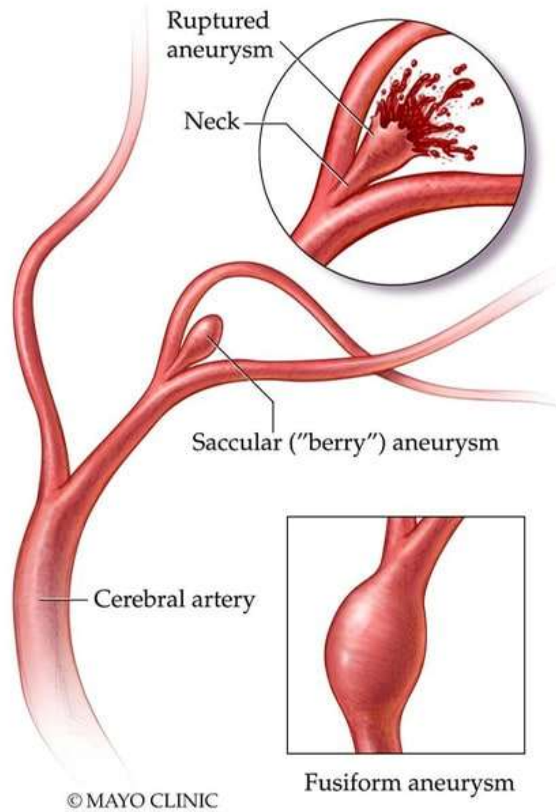
Aneurysm Rupture Team F24toSP25_02

Anna Mellin: Design and 3D Printing Lead
Amanda Ortiz-Velazquez: Budget and Testing Lead
Caden Adams: Casting and CAD Lead

What is a cerebral aneurysm?



Saccular and fusiform cerebral aneurysms

Project Description

Description

- The team will utilize 3D printing and the wax casting method to create a tube that simulates what occurs in an artery when an aneurysm ruptures.

Goal

- Design a working model of a brain aneurysm that is predictable and measurable.

Importance

- A working model could provide information on brain aneurysms and be a way to test products that could potentially prevent or fix aneurysms.

