Aneurysm Rupture Team F24toSP25_02

Anna Mellin
Amanda Ortiz-Velazquez
Caden Adams
NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

Project Description

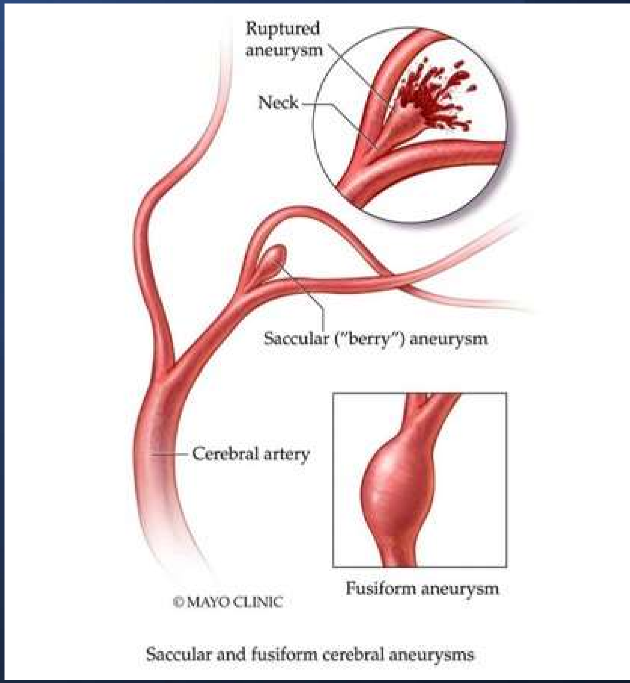
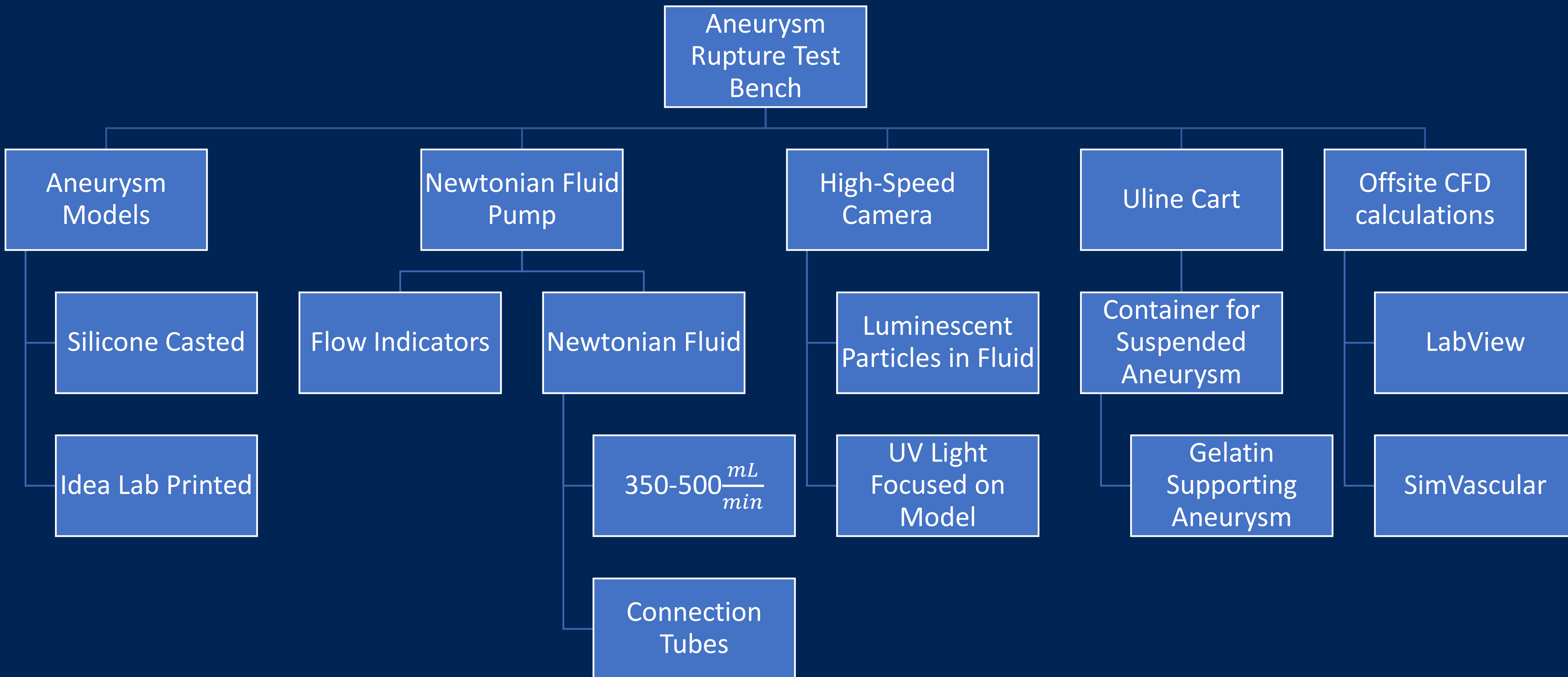


