New Insight into the Force Balance in the Mitral Valve Annulus.

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Background/Objectives:

Mitral valve ring annuloplasty re-establishes physiologic annulus dimensions during systole to facilitate proper valve closure. New insight into the 3D dynamic behaviour of the mitral valve apparatus has prompted a re-evaluation of ring designs, enabling saddle (hyperbolic paraboloid) conformity in systole and dilatation back to a flat configuration during diastole. This will improve stress distribution and increase repair durability. The systolic mitral annular saddle height is approximately 6-8mm, resulting in an annular height to commisural width ratio of 15-20%. The cause of this shape is assumed to be created by interactions between contractions of surrounding left ventricular myocardium and tension from the tendonious chords.

Hypothesis/Aim:

1. To obtain ex-vivo access of the forces acting in the apical direction on the annular commissural area necessary to remodel the annulus to its systolic saddle shape observed in vivo.

2. To determine the 3D force distribution in flat and saddle shaped stiff annuloplasty rings with Finite Element computer Models (FEM) and in vivo experimentation.

Materials & Methods:

1. A setup was constructed to correlate annulus force and deformation of the commissural area towards apex. Porcine hearts were excised, and non-flexible suture was secured at the commissural area and the tip of apex was removed allowing attachment of a force gauge to the suture through apex. A relative distance measurement system was utilized to quantify the annulus height.

2. Physiological tissue properties from MRI data and ex vivo stress strain measurements were utilized in FEM calculations to simulate annuloplasty ring forces. Rapid Prototyping models with strain gauges mounted were created and porcine in vivo animal experimentation performed to correlate FEM calculations with annular force and geometry measurements.

Results:

1. A linear correlation between the saddle height and the required force was demonstrated (R=0.97, n=6, F=0-5N). The clinically observed 8mm annular height required a force of approximately 2.7N.

2. FEM simulations showed high systolic stresses and strains in the commissural areas. In vivo experiments with strain gauges are compared with the computer models.

Conclusions:

The force required to obtain clinical deformation of the mitral annulus is comparable to previous papillary muscle and individual chordae force measurements. The FEM models and in vivo stress/strain measurements confirm this relationship. This establishes a biomechanical approach that forms a rational basis for innovative annuloplasty ring designs, allowing sufficient mobility and flexibility and ultimately reducing valvular incompetence.