Sponsor

- Dr. Dou
- Budget of $1000

SCHEDULE

Cerebral Aneurysm Rupture Project Schedule

Northern Arizona University Team F24toS25_02

Gantt Chart Template © 2006-2018 by Vertex42.com

Project Start Date: 8/26/2024 (Monday) Display Week: 1

Project Lead: Anna Mellin

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Hardware Model**		Mon 8/26/24	Thu 12/12/24	109	19%	79
1.1	Develop Casting model		Wed 9/11/24	Tue 10/15/24	35	10%	25
1.2	Perfect Casting model and rapid produce		Tue 10/15/24	Thu 12/12/24	59	0%	43
1.3	Learn Resin Printer		Fri 9/13/24	Fri 9/13/24	1	100%	1
1.4	Preview Becker's Model		Mon 9/16/24	Mon 9/16/24	1	0%	1
1.5	Develop 3D Printed model		Thu 9/26/24	Tue 10/15/24	20	5%	14
1.6	Perfect 3D Printed model		Tue 10/15/24	Thu 12/12/24	59	10%	43
2	**ME 476C Requirements**		Mon 8/26/24	Thu 12/12/24	109		79
2.1	Presentation 1		Mon 9/09/24	Mon 9/16/24	8	0%	6
2.2	Presentation 1 Feedback		Mon 9/16/24	Wed 9/18/24	3	0%	3
2.3	Peer Eval		Mon 9/16/24	Thu 9/19/24	4	0%	4
2.4	Staff Meeting #3		Mon 9/23/24	Mon 9/23/24	1	0%	1
2.5	Staff Meeting #4		Mon 9/30/24	Mon 9/30/24	1	0%	1
2.6	HW 03		Mon 9/16/24	Mon 9/23/24	8	0%	6
2.7	Presentation 2		Mon 9/16/24	Mon 10/07/24	22	0%	16
2.8	Presentation 2 Feedback		Mon 10/07/24	Wed 10/09/24	3	0%	3
2.9	Peer Eval 2		Mon 10/07/24	Thu 10/10/24	4	0%	4
2.10	Staff Meeting #5		Mon 10/14/24	Mon 10/14/24	1	0%	1
2.11	Report 1		Mon 10/07/24	Fri 10/18/24	12	0%	10
2.12	Staff Meeting #6		Mon 10/21/24	Mon 10/21/24	1	0%	1
2.13	Website Check #1	Caden	Mon 9/16/24	Fri 10/18/24	33	0%	25
2.14	Staff Meeting #7		Mon 10/28/24	Mon 10/28/24	1	0%	1
2.15	Analysis Memo		Mon 9/16/24	Wed 1/11/00	4	0%	-32529
2.16	Presentation 3		Thu 10/10/24	Mon 11/04/24	26	0%	18
2.17	Presentation 3 Feedback		Mon 11/04/24	Wed 11/06/24	3	0%	3
2.18	Peer Eval 3		Mon 11/04/24	Thu 11/07/24	4	0%	4
2.19	1st Prototype Demo		Mon 9/16/24	Wed 11/13/24	59	0%	43
2.20	DAC Meeting (extra credit)		Fri 11/15/24	Fri 11/15/24	1	0%	1
2.21	Staff Meeting #9		Wed 11/20/24	Wed 11/20/24	1	0%	1
2.22	Hw 04		Wed 11/13/24	Fri 11/22/24	10	0%	8
2.23	Report 2		Sat 10/19/24	Wed 11/27/24	40	0%	28
2.24	Staff Meeting #10		Wed 11/27/24	Wed 11/27/24	1	0%	1
2.25	Final CAD and BOM		Sun 11/03/24	Mon 12/02/24	30	0%	21
2.26	2nd Prototype Demo		Wed 11/13/24	Wed 12/04/24	22	0%	16
2.27	2nd Prototype Demo Feedback		Wed 12/04/24	Wed 12/04/24	1	0%	1
2.28	Project Management for 486C		Fri 12/06/24	Fri 12/06/24	1	0%	1
2.29	E-Fest Extra Credit		Fri 12/06/24	Fri 12/06/24	1	0%	1
2.30	Website Check #2	Caden	Fri 10/18/24	Sat 12/07/24	51	0%	36
2.31	Final Peer Eval 4		Sun 12/08/24	Sun 12/08/24	1	0%	0
2.32	Course Eval		Sun 12/08/24	Sun 12/08/24	1	0%	0

Figure 1: Gantt Chart

SCHEDULE

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Table 1: Team's Projected Schedule

BUDGET

Budget:		$1,000.00
Fundraising needed:		$100
Fundraising Obtained	$	771.25

Donation:	From Who	Amount
3D Printer	Dr. Dou's Lab (Pheatt Award)	$ 271.25
Pump	Dr. Dou's Lab	$ 500.00

Quantity	Item	Cost	Total Leftover
3	Resin	$ 16.00	$ 48.00
2	Silicone	$ 250.00	$ 500.00
30	Idea Lab prints	$ 3.00	$ 90.00
1	Lab grade Gelatine	$ 59.00	$ 59.00
			$ 697.00

