Strain, Strain Rate, Torsion
What are They and When Should We Use Them?
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Vectors of Myocardial Strain

Tissue Doppler: Velocity, Strain Rate and Strain

PROBLEMS WITH TISSUE DOPPLER STRAIN
Tissue Doppler Strain is measured along scan lines!

Strain Imaging by Tissue Doppler
Is Affected by Doppler Angle

Tissue Doppler Longitudinal Strain Analysis

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Gorcsan J, JACC 2011;58:1401-13

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**STRAIN vs. VELOCITY**

**STRAIN ISOLATES THICKENING**

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

- \(L_0\) = Original Length
- \(L\) = Length of Deformed portion

\[\text{Thickening}\]

\[\text{Passive Movement}\]

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**What Is Speckle Tracking?**

**Calculation of Strain From Speckle Tracking**

*Not Dependent on Doppler Angle*

\[\text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}}\]

\[\rightarrow \% \text{ Thickening}\]

\[\rightarrow \% \text{ Thinning}\]

**APPLICATION OF SPECKLE TRACKING TO ROUTINE ECHO IMAGES**

**Speckle Tracking Longitudinal Strain**

**JACC**

*STATE-OF-THE-ART PAPER*

**Echocardiographic Assessment of Myocardial Strain**

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Echocardiographic strain imaging, also known as deformation imaging, has been developed as a means to obtain quantitatively regional myocardial function. First introduced as post-processing of tissue Doppler imaging on data converted to strain and strain rates, strain imaging has more recently also been derived from digital speckle tracking analysis. Strain imaging has been used to gain greater understanding into the pathophysiology of cardiac function and interpretation, the effects of various disease on regional function, and the effects of various disease on compensatory function, to enhance our understanding of disease function. Strain imaging has also been used to quantify diastolic function by the timing of wall motion abnormalities and to improve patient outcomes on patients with severe left ventricular failure. Further advances, such as real-time speckle tracking strain imaging, have been developed to improve the accuracy and reproducibility and further applications of speckle tracking strain imaging, including real-time speckle tracking strain imaging and real-time speckle tracking strain imaging, have been developed to improve the accuracy and reproducibility and further applications of speckle tracking strain imaging, including real-time speckle tracking strain imaging and real-time speckle tracking strain imaging, have been developed to improve the accuracy and reproducibility and further applications of speckle tracking strain imaging, including real-time speckle tracking strain imaging and real-time speckle tracking strain imaging, have been developed to improve the accuracy and reproducibility.
**Speckle Tracking:**

**RADIAL STRAIN ANALYSIS**

% Thickening

% Thinning

Normal subject

**APPLICATION OF SPECKLE TRACKING TO ROUTINE ECHOIMAGES**

Circumferential Strain

**CIRCUMFLENTIAL STRAIN ANALYSIS**

Normal subject

**DYSSYNCHRONY ANALYSIS**

Longitudinal Strain

Apical 4-Chamber

Apical 2-Chamber

Apical Long-Axis

**TRANSVERSE STRAIN**

Impossible for Tissue Doppler

**Speckle Tracking Longitudinal Strain**

Normal subject

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**Speckle Tracking Transverse Strain**

- Apical 4-Chamber view
- Apical Long Axis view

*Normal*  
*Thickening*  
*Thinning*

**Early Diastolic Strain Rate vs. Interstitial Fibrosis**

*Park, Nagueh et al. 2006 Am J Physiol Heart Circ Physiol 290: H724–H731*

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**CONTRACTION-RELAXATION COUPLING**

**Contraction**  
- Actin  
- Ca ++  
- Myosin  
- ATP

**Active Relaxation**  
- Actin  
- Myosin  
- ATP

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**Longitudinal and Radial Strain and Strain Rate**


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**A Longitudinal Strain and Strain Rate**

Systolic-Diastolic Coupling


Echo vs. Cardiac Magnetic Resonance
Comparison

Onishi T, Saha S, ...Gorcsan et al. ESC 2011

Reproducibility of Global Circumferential strain by CMR & ECHO

Gorcsan J, Do Not Copy
Onishi T, Saha S, ...Gorcsan et al. ESC 2011

Global Longitudinal Strain

Cho et al. J Am Coll Cardiol 2009;54:618

Global Circumferential Strain & Prognosis in Heart Failure

- 201 HF patients
- EF = 23%
- HF Hospitalization or Death 5 yrs
Objectives: To evaluate if more sensitive echocardiographic measurements and biomarkers could predict later cardiac dysfunction in chemo-treated patients.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
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</thead>
<tbody>
<tr>
<td>10% decrease longitudinal strain</td>
<td>7/9 (78%)</td>
<td>27/34 (79%)</td>
<td>7/14 (50%)</td>
<td>27/29 (93%)</td>
</tr>
<tr>
<td>Increased cTnl at 3 months</td>
<td>6/9 (67%)</td>
<td>28/34 (82%)</td>
<td>6/12 (50%)</td>
<td>28/31 (90%)</td>
</tr>
<tr>
<td>10% decrease Long strain and increased cTnl at 3 months</td>
<td>5/9 (55%)</td>
<td>33/34 (97%)</td>
<td>5/6 (83%)</td>
<td>33/37 (89%)</td>
</tr>
<tr>
<td>10% decrease Long strain or increased cTnl at 3 months</td>
<td>8/9 (89%)</td>
<td>22/34 (65%)</td>
<td>8/20 (40%)</td>
<td>22/23 (97%)</td>
</tr>
</tbody>
</table>

Left Atrial Function Predicts Atrial Fibrillation Recurrence After Catheter Ablation

- 63 pts. AFIB Catheter Ablation
- 75% PAF, 25% Persistent AF
- 18±12 months of follow-up

Left Atrial Strain

Positive Peak Strain

Negative Peak Strain

Total Strain

Speckle Tracking Left Atrial Strain

MYOFIBER ORIENTATION IS THREE DIMENSIONAL

The Advantage of Echocardiographic 3D Tracking

2D Imaging, Myocardium Moves In and out of Plane

3D Imaging, Entire Myocardium Is Tracked
3D SPECKLE TRACKING ANALYSIS

NORMAL 3D STRAIN

3D Speckle Tracking
Wire Mesh View

APICAL TORSION

DECREASED LV ROTATION IN HEART FAILURE- NORMAL EF

HFNEF has Blunted Increases in LV Function with Exercise

Tan...Sanderson et al. J Am Coll Cardiol 2009;54:36–46
Strain, Strain Rate, Torsion

- Speckle tracking strain has emerged as the echocardiographic method of choice for advanced quantification of cardiac function.
- Emerging clinical applications include Global Longitudinal Strain, and Global Circumferential Strain to assess LV function.
- Torsion is helpful to understand diastolic function.
- Newer potential applications include 3D strain and RV strain imaging.