New Techniques in Echo Strain & Strain Rate Imaging

Dr Salwa Roshdy
Professor of Cardiology
Assiut University
Feb 2010

What is Strain & Strain Rate

- Strain and strain rate echocardiography is an emerging technique for assessing myocardial systolic and diastolic function both globally and regionally.
Major Current Methods of Assessment of Myocardial Function

I. Ejection Fraction for global assessment and is limited by being load dependent
II. Regional wall motion abnormality assessment which is limited by being subjective and needs high experience
III. Tissue Doppler Imaging (TDI) which assesses myocardial velocity in different segments but limited by the effect of tethering and the translation effect of chest wall motion

IV. Strain (S) and Strain Rate (SR) Imaging

- They are derived from the parent TDI and have the following advantages:
  I. Load Independent
  II. Can assess both global and regional myocardial function.
  III. Can assess both systolic and diastolic myocardial function
  IV. Have high both temporal & spatial resolution which is position independent
  V. They can give quantitative numerical data
**Motion and deformation**

- In the heart, the myocardial fibres have three directions: longitudinal, circumferential and transmural.
- In systole, myocardial muscle shortens in the longitudinal, and circumferential dimensions and thickens in transmural direction.
- Because different myocardial fibers have different velocities and directions, so the myocardium will change its shape during contraction which is known as deformity and measured by Strain and Strain Rate.

---

**Motion and deformation**

- On the other hand, motion is present when the different parts of an object have the same velocity and the same direction.
- Apex is relatively stationary and represents the thinnest myocardium and it pulls the basal part.
- The velocity increases from apex to base.
- The posterior and lateral walls contract later than the septum and inferior LV walls.
Strain & Strain Rate Definition

- The strain ($\varepsilon$) is the rate by which the deformation occurs and derived from Lagrangian formula:

$$\varepsilon = \frac{L - L_0}{L_0}$$

where $L_0$= baseline length and $L$ is the instantaneous length at the time of measurement. It is ratio so unitless.

- Where Strain Rate ($\dot{\varepsilon}$) is calculated as change in velocity between 2 points divided by the distance $L$

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

Strain in three dimensions. The cylinder shows Longitudinal strain Shortening.
Strain & Strain Rate Display

I. Color coded strain rate
   In color coded SR, yellow-red indicates compression, and blue-white indicates expansion, green indicates no motion.
   - strain rate imaging in the atria
     As the apex of the heart is relatively constant, as well as the atria the atroventricular plane has to be the piston of a reciprocating pump, expanding the atria while the ventricle shortens and shortening the atria while the ventricle expands.

Deformation in the atria is reciprocally related to the deformation of the ventricles
Strain & Strain Rate Display

II. Strain & Strain Rate Expressed Graphically
- This is derived from the parent tissue Doppler
- A gradient of peak velocity at different locations along the LV wall
- The gradient is used to generate a SR curve
- Integration of this curve provides data on deformation that represent strain
- For timing of different intervals Aortic valve closure is pointed over the curve

Gradients of peak velocities at different locations along the LV wall
A regression calculation generates the strain rate curve

Integrated Data to calculate strain
Measurement of Strain & Strain Rate

- Myocardial strain may be measured using a variety of echocardiographic techniques:
  
  I. M-mode technique; it measures strain along one dimension
  
  II. Current era of myocardial strain measurement depends on measurement of SR from comparison of adjacent tissue velocities by Heimedal et al. (1997)
  
  III. Subsequently strain has been measured using speckle tracking technique

Strain Rate by Speckle Tracking in Grey Scale Images (2-D Dependent)

- It is Doppler-independent and 2-D echo dependent
- These speckles are ultrasound reflectors behave like magnetic resonance tags
- Shortening may be calculated by comparison of these speckles from frame to frame
- Because the baseline length is incorporated it can measure Strain directly
- It offers radial measurement and new approach to assess torsional motion derived from circumferential strain
The speckles follow the motion of the myocardium so when the myocardium moves from one frame to the next, the position of this fingerprint will shift slightly, remaining fairly constant.
Optimal Parameters

I. Timing Parameters:
   a) Timing to peak systolic or Post-systolic thickening if present
   b) Time to onset of systole  c) time to relaxation

