INTRODUCTION
Hypertension is one of the most prevalent and death causing disease in the category of cardiovascular diseases. 2012 statistics estimate hypertension prevalence to be 27 % in the US, that is, 1 in 3 adults [1]. Of these, about 30 % Americans are not aware of their condition.

Hypertension or high blood pressure (HBP) is defined as a systolic pressure ≤ 140 mm Hg and/or a diastolic pressure ≤ 90 mm Hg [2]. Chronic hypertension, leads to damage to the brain cells, the kidneys and can lead to strokes. Figure 1 shows the causes of hypertension.

This research is a continuation of about 10 Union College graduates from the Mechanical Engineering and Biology departments. Recent achievements include the characterization of myocardial infarctions by Adams ’09. Currently, the main focus is hypertension.

OBJECTIVES
The goals for this research were:
1. To characterize the deformations of a heart during a simulated hypertension and
2. To investigate the breathing mechanism of the heart. The contraction model for the heart could be a peristaltic tube or a sphere chamber model.

The heart responds to hypertension by pumping a larger volume of blood more forcefully to quickly return to a normotensive state. The heart’s response is characterized by monitoring surface deformation fields using the speckle image photogrammetry technique.

EXPERIMENTAL PROCEDURE
A heart from a bull frog, Rana Catesbeiana, was used as the analog to the human heart. An amphibian heart has a single ventricle as shown in figure 2 while a human heart has two. The frog was pithed and dissected. A speckling pattern was developed using white titanium dioxide and black charcoal. Hypertension is induced by injecting a saline fluid directly into the heart ventricle using a syringe.

A non-contact optical full field strain technique that uses the ARAMIS photogrammetry software to monitor surface deformations over the entire three dimensional heart over several heart beats was used. The system is shown in figure 3 during experimentation set up. The two cameras shown are high speed cameras that can take images at a rate of 500 frames per second at full field. ARAMIS traces a speckle pattern during the experiment from which it computes the deformations and strains. Images were taken for a normotensive state and for a hypertensive state.

RESULTS

![Figure 2: A labeled amphibian heart showing the single ventricle](image1)

![Figure 3: The ARAMIS photogrammetry system set up during an experiment](image2)

![Figure 4: The displacement field on the heart. 1 – 3 shows selected facets used to generate the plots in figures 5 and 6.](image3)

![Figure 5: A plot of the displacements of points 1 – 3 as seen in figure 4.](image4)

<table>
<thead>
<tr>
<th>Z Displacement [mm]</th>
<th>Major Strain [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normotensive</td>
<td>1.45±0.15</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>1.63±0.05</td>
</tr>
<tr>
<td>Difference</td>
<td>0.18</td>
</tr>
<tr>
<td>Total</td>
<td>6.1</td>
</tr>
</tbody>
</table>

![Figure 6: A strain comparison for normotensive state versus hypertensive state.](image5)

CONCLUSION
The most suitable contraction mechanism for the frog heart is the sphere chamber model as shown by the synchronized plots in figures 5 and 6. Hypertension increases the strains and deformations on the heart’s ventricle as the heart ‘struggles’ to restore the ambient state. Table 1 shows that the displacements increased by 0.18 mm corresponding to a 12 % increase from a normotensive state to a hypertensive state. The strains also increased from 5.18 % to 11.3 % showing a 6.1 % increase. However, not enough data was collected to make this conclusions final.

FUTURE WORK
Three main things remain to be done in the future:
1) The development of a perfect speckling pattern to allow deformations to be computed for entire surface of heart.
2) Optimize lighting system to enable the use of short shutter times plus get rid of glare.
3) Connect pressure transducer to obtain pressure data.
Then obtain more data to validate pre-conclusions.

REFERENCES

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