Figure 2: Budget List

BACKGROUND AND BENCHMARKING

Figure 3: Aneurysm Model cast In Silicone

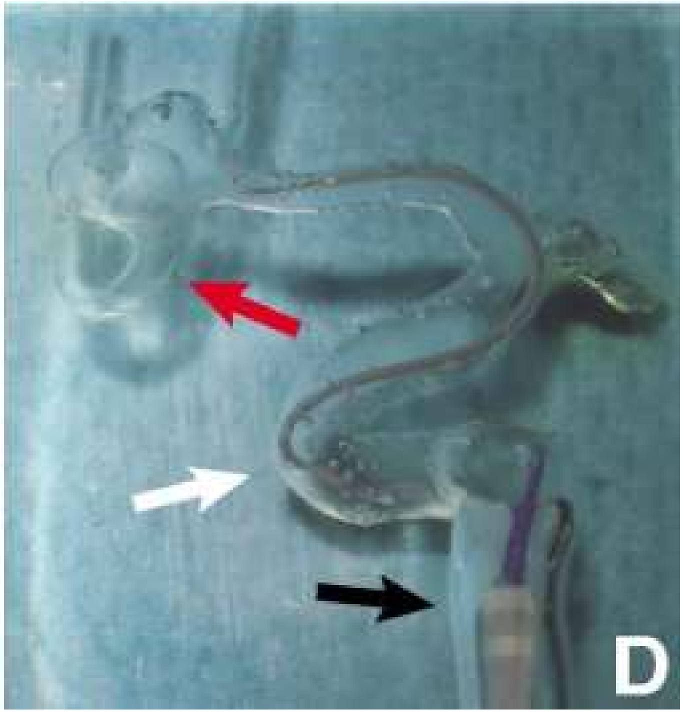


Figure 4: Catheter Placement

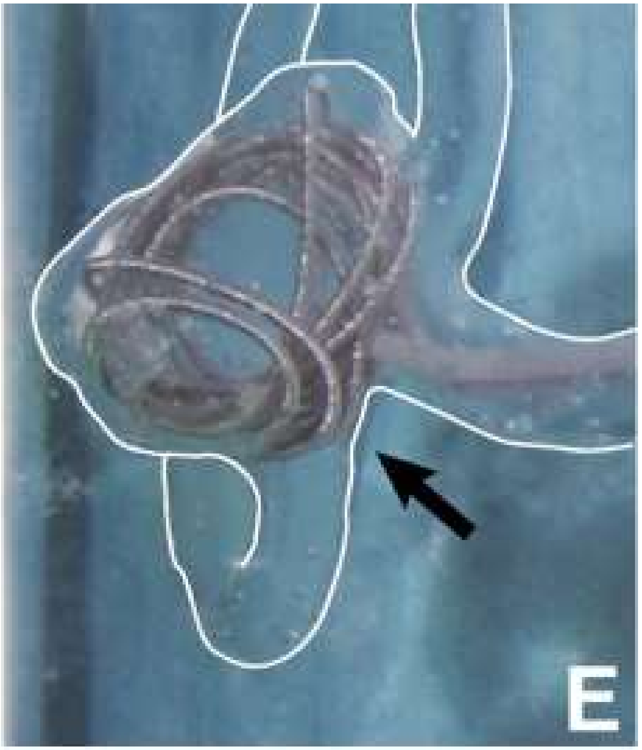


Figure 5: Coil Flow Diverter Placement

BACKGROUND AND BENCHMARKING

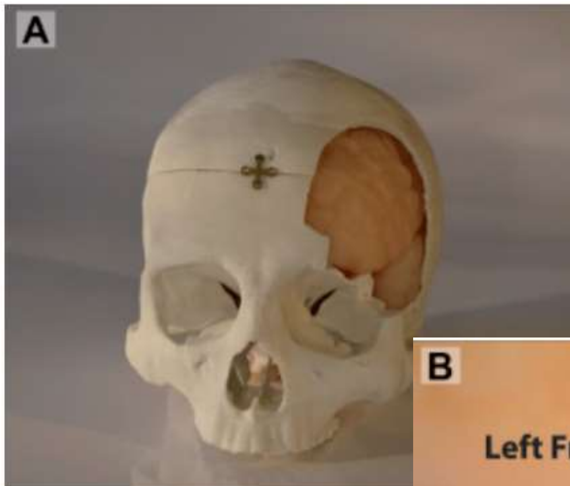


