3D Printed Brain Aneurysm Model for Aneurysm Clipping Practice

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**Background**

**Introduction**
Clipping is a common surgical treatment for brain aneurysms. First, the head is imaged to analyze and assess the location of the aneurysm. Once a prediction of the best possible approach is made, the surgeon will perform a craniotomy to place a small metallic clip on the neck of the aneurysm. This prevents blood from entering into the aneurysm sac so that it can no longer pose a risk for bleeding. The clip remains in place for life, and the aneurysm will shrink and scar down permanently after clipping.

**Problem**
In an aneurysm clipping, doctors usually are not aware of what type of clip they will need before the surgery. Everyone’s brain is different and the shape of an aneurysm is always unique as well as the placement within the brain. This creates different pathways and obstacles within the brain that must be avoided and worked around in order to perform a successful clipping.

**Objective**
The purpose is to create an arbitrary system using 3D printing to model the brain aneurysm that will function as a way for doctors to be able to practice/train clipping specific aneurysms on a model before clipping the aneurysms during surgery.

**Design Overview**

**Specifications**
The model needs to be durable enough to be able to perform mock clippings, as well as mirror a specific patient’s brain.

**Materials**
The model is primarily constructed from an acrylonitrile butadiene styrene (ABS) polymer, which is compatible with the Fortus 400mc printer in the MABE Maker Lab.

**Specifications**
ABS is utilized to represent comparably hard structures within the region of interest (ROI), such as bone, blood vessels, and cranial nerves. Because ABS is a rigid plastic with tensile yield stress of around 41 MPa, it is similar to that of cortical bone (around 50 to 70 MPa).

**Dimensions**

**Cube prototype model**
The current prototype cube model has outer dimensions of 51x51x51 mm, with wall thickness of 2.5 mm. The craniotomy hole, which can vary in size depending on the necessary surgical pathway is approximately 13 mm in diameter. The neck diameter of the arbitrary aneurysm structure is 2.5mm.

**Final model**
The final model, consisting of one quadrant of the upper skull (sliced coronally at the midline of the zygomatic bone), will have dimensions identical to those of the patient from which the skull data is derived. The length (front to back) of the model will be roughly 110 mm, the width will be 90 mm, and the height will be roughly 100 mm. The thickness will be around 6.8 mm. The diameter of the middle cerebral artery, where aneurysms can often manifest, is approximately 4 mm. Aneurysm neck (area to be clipped) diameter can range approximately from 1.5 to 9 mm depending on the size and type of the aneurysm. The aneurysm itself may have a maximum diameter of anywhere from 4 to 20 mm³.

**Methods**

**Segmentation**
The region of interest (ROI) that contains the aneurysm and other supporting vessels can be defined using Inveon software at the UT Medical Center or using Avizo, accessible in SERF. Once the ROI is selected, the data is segmented using Avizo. A tolerance in Avizo is utilized to represent comparably hard structures within the region of interest (ROI), such as bone, blood vessels, and cranial nerves.

**Methods (cont’d)**

**Insight**
The STL files from Avizo and Solidworks are brought into Insight to slice the models and create support structures to prepare for 3D printing. In this step, we review our fundamental engineering knowledge to optimize the orientation to print with minimal support material. Further, this optimization will minimize the cost of printing. Once orientation and slicing are finalized, the file is saved as a CMB and sent to the MABE Maker Lab for printing.

**MABE Maker Lab**
The Fortus 400mc printer uses ABS and a dissolvable support material that is water soluble to print the model. Once the model is printed, it sits in a bath until the support structures have dissolved.

**Current Prototype**
We have created a full working prototype and are working on our final design. For the prototype, there was success with clipping the vessel, as seen in Figure 6.

**Results**

**Final Prototype**
The first step of the final prototype has been completed, the section of the skull. The steps we have left are to create the aneurysm and the slits to attach it to the skull.

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