II. Magnitude Parameters:
   a) Normal resting longitudinal SR is 1-1.4 (±0.5-0.6)/s
   b) Normal longitudinal systolic strain is 15 – 25%
   c) Normal radial strain is 50 – 70% (±5-7%)
Clinical Applications of S & SR

I. Coronary Heart Disease
a) Reduced strain rates (Voigt, JASE 2000)
b) Reduced strain (Jamal et al, JASE 2002)
c) Heterogeneity of mechanical activity (Pislaru, JACC 2001)
d) Superior to tissue Doppler (Abraham, Circulation 2002)

Assessment of Myocardial Ischemia

- Human studies obtained during angioplasty proposed
  a) Longitudinal SR of 0.8/s (sensitivity 75%, & specificity 63%)
  b) Peak Systolic Strain of -10% (sensitivity 86%, & specificity 83%)
  c) A post-systolic shortening of > 35% (sensitivity 82% specificity 85%)
- These measurements are considered suitable cutoff for detection of ischemia
Strain and Strain Rate Profiles in Ischemic Basal Inferior Wall

Strain and Strain Rate Profiles in Ischemic Septum
Strain and post systolic strain

Longitudinal strain rate (SR) maps in normal anterior (A) and ischemic posterior (B) left ventricular (LV) wall

Jamal et al, JASE 1999;12:994-6
II. Stress Echocardiography with Strain and Strain Rate Imaging

a) Quantitative assessment of regional myocardial function
   (Weidemann, JASE 2002)
   (Cain et al, AJC 2001)

b) Earlier detection of ischemia
   (Armstrong, JASE 2000)

c) Dobutamine SRI assessment of viability was in agreement with PET in 83% of segments.
   (Hoffmann et al, 2002)

d) Delayed local relaxation
   (Abraham, JACC 2002)

Strain rate imaging of the septal wall at rest (upper) and during dobutamine stimulation (lower). The color changes from green to yellow indicate viability.
Dobutamine Stress – time to onset of relaxation

III. Cardiac Resynchronization

- a) Mechanical asynchrony versus electrical asynchrony  
  (LeClerq, Circulation 2002)

- b) Predict clinical responders  
  (Yu, Circulation 2002)

- c) Identify delayed segments  
  (Sogaard, Circulation 2002)

- d) Locate optimal pacing site  
  (Ansalone, JACC 2002)
IV. Other Clinical Applications of S & SR

- **Myocardial Disease:** SR is very effective in the evaluation of subclinical myocardial disease as in amyloidosis, diabetic heart disease and Friedrich ataxia
- **Valvular Heart Disease:** Subclinical myocardial dysfunction may be identified as a potential guide to the timing of surgical intervention in regurgitant valve lesion
- **Diastolic Dysfunction:** A direct myocardial parameter for identifying abnormal relaxation and its response to therapy could be of significant value

---

IV. Other Clinical Applications of S & SR

- **Right Ventricular Function:** Measurement of RV Strain & SR is applied to RV free wall and is used in assessing RV function in:
  - Senning procedure in TGA
  - After Falot-Tetralogy correction surgery
  - Ventricular non-compaction
  - Arrhythmogenic RV dysplasia
Limitations of Strain imaging by TD

- The need for a long Learning curve
- Noisy signals (could be improved by ↑ sample distance & curve smoothing but on expense of others)
- Doppler Angle dependant
- ↑ Sector width on expense of ↓ frame rate which decreases resolution.

- ↑ Sector width on expense of ↓ frame rate which decreases resolution.
- On the other hand ↓ Sector width will ↓ lateral resolution
- It can not measure radial strain and strain rate which is now measured by the 2 dimensional echocardiography speckle tracking
Conclusions

- SRI has provided a physiologic tool for understanding the myocardial mechanics.
- The most current clinical applications is related to myocardial viability & identification of LV subclinical dysfunction.
- The application of Stress Echo and Quantification of resting function are emerging.

Conclusions

- Barriers to its every day use include:
  - complex methodology
  - technical challenges of acquisition and analysis
  - lack of complete consensus regarding the
    superiority of any one parameter among others
  for different applications.