Figure 6: Skull Model

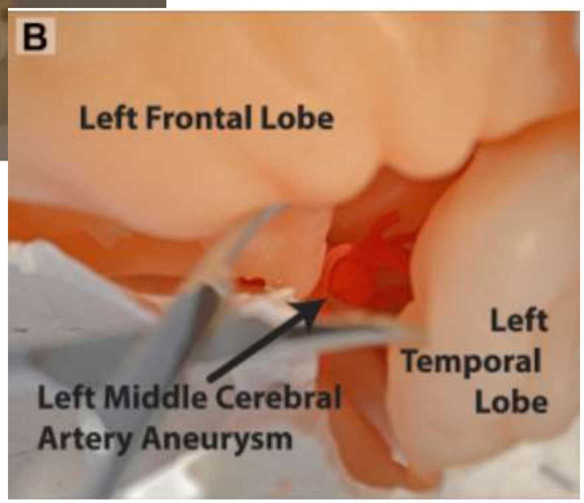
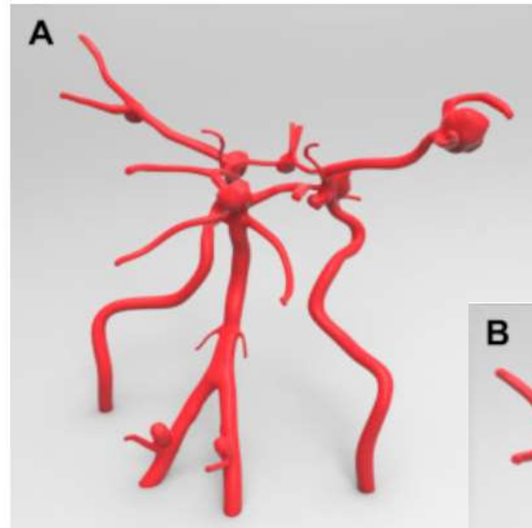
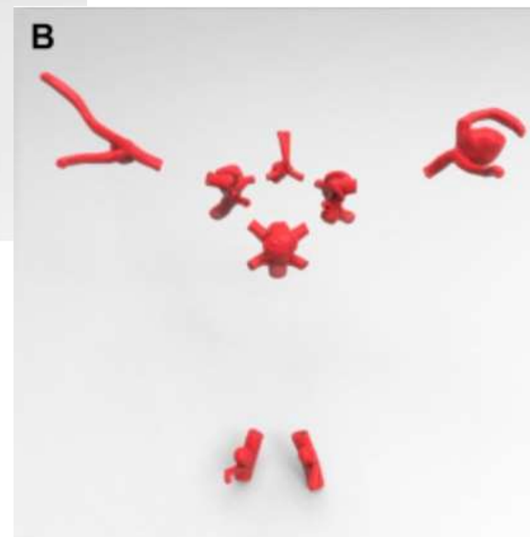


Figure 7: Clipping





Figures 8 & 9: Vessel and Aneurysm casts

BACKGROUND AND BENCHMARKING

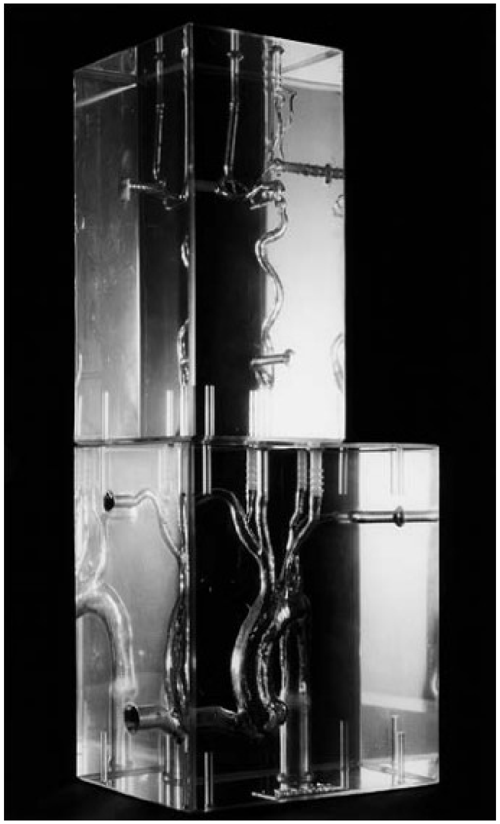
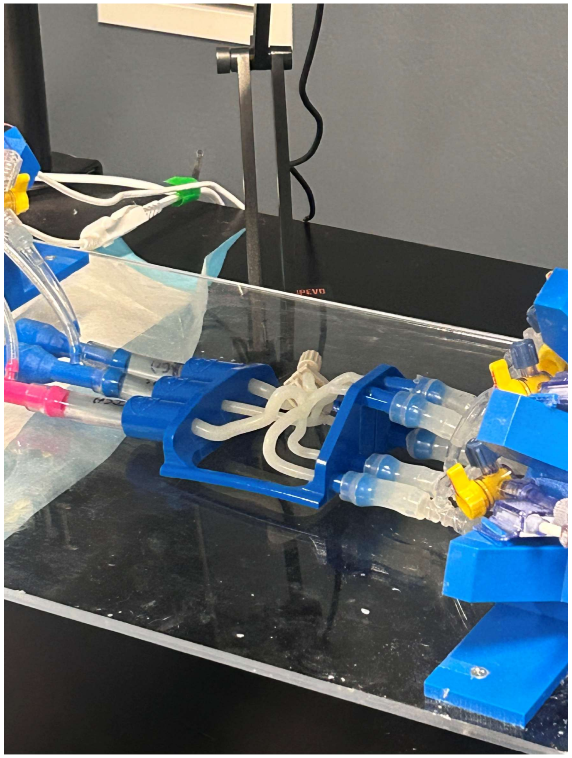


