Mitral Valve Regurgitation and Valve Biomechanics
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OBJECTIVES

- The purpose of this research is to further understand the biomechanical structure of the Mitral Valve (MV) leaflets in combination with the chordae tendineae by conducting tests based on pressure and fluid dynamics (hemodynamics). “The heart beats more than 100,000 times per day handling approximately 5 liters of blood per minute. Over the average lifetime, there are greater than 3 billion heart beats, or cardiac cycles” (4) Constructing a closed system designed to run high repetitions, track flow, maintain a pressure consistent with the heart is key to understanding limitation of intracardiac devices to repair the MV. “Valve tissue has exceptionally high strain because the tissue cycles to a completely unloaded state with each heart beat.” (4) The closed system must also be able to change materials being tested as the leaflets and chordae tendineae to best represent current tissue data (of CT and leaflets). Through use of this closed system device the hope is to explore new device concepts relating to the potential repair of mitral regurgitation (MR) and mitral valve impairments. The closed system uses a fee back loop that maintains hemostasis (equilibrium of blood) to which the force of the chordae tendineae can be monitored in unison with the leaflets and see and MVr taking place.

APPROACH

- General overview of valve anatomy
  - “The mitral valve is composed of two leaflets, the anterior (or aortic) and posterior leaflets. The supporting tendinous cords (chordae tendineae) on the ventricular aspect of the valve leaflets, insert into two well-defined papillary muscles that are continuous with the left ventricular myocardium. The posterior leaflet dominates the majority of the mitral valve annulus circumference, but the anterior leaflet is larger and makes up a greater area.” (4)

  - Synthesis of heart valve mechanics
    - "Valvulogenesis is an extremely complex process by which a fragile gelatinous matrix is populated and remodeled during embryonic development into thin fibrous leaflets capable of maintaining unidirectional flow over a lifetime.” (1) This process is what gives the leaflets a high capacitance of mechanical capability and allows for proper performance over a life of the individual. This process complicates the overall study of leaflet structure, since it “occurs during exposure to constantly changing hemodynamic forces, with a success rate of approximately 99%,”(1) meaning that there is variability from subject to subject in leaflet structure.

  - Defective Valvulogenesis will in some result in increased leaflet complications that can further evolve into hemodynamics impairments and overall cardiac impairment.

METHODOLOGY

- In current market studies it was discovered that, “Bio prosthetic valve replacement has become increasingly popular, however continues to suffer from longevity issues. There have been exciting advances in interventional cardiac catheterization, including percutaneous insertion of the pulmonary valve.” (4) A reason for this driving popularity stems from the fact that heart diseases continue to be the number one cause of death with “Valve disease resulting in approximately 20,000 deaths annually.” (4)
  - “The actual direct cost for valve disease in the United States alone has been estimated at 1 billion dollars per year. Taken together, the public health impact of valve disease and burden to society is underappreciated. Valve disease may manifest as stenosis, an obstruction to outflow, or regurgitation, a defective closure resulting in backward flow.” (4)
  - There are two major impairments that can occur in the mitral valve that will lead to mitral valve regurgitation (MVr). The first being non-functional valve closure or coaptation in which the valves are not creating proper contact with one another and the gap between them is allowing the back flow to occur. Many devices on the market currently target this type of MVr, some being the complete replacement of the valve with a prosthetic (leaflet resection) or the other involving stitch mechanisms to pull membrane tissue closer to eliminate the gap between leaflets. Devices like... are similar to the stitch mechanism. Another mechanism that was studied was the MitraClip® which uses a clip mechanism through intraprostatic intervention using a surgical cather to be implemented (minimally invasive beating heart surgery). The MitraClip treatment has benefits, but when considering the hemodynamic and orifice area that is lost there is still room for growth in hemodynamic ability in MR.
  - The second method or operation for repairing MVr stems from the idea of chordae tendineae rupture (CTR), in which the chordae tendineae (CT) are no longer attached to the papillary muscle that prevents back flow into the left atrium during systolic contraction of the left ventricle. “While the physiological geometry of the leaflets and annulus have been previously investigated, little effort has been made to quantitatively and objectively describe CT geometry” This will be the focus of some of the future research that is intended to take place after enough mechanical trials have occurred. Once there is a advanced understanding of the forces acting on the CT structure artificial devices can be better adapt to replicate organic tissue. It has also been found that by using existing leaflet and overall mitral valve construction in this case is much better for hemodynamics, cardiac output and longevity versus complete replacement of the valve with prosthetics. “At 2.9-year follow-up, Chord MVr for isolated posterior mitral valve prolapse was associated with a low reoperation rate and favorable valve hemodynamics, when compared with leaflet resection.” (5)

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THANK YOU FOR YOUR TIME

Sources

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