Strain Analysis
by Speckle Tracking Echocardiography

Natesa G. Pandian, MD, FACC
Co-Director
Heart Valve Center & Noninvasive Cardiac Imaging
Hoag Hospital, Newport Beach, CA

Professor of Medicine and Staff Cardiologist
Tufts University School of Medicine, Boston

Speaker – Toshiba
Speaker Bureau – Lantheus Inc.
LV Systolic and Diastolic Performance is Complex

Intramural pathology and dysfunction occur before detection by conventional parameters
Tissue Doppler Imaging!
Speckle Tracking Technique
Why 3D Speckle Tracking?
2D Tracking
3D Tracking
What Parameters Can Be Obtained?
Speckle Tracking
(Global and Segmental Information)

Radial 3D-strain

Segmental Information

Global volume and EF

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV</td>
<td>135.95 mL</td>
<td>0 msec</td>
</tr>
<tr>
<td>ESV</td>
<td>43.85 mL</td>
<td>341 msec</td>
</tr>
<tr>
<td>EF</td>
<td>67.74%</td>
<td></td>
</tr>
<tr>
<td>max MV</td>
<td>213.85 mL</td>
<td>974 msec</td>
</tr>
</tbody>
</table>
STE Parameters

- Displacement
- Strain
- Strain Rate
- Rotation
- Twist, Twist Rate
- Untwist, Untwist Rate
- Torsion
Radial
Circumferential
Longitudinal
Systolic Radial Strain (Thickening)
Circumferential Strain (Shortening)
Longitudinal Strain (Shortening)
3D Speckle Tracking

Rotation

Twist

Torsion
Basal and Apical Rotation

Basal Rotation:

- Briefly initial counter-clockwise rotation
- Globally clockwise rotation

Apical Rotation:

- Counter-clockwise rotation
All These Numbers and Curves...

How correct are they?
Validation
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>STE parameter</th>
<th>Reference Std</th>
<th>Subjects</th>
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</thead>
<tbody>
<tr>
<td>Toyoda et al, JASE</td>
<td>2004</td>
<td>2D RSt</td>
<td>sonomicrometry</td>
<td>animal</td>
</tr>
<tr>
<td>Korninek et al, JASE</td>
<td>2005</td>
<td>2D Strain</td>
<td>sonomicrometry</td>
<td>animal</td>
</tr>
<tr>
<td>Notori et al, JACC</td>
<td>2005</td>
<td>2D Torsion</td>
<td>tagged MRI</td>
<td>human</td>
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<tr>
<td>Amundsen et al, JACC</td>
<td>2006</td>
<td>2D Strain</td>
<td>sonomicrometry and tagged MRI</td>
<td>animal</td>
</tr>
<tr>
<td>Roes et al, AJC</td>
<td>2009</td>
<td>2D global and regional LSt</td>
<td>MRI LGE</td>
<td>human (patients with isch. LVD)</td>
</tr>
<tr>
<td>Nesser HJ, EHJ</td>
<td>2009</td>
<td>3D-STE LV volumes</td>
<td>MRI</td>
<td>human</td>
</tr>
<tr>
<td>Seo Y, Circ-Img</td>
<td>2009</td>
<td>3D Strain</td>
<td>sonomicrometry</td>
<td>animal</td>
</tr>
<tr>
<td>Seo Y, JACC-Img</td>
<td>2011</td>
<td>3D area tracking</td>
<td>sonomicrometry</td>
<td>animal</td>
</tr>
</tbody>
</table>
Global Longitudinal Strain Among Various Vendors

GLS_{AV}%

-30 -20 -10 0

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

Normal Values

Normal reference values of left ventricular strain using three-dimensional speckle tracking echocardiography: results from a multicentre study


DOI: http://dx.doi.org/10.1093/ehjci/jeu213 jeu213 First published online: 26 October 2014