Figure 10: Hard Model

Figure 11: Soft Model

BACKGROUND AND BENCHMARKING



CUSTOMER AND ENGINEERING REQUIREMENTS

Customer Requirements

- Cost
  - Budget of $1000
- Predictability of Rupture
  - See-through
  - Inlet and outlet for data collection
- Idealized Model
  - Easily Measured
- Patient Models
- Low Labor
  - Easy to produce and clean
- Multiple Iterations
- Complete Products by 12/15

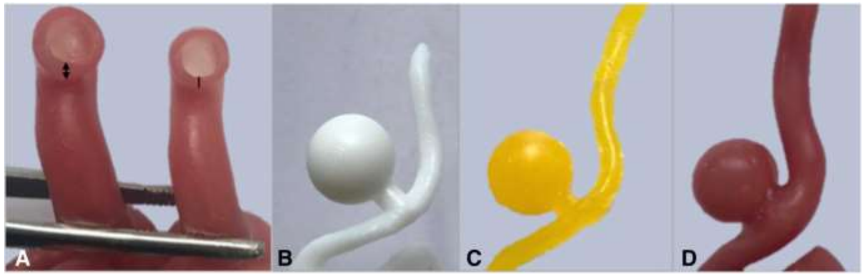


Figure 13: Patient Specific (Left) and Wax Casted Idealized (Right) aneurysm models [13]

CUSTOMER AND ENGINEERING REQUIREMENTS

Engineering Requirements

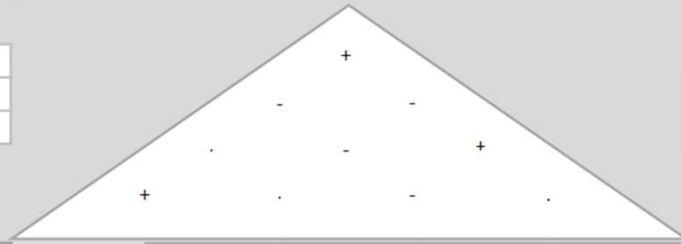
- Dimensional Accuracy
  - Within 0.15mm for small (<5mm)
  - Within 0.25mm for medium (5-10mm)
  - Within 0.35mm for large (10-25mm)
  - Within 0.4mm for giant (>25mm)
- Repeatability
  - Model consistency
- Material Similarity to Human
  - Wax casting vs Resin Printing
- Material Cost and Availability
- Easy to Manufacture

Figure 14: Example of a Resin 8k Printer Provided by Dr. Dou's Lab

PROJECT QFD

Quality Function Deployment

Project title: Aneurysm Rupture Model
Project leader: Anna Mellin
Date: 9/7/24-5/12/25



Correlation:

+	.	-
Positive	`	Negative

Relationships:

