Myocardial Strain Imaging in Cardiac Diseases and Cardiomyopathies.

Session: Cardiomyopathy

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Outline/Educational Objectives

• What is myocardial strain?
• Why measure myocardial strain?
• How do we measure myocardial strain?
  – Echo (TDI versus Speckle tracking)
  – MRI
  – Pearls and Pitfalls
• Clinical Utility & Applications
  – Current literature and Utility of Strain Imaging
What is myocardial strain?

- Strain is defined as the percent change in myocardial deformation.
  - Compression (Shortening)
  - Distraction (Lengthening)
- This deformation can be conveniently divided into the basic components:
  - longitudinal,
  - radial,
  - circumferential motion.
Myocardial Deformation & Strain
Myocardial strain

• Several strain derivatives can also be calculated:
  – Tissue velocity (velocity of deformation)
  – Strain rate (rate of myocardial deformation)
  – Displacement (displacement of the myocardium during deformation)
# Why do we need to measure myocardial strain?

1. **Detection of altered myocardial performance beyond EF**

<table>
<thead>
<tr>
<th>Ejection Fraction</th>
<th>Myocardial Strain/Strain rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited as a measure of contractility due to load dependency.</td>
<td>Less Preload dependent</td>
</tr>
<tr>
<td>Limited prognostic value in low-normal or higher range.</td>
<td>Greater utility in those with preserved EF</td>
</tr>
<tr>
<td>By the time EF decreases, it is too late!</td>
<td>Allows better understanding of progression of preclinical disease to overt heart failure.</td>
</tr>
</tbody>
</table>
Why do we need to measure myocardial strain?

1. Detection of altered myocardial performance beyond EF

- Advanced Age
- Obesity
- Hypertension
- Renal Failure
- Diabetes
- Atrial fibrillation
- Cardiomyopathies
  - Carriers of HCM mutations
  - Duchenne Muscular Dys.
  - Fabry’s
- Valvular heart disease
  - Severe AS
  - AR
  - MS
- Acute CAD
  - After MI, global strain values may predict subsequent remodeling and function recovery
How to measure myocardial strain?

• Can be measured on *Echo and MRI*
  – most experience with echocardiography.

• Two main methods on Echo:
  – *Tissue Doppler Imaging*
    • Conversion of tissue velocity data to strain and strain rate
  – *Speckle tracking*
    • Tracking of echo speckles using computer post processing
Strain Rate: TDI

$$\varepsilon = \frac{V_1 - V_2}{L}$$

$\varepsilon =$ strain rate,
$V_1 =$ velocity at point 1,
$V_2 =$ velocity at point 2, and
$L =$ length, usually set at 10 mm.
Strain Rate \[= \frac{V_1 - V_2}{L}\]
Strain is calculated as the change in length (L) divided by the original length (L0) and expressed as a percentage.

\[
\text{Strain} = \frac{\Delta \text{Length}}{\text{Length}_0}
\]
## Echocardiographic Myocardial Strain Techniques

<table>
<thead>
<tr>
<th>TDI</th>
<th>Speckle Tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Indirect measure of strain</td>
<td>• Direct measure of strain</td>
</tr>
<tr>
<td>• Derived from myocardial velocities</td>
<td>• Measures myocardial displacement</td>
</tr>
<tr>
<td>• Based on Doppler principle</td>
<td>• Based on computer-based tracking of speckles</td>
</tr>
<tr>
<td>• Dependent on angle of insonation</td>
<td>• Independent on angle of insonation.</td>
</tr>
</tbody>
</table>
Myocardial Strain: MRI techniques

- Grid tagged MRI
- Feature Tracking
Grid Tagged MRI

- Fading of grid tags
- Needs prospective application of tags
- Cannot use regular Cine Images
Feature tracking & Strain analysis
MRI Feature Tracking: LV

7.6 mm

8.2 mm
MRI Feature Tracking: RV
RV Strain: Feature Tracking
## Myocardial strain: Considerations

<table>
<thead>
<tr>
<th>LV Strain</th>
<th>RV Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easier to perform</td>
<td></td>
</tr>
<tr>
<td>Thicker LV walls</td>
<td></td>
</tr>
<tr>
<td>LV chamber is simpler</td>
<td></td>
</tr>
<tr>
<td>Greater utility in health and disease</td>
<td></td>
</tr>
<tr>
<td>Technically difficult</td>
<td></td>
</tr>
<tr>
<td>Thin RV walls</td>
<td></td>
</tr>
<tr>
<td>Hyper-trabeculated RV</td>
<td></td>
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<tr>
<td>More irregular shape and volume</td>
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<tr>
<td>Lesser clinical applications</td>
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<td>No reliable non-invasive surrogate</td>
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</table>
LA Strain
Strain: MRI Technique, Pearls & Pitfalls

