Alternate Designs

A System to Quantify 3D Spatial Deformation of Heart Valve Leaflets

Team #8

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1. Introduction

The purpose of the project is to design and fabricate a strain measurement system that can be used to quantify 3D heart valve deformation in static and dynamics loading conditions. There are several aspects to the proposed strain measurement system: a fluid chamber that houses a bioprosthetic heart valve, an optical strain measurement system to capture 3D leaflet cusp deformations under a variety of hydrostatic loading conditions, and a pressure transducer that simultaneously measures the transvalvular pressure. In addition, the system should be computer controlled with automatic data visualization and analysis. 3D motion of the leaflets should also be numerically constructed. Our design choices will focus on creating the most accurate and reliable system possible while minimizing costs.

2. Optical Measurement

To capture the 3D motion of the leaflets, an inflation method corresponding to thin-walled tissues will be utilized. Such a method requires small markers and several high-speed digital cameras. In order to see the strain, 60-90 marks will be placed on each leaflet. The cameras then record the displacement of each marker, allowing for the precise calculation of inflation and strain.

2.1. Two Camera System

Two cameras are needed to follow all of the markers and give stereoscopic vision. Using only two cameras is the cheapest option, but can result in experimental limitations. When the leaflets deform, only one camera will be able to see the markers around the boundaries, which could lead to a loss of information in that region.

2.2. Three Camera System

Three cameras can be used in to ensure all markers are in the field of view, especially near the boundaries, and the third camera can act to increase accuracy when calculating marker positions. However, with an additional camera, several aspects of the system such as the algorithm used to analyze the gathered data will need to be altered in order to incorporate the additional information. There will also be additional financial costs for a third camera.
3. Apparatus Design:

The project can be broken down into two parts, static loading and dynamic loading, each calling for a unique testing apparatus. The static loading apparatus requires a simple water column placed on the heart valve, to be filled with varying amounts of water. Each valve will be tested under 0, 20, 40, 60, 80, 100, and 120 mmHg. The dynamic loading apparatus is a bit more complex, and requires the use of a closed pump system to force saline through the valve.

3.1. Static Apparatus
The static apparatus (Figure 1) will be comprised of a clear acrylic glass housing chamber, a mounting post, and a loading hopper. The hopper will be filled with saline in order to reach the desired trans-valvular pressures. This open bath type of design is appealing because it is simple and easily built.

3.2. Dynamic Apparatus
As opposed to the static loading device, the dynamic apparatus will have a hydraulic pump to change the transvalvular pressure over time by cycling saline at different rates through the valve. The design will differ from the static apparatus in that it will have closed-loop tubing with a pump integrated. The hopper in the static conformation will be detachable to allow the testing mode to be switched between static and dynamic.
4. **Heart Valve Mounting**

Heart valves come in an assortment of sizes with varying exterior surfaces. We need to make sure we can accurately test, at the very least, the most common types of heart valves. Leaking fluid will result in inaccurate results, and therefore, the mounting design is imperative. A tight seal must be made between the system and valve tissue in order to eliminate any fluid leakage. Sutures and mechanical fits are two different ways to achieve a seal.

4.1. **Sutures**

If sutures are used we would have to suture the valve into the apparatus so that it was fixed into position. Sutures are appealing because they do not require the creation of customized mounting plates for every new valve that is being tested. However, the process of suturing and then removing sutures for each valve will be a time consuming process and damage the valve.

4.2. **Mechanical Fit**

Mechanical fits are appealing because they do not cause damage to the valve and can be quickly interchanged. This allows for the testing of multiple valves in a shorter period of time and the ability to reuse the same valves for far longer than one could when using a suture method. The disadvantage of mechanical fits is that each heart valve will likely require the creation of its own mounting plate. This means that Dr. Sun will likely have to create his own plates if he wants to test new valves after the conclusion of our project.