9	3	1
Strong	Moderate	Weak

	1: low, 5: high Customer importance rating	Desired direction of improvement (↑,0,↓) Functional Requirements (How's) Customer Requirements - (What's) ↓	Dimensional Accuracy of Model	Repeatability of Tests	Material Similarity to Human Blood Vessel	Cost of Materials	Ease of Construction	Weighted Score
		Desired direction of improvement (↑,0,↓)	↑	↑	0	↓	↑	
1	1	Cost	9	3	9	9	3	33
2	5	Predictability of Rupture	9	3	3	1		80
3	5	Standardized Idealized Model	3	9		1		65
4	4	Patient Model	9	3	9	9	3	132
5	3	Low Labor Vessels					3	9
6	4	Multiple Iterations of Vessel		3		3	9	60
7	5	Completed Model by 12/15	9	9	9	1	3	155
		Technical importance score	150	132	105	72	75	534
		Importance %	28%	25%	20%	13%	14%	100%
		Priorities rank	**1**	**2**	**3**	**5**	**4**	

Figure 15: Project QFD

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LITERATURE REVIEW

- Flow Simulation in Intracranial Aneurysms [1]

This source provided sketches and pictures of existing flow simulators as well as a detailed description of the effects of an aneurysm rupture on the cardiovascular system.

- Computational Fluid Dynamics in Brain Aneurysm [2]

This source discusses the two types of brain aneurysms, saccular and fusiform, and provides information on the fluid dynamic equations for each of the types. The source also mentions the use of patient specific CFD models in order to assess if a patient has a higher risk of developing a brain aneurysm.

- Engineering additive manufacturing and molding techniques to create lifelike willis circle simulators with aneurysms for training neurosurgeons [3]

This source describes the method of using 3D printing as a way to create a willis circle that is has lifelike dimensions and elasticity while also being clear in order to help train neurosurgeons.

Slide 14

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Anna Fuling Mellin, 2024-09-14T21:58:58.091

LITERATURE REVIEW

- "Brain aneurysm - Symptoms and causes" - *Mayo Clinic* [8]

Provides information on what a brain aneurysm is.

- "Endovascular Coiling" - *John Hopkins Medicine* [4]

Provides information on a technique used to prevent aneurysm rupture.

- *Rapid Manufacturing An Industrial Revolution for the Digital Age* [9]

Provides guideline for additive manufacturing.

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LITERATURE REVIEW

- Advanced 3D printed model of middle cerebral artery aneurysms for neurosurgery simulation [13]

This article depicts a simple wax-casting method to create a vascular model with a defined aneurysm neck w/ evacuation points.

- Engineering a 3D human intracranial aneurysm model using liquid-assisted injection molding and tuned hydrogels [14]

This study developed a three-dimensional intracranial aneurysm model using a modified liquid-assisted injection molding technique with Gelatin Methacryloyl hydrogel.

- Definitions of intracranial aneurysm size and morphology [15]

Discusses the differences in standard sizing for aneurysm models, agreeing that the Japanese standard should be followed, and wide neck aneurysms are standard for evaluation.

Slide 16

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Anna Fuling Mellin, 2024-09-14T21:58:58.091

MATHEMATICAL MODEL

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

$$\rho\left[\frac{\partial u}{\partial t}+\frac{\partial u}{\partial x}u+\frac{\partial u}{\partial y}v+\frac{\partial u}{\partial z}w\right]=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+\rho g_x$$

$$\rho\left[\frac{\partial v}{\partial t}+\frac{\partial v}{\partial x}u+\frac{\partial v}{\partial y}v+\frac{\partial v}{\partial z}w\right]=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+\rho g_y$$

$$\rho\left[\frac{\partial w}{\partial t}+\frac{\partial w}{\partial x}u+\frac{\partial w}{\partial y}v+\frac{\partial w}{\partial z}w\right]=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+\rho g_z$$

Equation 1: Navier-Stokes [10]

Computational Fluid Dynamics & Finite Element Analysis (SolidWorks or LabVIEW)

Figure 15: Vascular Model Repository [12]
0199_H_CERE_CA

MATHEMATICAL MODEL

Power for Pump

$$P = \frac{Q\rho g h}{\eta_t}$$

Equation 2: Pump Power

P = power
Q = flow rate
g = gravity
h = head of the pump
ρ = density of fluid
η = efficiency