303 Healthy Subjects
Males 51%, Females 49%
<table>
<thead>
<tr>
<th>Variable</th>
<th>All ($n = 303$)</th>
<th>Men ($n = 156$)</th>
<th>Women ($n = 147$)</th>
<th>$P$-value (gender)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volumetric</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDV (mL)</td>
<td>110 ± 20</td>
<td>118 ± 22</td>
<td>103 ± 15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ESV (mL)</td>
<td>44 ± 10</td>
<td>47 ± 11</td>
<td>40 ± 8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SV (mL)</td>
<td>67 ± 11</td>
<td>71 ± 12</td>
<td>63 ± 9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EF (%)</td>
<td>61 ± 3</td>
<td>60 ± 3</td>
<td>61 ± 3</td>
<td>0.02</td>
</tr>
<tr>
<td>Mass (g)</td>
<td>118 ± 19</td>
<td>125 ± 19</td>
<td>109 ± 16</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Global strain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radial (%)</td>
<td>35.6 ± 10.3</td>
<td>35.2 ± 9.5</td>
<td>35.9 ± 11.0</td>
<td>0.58</td>
</tr>
<tr>
<td>Circumferential (%)</td>
<td>-30.6 ± 2.6</td>
<td>-30.5 ± 2.5</td>
<td>-30.6 ± 2.7</td>
<td>0.63</td>
</tr>
<tr>
<td>Longitudinal (%)</td>
<td>-15.9 ± 2.4</td>
<td>-15.5 ± 2.4</td>
<td>-16.3 ± 2.3</td>
<td>0.003</td>
</tr>
<tr>
<td>Area (%)</td>
<td>-42.0 ± 2.4</td>
<td>-41.7 ± 2.5</td>
<td>-42.4 ± 2.2</td>
<td>0.01</td>
</tr>
</tbody>
</table>
3D Speckle Tracking Study of the Normal LV Mechanics

Heterogeneity

Evangelista/Patel/Pandian et al. JACC 2009
Ischemic Heart Disease
Speckle Tracking
(Global and Segmental Information)

Global volume and EF

Segmental Information

Radial 3D-strain
<p>| | | |</p>
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Diastole to ...
...Systole.
Normal
Speckle-tracking echocardiography correctly identifies segmental left ventricular dysfunction induced by scarring in a rat model of myocardial infarction.
Relation Between Arterial Elastance and Circumferential Strain

\[ N=58, r=0.73, P=0.001 \]
Relation Between Ventricular Elastance and Circumferential Strain

N=68, r = -0.41, P<0.001
Fig. 12. Bulls-eye plots showing end-systolic longitudinal, circumferential and transmural strain estimated by 3-D speckle tracking in three subjects, and wall motion scoring based on 2-D apical images from the two patients. White spots correspond to areas with insufficient tracking. LAD = Left anterior descending artery; RCA = right coronary artery; Ant = anterior; Inf = inferior, Sep = septal; Lat = lateral.
Normal

CAD with RWMA
CAD with RWMA
Comparison of Longitudinal Strain in Normal and CAD with RWMA.
Impact of Transmural MI on Endo and Epicardial Circumferenecial Strain

- Subendocardial MI
  - Subendocardial
  - Subepicardial No Change

- Transmural MI
  - Subendocardial
  - Subepicardial
## Deformation Changes in Myocardial Ischemia

<table>
<thead>
<tr>
<th></th>
<th>Subendocardial</th>
<th>Transmural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Longitudinal Strain</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Global Circumferential Strain</td>
<td>—</td>
<td>↓</td>
</tr>
<tr>
<td>Global Radial Strain</td>
<td>—</td>
<td>↓</td>
</tr>
<tr>
<td>Twist</td>
<td>—</td>
<td>↓</td>
</tr>
</tbody>
</table>

Longitudinal Strain at Rest Predicts Left Main and 3VD in Patients Without RWMA
2/3 of NSTEMI patients undergo coronary angiography
2D Speckle for Detection of Significant CAD – A Meta-analysis

19 studies, 2189 patients

- Sensitivity 84%
- Specificity 82%

Singh et al. JACC 2013
Ischemic Cardiomyopathy

Detection of wall motion abnormalities

**RADIAL STRAIN**
in a patient with Isc CMP, EF 25%

Distal septum and anterior wall akinesia (thinning)
Lateral wall hypokinesia (reduced thickening)
Dyssynchrony
CMP Patient
Dyssynchrony
CMP Patient

After CRT
Severe LV Dysfunction

Normal (-17 ± 5%)

Diastolic Strain and Strain Rate Indices For Estimation of LV Filling Pressure
Valve Disease
Illustrative cases of 2 patients with normal flow low gradient (left) and low flow low gradient (right) aortic stenosis with normal EF.