Figure 1: Aneurysm model [Mayo Clinic]

- Background:
  - Forms from a weakening of arterial walls
  - Pressure + weak walls = ballooning in the walls and aneurysm formation
    - Aneurysm rupture >> Hemorrhagic stroke >> **DEATH**
- Overview:
  - Model an aneurysm rupture using various manufacturing methods
- Currently working on:
  - Designing the geometry for the molds, the cores, and the hollow bodies
- Sponsored by: Dr. Zhongwang Dou


Aneurysm Rupture Test Bench
Aneurysm Models
Silicone Casted
Idea Lab Printed
Newtonian Fluid Pump
Flow Indicators
Newtonian Fluid
350-500$\frac{mL}{min}$
Connection Tubes
High-Speed Camera
Luminescent Particles in Fluid
UV Light Focused on Model
Uline Cart
Container for Suspended Aneurysm
Gelatin Supporting Aneurysm
Offsite CFD calculations
LabView
SimVascular

Concept Generations for the Support System

- Team needed to create a way to make sure that parts would not move inside mold

Figure 2: Support Concepts

Idea 1: No supports
Idea 2: Cylinder supports at the end
Idea 3: Cylinder supports along structure
Idea 4: Square supports at end of structure

A Ortiz-Velazquez

Concept Generations for the Support System

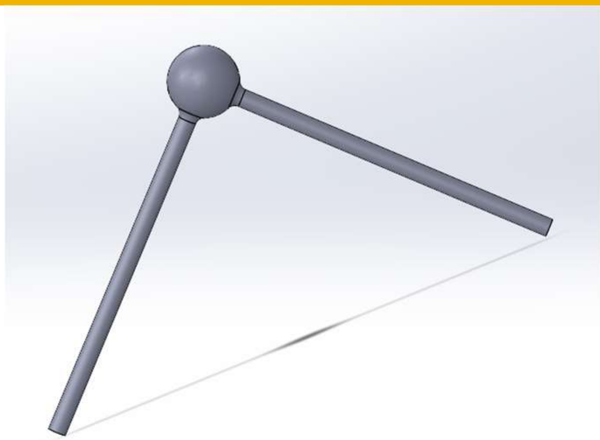


Figure 3: No Support

Advantages	Disadvantages
•Low production cost	•No support
•Easy to design	•Would move inside mold
	•Silicone would leak out

Figure 4: Cylindrical Supports

Advantages	Disadvantages
•Less use of material	•Silicone would leak out
	•Does not provide stable support

A Ortiz-Velazquez

Concept Generations for the Support System

Figure 5: Cylindrical Supports along Structure

Advantages	Disadvantages
•Provides support throughout structure	•Would create holes in silicone that would need to be filled
	•Silicone would leak out
	•More time consuming to design and print

Figure 6: Square Supports

Advantages	Disadvantages
•No silicone leaks out	•Utilizes more material
•Simples to design	•Increased cost
•Will provide adequate support	

A Ortiz-Velazquez

Concept Generations for the Negative Mold

- General Requirements: create the inverse of the core with a tolerance of 0.75 mm between the core and the negative.