- Image Selection
- Contouring
- Quality Assurance
Strain: MRI Technique, Pearls & Pitfalls

- **Image Selection**
  - Use series composer tool to create a **full** SAX stack
    - Exclude basal images with significant tricuspid or pulmonic systolic valve presence.
    - Exclude apical slices with too much through-plane motion.
  - Select 4CH image most central to the tricuspid valve and which has the clearest myocardium
Strain: MRI Technique, Pearls & Pitfalls

• Contouring
  – All images contoured at end diastole

• LAX: The septum is excluded.
  – The basal bulge is included as long as it was able to be tracked as well as the free wall myocardium.
  – A LAX RV extent contour (orange) is also used to define the systolic excursion of the tricuspid valve.

• SAX: The septum is included in the endocardial contour (since it must be a closed surface), but not the epicardial.
  – Nonetheless, like with the 4CH view, only the free wall myocardium is tracked for strain analysis.
Strain: MRI Technique, Pearls & Pitfalls

• Quality Assurance
  – Lengthiest process
  – Use of the cinematic loop is essential to QA.
  – Enable boundary points overlay to assess this.
    • The boundary points reflect the movement of the tracking algorithm, and any time this does not appear to reflect the actual motion of the myocardium, the contours are adjusted to improve the tracking.
Strain: MRI Technique, Pearls & Pitfalls

- Quality Assurance
  - If the boundary points move too far in, and end up in the blood pool at systole (green circle), then the contours must be adjusted outwardly.
  - If the boundary points are too far, out, ending up extracardiac during systole (green circle), then the contours must be adjusted inwardly.
• Quality Assurance
  – Exclude large artifacts that obscure entire portions of myocardium yielding nonsensical results from analysis:
    • brightness from the fat obscures the free wall anterolaterally, giving results which are clearly erroneous, with negative radial strain rates in that region.
Strain: MRI Technique, Pearls & Pitfalls

- Quality Assurance
  - Exclude large artifacts that obscure entire portions of myocardium, yielding nonsensical results from analysis:
    - brightness from the fat obscures the free wall anterolaterally, giving results which are clearly erroneous, with negative radial strain rates in that region.

The purple region in the ES image, with very poor tracking, can be seen in this regional radial strain graph as a purple trend line, giving paradoxical results.
Strain: MRI Technique, Pearls & Pitfalls

• Quality Assurance
  – Exclude large artifacts:
    • As a solution, the entire anterolateral portion of the RV myocardium should be excluded (ED and ES)
      – Caveat: exclusion will render segmental strain analysis incorrect
Myocardial Strain: Clinical Applications
#1. Heart Failure

Longitudinal RV strain in Heart Failure
Circ. RV strain in Heart Failure

Normal

Heart Failure
Radial RV strain in Heart Failure

![Graph showing radial RV strain in normal and heart failure conditions.](image-url)
#2. Ventricular Dyssynchrony (Radial LV Strain)

Normal

Heart failure with LBBB

Ventricular Dyssynchrony
(Circumferential LV Strain)

Normal

Heart failure with LBBB

Strain: Ventricular Dyssynchrony

Normal

Heart Failure

Radial

Circumferential
#3. Cardiomyopathy
Myocardial Strain in Cardiomyopathies

Normal

Myocardial Amyloidosis
LV Strain in Cardiac Amyloidosis

RV strain in Myocardial Amyloidosis

\[ p = 0.0299 \]

\[ p = 0.0080 \]

\[ p < 0.0001 \]
Apical Sparing in Cardiac Amyloidosis
#4: Myocarditis/Pericarditis
#4 Myocarditis Vs Pericarditis
#4 Myocarditis Vs Pericarditis

![Graph comparing Myocarditis and Pericarditis](image)

- **Myocarditis**
- **Pericarditis**
#4 Myocarditis Vs Pericarditis

Pericarditis

Myocarditis
#4 Myocarditis Vs Pericarditis

Myocarditis

Pericarditis
Conclusions

• Myocardial strain evaluation with CMR is feasible
• Evolving field with several challenges
  – Technique
  – Paucity of normative Data
  – Vendor variability
  – Large scale data on clinical utility is lacking.
• Offers a great opportunity for research and with further refinement it will establish as a useful technique.
Thank you...
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