Cardiomyopathies
Anthracycline-induced cardiomyopathy

Normal EF

RES Vol 6, 2011
Myocardial Strain Is Associated with Adverse Clinical Cardiac Events in Patients Treated with Anthracyclines

2. GLS was associated with cardiac events in patients with normal LVEFs.

(J Am Soc Echocardiogr 2016;29:522-27)
GLS threshold of -17.5% identified patients who did not develop cardiac events with 99% negative predictive value.

Cardio-Oncology Screening Strategy

Baseline Evaluation of 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)

CTRCD
Detecting Preclinical Disease

Doxarubicin Cardiotoxicity
• Abnormal strain at half the “cardiotoxic” dose
• ? Should trigger beta blocker or ACE inhibitor therapy

Infliximab (Remicaide) Cardiotoxicity
• Incidence of CHF 0.2%
• Asymptomatic low strain: 30%
• Normalization of strain with discontinuation of infliximab
Twist and Untwist in HCM vs Controls

Urbano Moral/Patel/Pandian AJC 2011
Longitudinal Strain: Cardiac Amyloidosis

Amyloid

Normal

Urbano-Moral/Patel/Pandian, Echocardiography 2011
Relative apical sparing of longitudinal strain is sensitive and specific for the diagnosis of cardiac amyloidosis

Cardiac Amyloidosis

Urbano-Moral/Patel/Pandian, Rev Esp Cardiol 2015;68:657
HCM Genotype (+)  

Peak LV Twist $\approx 20^\circ$  
Untwist Rate $\approx 35 \%/s$  
MVO  
Untwist at MVO $\approx 30\%$  
Peak Untwist Velocity After MVO

Normal

Peak LV Twist

Urbano-Moral/Patel/Pandian, Echocardiography 2011
Diastolic Strain and Strain Rate Indexes For Estimation of LV Filling Pressure

\[
E/10Dsr = 0.2 + (0.9 \times \text{Pre-A Pressure})
\]

\[N = 60 \quad R = 0.80 \quad p < 0.001\]

# Mechanics in Heart Failure

## Functional Impairment

<table>
<thead>
<tr>
<th>Longitudinal Mechanics</th>
<th>Circumferential Mechanics</th>
<th>Radial Mechanics</th>
<th>Torsional Mechanics</th>
<th>Global EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marked impairment</td>
<td>Preserved</td>
<td>Preserved/ minimal impairment</td>
<td>Preserved</td>
<td>Preserved/ minimal impairment</td>
</tr>
<tr>
<td>Preserved/ minimal impairment</td>
<td>Marked impairment</td>
<td>Minimal impairment</td>
<td>Marked impairment</td>
<td>Preserved/ minimal impairment</td>
</tr>
<tr>
<td>Marked impairment</td>
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</tr>
</tbody>
</table>

How about the Right Ventricle?
Reference Range for RV Strain

N=169 patients with normal TTE

Mean RV free wall strain = $-25 \pm 5\%$

Proportion of Patients (%)

Longitudinal displacement:

Significantly different in Amyloid, HCM and Hypertensive Hypertrophy

Differentiating feature between HCM and Amyloid Heart

Panetta/Pandian et al, EuroEcho 2013
Right Ventricle - Global apical LD

Panetta/Pandian et al
RV Strain Predicts Outcomes in PH

All-cause mortality

Time free of cardiac events or PH medical intervention

Fine et al. Circ CV Img 2013
Right Ventricular Pathology

- Measurement of RV strain is feasible
- RV contraction is predominantly longitudinal
- RV strain is abnormal in a variety of disorders
Strain by Speckle Tracking

- Identification of subtle regional & global contractile abnormalities
- Identification of dyssynchrony
- Evaluation of diastolic mechanics of the heart
- Prognostic value
Future Directions

- Need robust prognostic data
- Need values to define therapy
  - Real-time 3D quantitation
  - Fusion Imaging
Thank you!