MATHEMATICAL MODEL

- Mean Arterial Pressure

$$MAP = \frac{SBP + 2 \times HBP}{3}$$

SBP = Systolic Blood Pressure
DBP = Diastolic Blood Pressure

Type 2 Hypertension: $\frac{SBP}{HBP} = \frac{140}{90} > \frac{140+2\times 90}{3} = 106.67mmHg$

$$P_1 = 15mmHg\ (Static\ Pressure\ from\ Brain)$$

$$S = 0.192mm\ (Aneurysm\ Tube\ Diameter)$$

$$V_1 = 8.3ml\ (Per\ pump, based\ on\ Becker\ setup\ of 0.5\frac{L}{min}$$

$$\rho = 1$$

$$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2$$

$$V_2 = 0:\ blood\ flow\ near\ top\ of\ aneurysm\ stagnates$$

$$h_2 = 0: Start\ and\ end\ height\ the\ same$$

$$15mmHg + \frac{1}{2}(\frac{MAP}{Rv \times \pi * r^2})^2 = P_2$$

$$P_2 = 49.445mmHg = 6592.106Pa$$

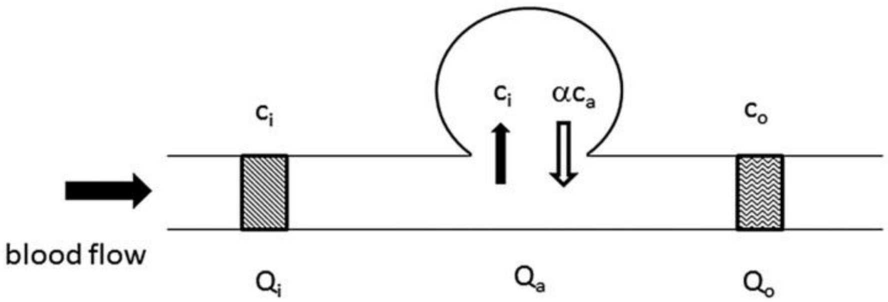

Figure 15: Idealized Blood Flow

ANEURYSM GEOMETRY

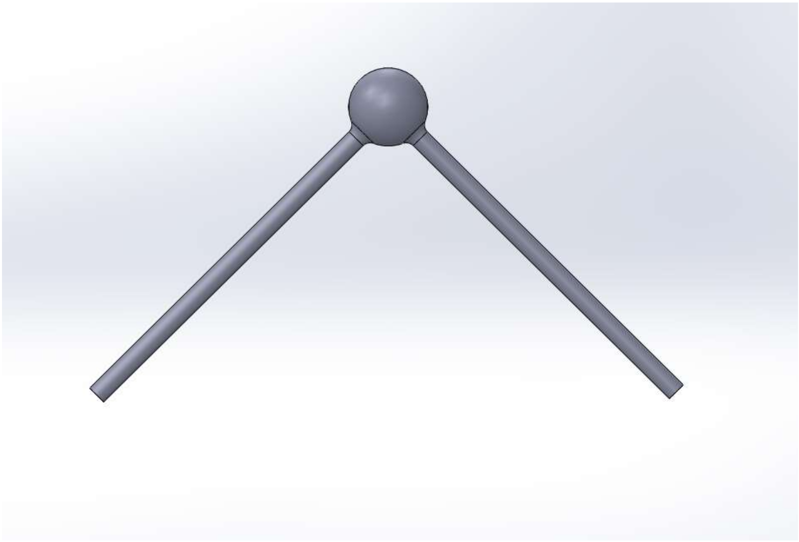
Figure 16: Ideal Model


Figure 17: Patient Specific Model

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[2] D. M. Sforza, C. M. Putman, and J. R. Cebral, “Computational fluid dynamics in brain aneurysms,” *International journal for numerical methods in biomedical engineering*, vol. 28, no. 6–7, pp. 801–808, 2012, doi: 10.1002/cnm.1481.

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THANK YOU

NAU NORTHERN ARIZONA UNIVERSITY