The Mitral Valve in Ischemic Cardiomyopathy

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Background

Mitral Valve (MV):
- one of four heart valves that ensure unidirectional blood flow
- may dysfunction in terms of leakage: mitral regurgitation
- or excessive narrowing: stenosis

Motivation/Aim

Motivation:
- Recent studies suggest mitral leaflets can grow to reduce degree of regurgitation
  - May open exiting new treatment options for patients with ischemic mitral regurgitation

Aim:
- quantify regional and direction variation in growth across the anterior mitral valve leaflet

Prevalence:
- 12.6 Million Americans have history of myocardial infarct
- 1.2-2.1 Million have IMR

Rings 1-4: Edwards Lifesciences  Rings 5: St. Jude Medical
Methods

Animal Experiments:
- N=25 male Dorset sheep
- 30 markers implanted on MV anterior leaflet & around annulus
- kinematics: marker locations from biplane videofluoroscopy
- forces: left ventricular, atrial, and aortic pressure

Methods

Mechanical Characterization of the Leaflet:
- linear interpolation in terms of curvilinear coordinates
  \[ x(\theta_1, \theta_2) = \sum N_i(\theta_1, \theta_2) \psi_i(\theta_1, \theta_2) \]
- covariant base vectors define surface metrics
  \[ e_\alpha = \partial x / \partial \theta_\alpha \]
- strain tensor is directly calculated from the above
  \[ \varepsilon = e_{\alpha} \otimes e^\beta = \frac{1}{2} \left[ e_{\alpha} - g_{\alpha} \right] \]

Methods

Mechanical Characterization of the Annulus:
- functional representation through piecewise cubic spline
  \[ c(s,t) = \sum n_i(s,t) \psi_i(s,t) \]
- least square's fit
  \[ \sum \left| c(s,t) - c(s,t) \right| \lambda \left( \frac{d^2c(s,t)}{dt^2} \right) \to \min \]
- displacements
  \[ u(s,t) = c(s,t) - c(s,t) \]
- stretch & strain
  \[ \lambda(s,t) = \sqrt{ \frac{d[x(s,t)]}{d[x(s,t)]} \left( \frac{d[x(s,t)]}{d[x(s,t)]} \right)} \quad E(s,t) = \frac{1}{2} \left[ \lambda(s,t)^2 - 1 \right] \]

Methods

Strain throughout the cardiac cycle

Strain throughout the cardiac cycle
Methods

Temporal Evolution of the Averaged Areal Strain, N=55:

Normal Ventricular Pressure

Acute Ventricular Pressure

Chronic Ventricular Pressure

Strain throughout the cardiac cycle
### Additional Results

- **Acutely:** no statistically significant growth
- **Chronically:** statistically significant growth
- No statistically significant difference between regions


### Results

#### Areal Growth of the Anterior Mitral Valve Leaflet:

- Over 30% area growth within 5 weeks
- Strain varies across the leaflet and across animals
- Homogenous growth distribution on average

#### Circumferential Growth of the Anterior Mitral Valve Leaflet:

- Over 10% circumferential growth
- On average strain primarily in anterior region

#### Radial Growth of the Anterior Mitral Valve Leaflet:

- Over 10% radial strain
- As with circumferential strain, primarily in anterior region
Results

Summary:
- within 5 weeks post infarct: leaflets do grow
- average area growth: 16%
- average circumferential growth: 6%
- average radial growth: 4%

Conclusion:
- growth is heterogeneous across the leaflet
- growth varies across subjects
- growth is anisotropic

Future Direction:
- design ex-vivo leaflet stretcher

Results

Tangential annular enlargement along the annulus:
- over 50% strain in some annuli
- strain varies along the annulus
- on average a posterior-lateral deformation

Results

Curvature variation along the annulus:
- curvature decreases primarily, with local increases
- again, variation along the annulus within each subject
- again, some inter-subject variation

Summary:
- within 5 weeks post infarct: annuli enlarge
- annular strain of up to 50% and more
- significant curvature alterations

Conclusion:
- leaflet growth may be initiated by mechanical force from the surrounding annulus