Modeling of Patient-Specific Cerebral Aneurysms

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ABSTRACT

Cerebral aneurysms, weakened outgrowths of the high pressure arteries in the brain, develop with little to no symptoms until they rupture, leading to outcomes ranging from mild headache to stroke or death. Once diagnosed using imaging, a variety of treatment options exist for ruptured aneurysms, the choice of which depends on factors such as location and size of the aneurysm, as well as degree of collateral vasculature. Having the patients knowledge increased, they could make a knowledgeable decision on whether or not to perform the surgery. This would also inform the patient and have them being fully aware of what will be happening and what has happened to the arteries in the brain. Both medical costs and caretaker cost increase after a rupture so futuristically, having the model available will help the doctor plan, train, and perform a surgery without having to do things after a rupture occurs so money can be saved. The model can be used to plan a safe and secure operation for the patient and allowing even the newest doctors to see or learn how to perform a difficult procedure. The ideal method would involve a minimal number of steps and result in models that could be built using commercial 3-D printing machines.

Keywords: Cerebral Aneurysm, Modeling, Medical Imaging, Additive Manufacturing

1. INTRODUCTION

The study of cerebral aneurysms is important because about forty percent of all ruptured cerebral aneurysms are fatal. However, a less severe rupture will cause a leak which can cause minor symptoms, but can still leave the patient with some type of permanent damage. With the use of rapid prototyping it is possible to make seemingly realistic models that could be used to increase the knowledge potential of all involved. Operations exist to solve problems related to cerebral aneurysms, many consisting of open brain surgery or surgery that involves going behind the eye; both are very dangerous for the patient involved. Using these potential models, doctors may make knowledgeable decisions on how to approach the operation and the best way to provide care to the patient. Moreover, the models could assist physicians in explaining to patients their surgical options.

1.1 what an aneurysm is

Starting off, an aneurysm occurs from a weak spot in the lining of the artery. As blood flows through the arteries, the lining in the wall gets weak and starts to bulge. That bulge is called an aneurysm. An aneurysm can occur in two ways: a saccular (berry) type or fusiform type. The saccular type aneurysm occurs at branch points in arteries. It forms a berry shaped bulge in between two arteries and has a high chance of rupture. The fusiform type aneurysm expands the artery outward making its diameter larger in the area, as shown in Figure 1.
Brain aneurysms are all different. Besides the variation in shape, aneurysms can vary in size and location. The size of the aneurysm can get to be larger than 25 mm, or about 1 ¼ of an inch. As the aneurysm grows, it has more of a chance to rupture, but it can still rupture no matter how large or small it is. Depending on how large of a rupture or leak, blood gets in the brain causing severe symptoms ranging from a severe headache to a possible coma. A hemorrhage may also damage the brain directly which can lead to possible seizures, vision problems, or even death.

1.2 where cerebral aneurysms are located

Cerebral aneurysms commonly occur in a collection of arteries called the Circle of Willis. The Circle of Willis, illustrated in Figure 2, acts as a collateral circulation of arteries in a way that they work together if a part of it clots. For cerebral aneurysms, eighty percent occur in the parts of the Circle of Willis. The Circle of Willis was named by Thomas Willis, a pioneer in brain research as well as research in the nervous system and the muscles.
1.3 finding cerebral aneurysms

As aneurysms occur internally, there is no telltale sign that you have one. Even if one has symptoms of an aneurysm, it does not mean that there is one there. Oppositely, if there are no symptoms, there is still a possibility that one could exist. When one is suspecting that there is an aneurysm, we resort to the medical technology that is available to image what is inside of the skull. There are three types of scans that are available to see a cerebral aneurysm. The first, cerebral angiography (CA), is an invasive test. A catheter is pushed up from the femoral artery to the neck area. The catheter injects a dye to act as a contrast agent when taking an x-ray. This is the gold standard of tests providing the most precise images of size and location. Another similar test, computed tomographic angiogram (CTA), uses the same type of dye and x-ray but does not use a catheter to inject it. This is a less invasive test, as the dye is only injected in a vein in the hand or forearm. The last test uses magnetic resonance imaging (MRI). Although this test is not invasive at all, it requires a special technician and takes time with its equipment. The difference of image quality between MRI and CT can be seen in Figures 3 and 4.

![MRI Image](image1)

Figure 3: MRI Image. Illustrates the Quality of an MRI Image for Cerebral Aneurysms

![CT Image](image2)

Figure 4: CT Image. Illustrates the Quality of a CT Image for Cerebral Aneurysms
2. METHODOLOGY AND RESULTS

2.1 images

Finding and receiving a set of medical images of a cerebral aneurysm is the start of the process. Using different open source databases that have medical images, some were found. However, the quality and number of images were very limited making these sets inadequate. This being a problem, IRB approval was necessary to use a set of images obtained from the University of Virginia, Department of Radiology. The set of images obtained contained many that needed to be gone through to determine what area the images were from to find a proper set of images to be used. After finding an adequate set of images, the Rapid Prototyping Center at Milwaukee School of Engineering will be used for image processing and modeling.

2.2 rapid prototyping

At the Rapid Prototyping Center, the images will be put into a combination of software to model and configure the images provided. As the medical images are slices of a 3D image, the first thing to do is import them to make a 3D image. The software used to import them is called MIMICS (Materialize, Leuven, Belgium). MIMICS is a biomedical modeling software. It was used to import the DICOM files from the medical images. DICOM is the file type of the images that are most commonly used in medical imaging equipment. The grayscale of the images is then used as a threshold. This threshold is used to identify structures of interest and remove any unneeded parts. As these are 3D slices, the images are then exported with their slice thickness to a modeling software to clean the images and repair them if needed. Repairs include filling in holes that could be missing when adjacent slices are combined. Additionally patching or filling may be necessary due to mistakes in removal.

2.3 model

After the images are repaired with software the file can then be used to make a model. The machine that will be used to make the model is the Selective Laser Sintering machine (SLS)\(^1\). This machine uses a laser to create objects, layer by layer. It also allows for complex geometries without the use of supports, making it an ideal choice when modeling arteries. The material that would be ideal to start with is DuraForm Flex plastic\(^1\). As the model has no need to have the material properties of actual arteries, DuraForm Flex plastic has properties that make it easy to use. The plastic has a low cost per part as well as minimal finishing requirements. It is also fully recyclable, making this an ideal choice if using this in a commercial setting.

3. CONCLUSION AND DISCUSSION

In conclusion of this research, a physical model can be made. Although one was not obtained due to time, the model can be made with the software described and used in the Rapid Prototyping Center. As research continues the physical model will prove to be more of an asset as it could be used with materialistic properties and used to try new procedures. As the current proposed model is feasible for the described outcomes, research can continue and expand on this knowledge extensively.

While the model is an important feature of the outcomes, it is not the most important. The increase of medical knowledge with the use of a model can be expanded. Surgeons would be able to train or plan an upcoming surgery with a patient specific model. Generic models could be used in training where a first look could be taken. Another important outcome is the increase of the patient’s knowledge. When doctors show their patients scans of what there is, there is no real insight. With a physical model, the patients would know what it is inside of them and they would be able to make a better decision with a continuation of surgery or not. As patient’s knowledge is the main focus, a generic model can easily be made of different size aneurysms to show different patients. Another outcome is the use of further research. The model could be remade with materialistic like properties so that flow analysis could be done or even practice new procedures.
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5. REFERENCES


