Three Alternative Designs

A System to Quantify Heart Valve Leaflet Strain

Team #10
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Alternate Design 1

The design will have two distinct cylindrical chambers made of Plexiglas. All of the holes will be threaded to help maintain pressure in the system. The holding tank and testing chamber will sit on a wooden frame as shown in (Figure 1). The testing chamber will have a nozzle to let out any air bubbles that may be trapped at the top.

![Figure 1: Holding tank and testing chamber set up.](image1)

The testing chamber will house the valve on the bottom. The platform in which the valve sits on is able to swivel a full 360 degrees. This will allow for us to image all three of the leaflets with ease. The testing chamber will also be short in stature to allow for the human eye to see the leaflets as close as possible. There will be two holes in the testing chamber specifically for the borescopic lenses. The lens will enter the testing chamber via a venous transcatheter which will allow the lens to pass through without any water leakage in order to maintain pressure in the system. There will be another hole at the same level as the valve to connect the pressure transducer. There will be a calibration cube mounted in the system to calibrate the cameras while the valve is mounted in the chamber. Once calibration is completed the cube will then be taken out of view. There will also be a hole at the approximate level for the surgical valve as well as the transcatheter aortic valve so the calibration cube can be used for both valves. The calibration cube will use the same system as the lenses entering the chamber through a venous catheter (Figure 2).

![Figure 2: Step up of the testing chamber.](image2)
There will be a large hole on the top where the holding tank and large cylinder will attach. The holding tank will have two holes for the pump and the hose. This chamber will be a tall and wide cylinder.

The data collected by the pressure transducer will be sent to a computer and analyzed using DataTrax software. The images uploaded from the cameras will be recorded through image analysis program and further analyzed using LabVIEW.

The mechanical pump will be analyzed through the DataTrax software and LabVIEW. A purchased mechanical pump that measures blood pressure will be manipulated to provide the pressurized tank the desired pressure. The pump will also be able to maintain the pressure.

Alternate Design 2

The design for this project is something that needs to be very precise, while being as cost efficient as possible. This design idea will take one cubic plexiglass container in which the testing valve, solution being tested in, cameras with boroscopic lenses, pressure mechanical pump, and pressure sensor will be held. The cubic plexiglass container will be a two piece container. The reason that this container will be designed into two pieces is so that the top part of the container can be taken off in order to make it easy to change the transcatheter valve being tested. In the top portion of the container there will be two cameras being used with boroscopic lenses in order to give the user the ability to have a 3D visualization of the valve leaflets. One of the cameras will be directly above the trascatheter valve and the second camera will be on the same plane horizontally as the valve in order to get an accurate visualization of the valve leaflets. Also in the top portion of the container there will be a pressure mechanical pump attached in order to be able to reach the appropriate pressure, between 40 mmHg to 200 mmHg, needed in order to close and test the three leaflets. Lastly in the top portion of this container there will be a removable calibration cube needed for the boroscopic lenses of the camera. This calibration cube will give the user the ability to line up, and accurately test the three different valve leaflets individually. Silicone skin will be shaped around the boroscopic lenses of the camera, and the pressure pump in order to maintain a constant pressure in the container. The bottom half of the container will then contain, the valve on a rotational holder, the solution, the pressure sensor, tubing from the valve to the collecting jar, and the collecting jar. The transcather valve will be located directly in the center of the lower half of the container. This valve will have its three leaflets broken into six different regions and marked with permanent marker in order to specifically test and analyze every section from each leaflet. This design will have the valve on a rotational holder. This holder will be able to securely keep the valve still during the pressurized testing period for one of the leaflets and then give the ability to rotate the valve in order to test the second leaflet individually without needing to move the camera lenses. This type of design will make it easier for the user to accurately quantify each leaflet individually without risking destruction of the testing setup. Also in the bottom part of the container there will be the testing solution which will be set to the same temperature as body temperature. Next to the valve on the bottom part of the container there will be a pressure sensor which shows the user that the wanted pressure is being reached inside the testing container. From the transcatheter valve there will be tubing connecting the valve to the
collecting jar. This tube will give the valve the ability to allow water to leak through it which then will be quantified. This tube should have the ability to be opened and closed dependant on which part of the test the user is up to. This tube should be closed originally and then during testing it should be opened to allow the water to be released through the valve. The last part in the bottom section of this container will be a collecting jar. This is something that is very important in the design because this collecting jar will give the user the ability to quantify the amount of water that is leaking through the valve during the pressurized testing. Labview is the computer program that will then be used in order to analyze the data shown in the pressure sensor and the images taken from the camera. This program will be used to design a very articulate code which will be able to manipulate and control the 2D images in order to analyze the stress and strain deformations in the valve leaflets. The Labview program will also be able to take the high speed 2D images and turn the images into 3D. The Figure below shows a general setup of this specific design (Figure 3).

![Figure 3: Alternate design setup](image)

*Alternative Design 3*

This alternative design will consist of two square chambers made of Plexiglas, where the holding chamber is separate from the testing chamber. The design will be obtained using a 3D CAD software program. The Holding chamber will begin the water flow from a saline solution source that consequently will fill the testing chamber where the leaflet will experience the different applied loads. Holding tank will maintain a solution temperature of 37° Celsius. The transcatheter and bioprosthetic valves must be tested with water at normal human body temperature to ensure the correct mechanical
properties and obtain more accurate data for the deformation of the heart valve leaflets. The two chambers will be connected by plastic tubing that will supply the saline solution into the testing chamber. The plastic tubing will be connected to a 90 degree Elbow PVC pipe fitting that will connect the testing and holding chambers. This connection cannot be detached because the pipe fitting and tubing will be sealed with silicon. The testing chamber will have the heart valve mounted. Also, the testing chamber will have boroscope lens that will digitally measure the strain as the various loads are applied. This area will be well lit with convectional lamps so the user can view the valves. The testing chamber will also contain a pressure sensor so that the user can make sure the right amount of pressure is being reached. The chambers will also be supported by a wooden platform so that it remains steady. Below where the valve is mounted, there will be a hole which will allow water to leak through the valve. This hole will be connected to a collecting jar where the rate of leakage through the heart valve can be measured. Also, the hole can be opened or closed at anytime during the trials (Figure 4).

The images capture by the high speed cameras along with the measured pressure from the pressure sensor, will then be analyzed by a LabVIEW program. The program will be able to measure and quantify the strain and stress of the leaflets. Ultimately, the program will construct a three dimensional structure of the deformation of the heart valve leaflets.

Figure 4: Alternative Design Three Set-up

Alternative Design 1 described above has been chosen to be our optimal design. This design has been slightly adjusted to help solve the few complications that Alternative Design 1 would encounter. It has been decided that in the optimal design we will not pressurize the water being held in the holding tank since there is no need for this. Also, the client has decided on a mechanical pump. The mechanical pump will provide more pressure than wanted, so a divergent loop will be created. This divergence loop will have two valve controls; one for the testing chamber and another for the excess water and pressure to be circulated back into the holding tank. This design will create the pressure
needed without air bubbles forming and disturbing the high speed cameras. Also, it
should prevent the pressure from leaking out of the system, so, the optimal pressure can
be reached. The sustainability should not be an issue because of the use of the calibration
cubes. The cubes will make it easier for the user to keep the same setup without having to
constantly drain the system. This design has been determined by the client to reach all
realistic constrains while remaining in the given $1000 budget.