: echocardiographic measurement and utilities of vortex formation time

European Heart Journal – Cardiovascular Imaging (2012) 13, 385–393
Vortex Imaging

MRI

Echo

Vortex Imaging

Vortex Depth

Vortex Transverse Position

Vortex Length

Vortex Width
Vortex Imaging – steady streaming field

No Thrombus

Thrombus

Contrast echocardiography for assessing left ventricular vortex strength in heart failure: a prospective cohort study

European Heart Journal – Cardiovascular Imaging (2013) 14, 1049–1060
Age, gender, blood pressure, and ventricular geometry influence normal 3D blood flow characteristics in the left heart

Contrast echocardiography for assessing left ventricular vortex strength in heart failure: a prospective cohort study
Summary

• 3D LVEF is more accurate and reproducible than 2D LVEF
• However, LVEF is relatively insensitive to myocardial changes
• Strain is used to identify myocardial changes
• Strain is related to LVEF
• However, LVEF and strain measure different components of systolic ventricular function
• Vortex imaging allows measurement of intraventricular flow and is a promising new technique for assessment of ventricular function

Thank you for listening