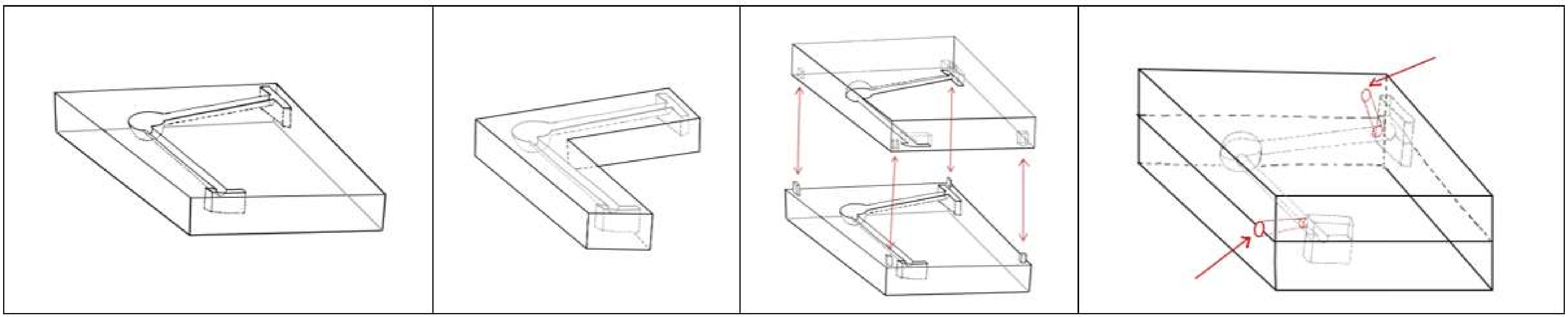


Figure 7: Negative Mold Concepts

Idea 1: Basic square negative, unshown half is mirrored
Idea 2: Negative without excess, unshown half is mirrored
Idea 3: With keys, male and female parts indicated by red arrows
Idea 4: With holes for silicone injection, indicated by red arrows

Concept Generations for the Negative Mold

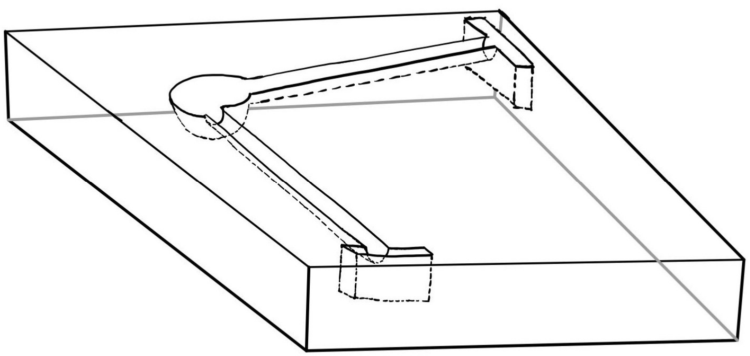


Figure 8: Basic Square Mold

Advantages	Disadvantages
• Sturdy • Simple	• Lots of material • Parts can slide

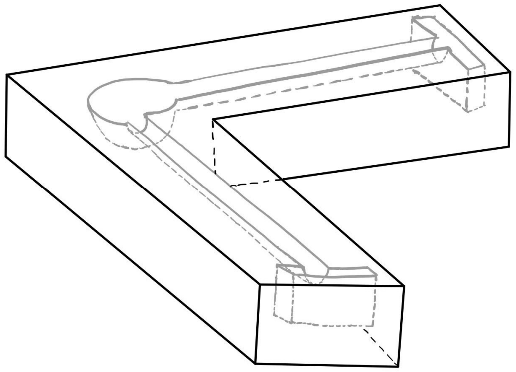


Figure 9: Mold with excess removed

Advantages	Disadvantages
• Less material • Still relatively simple	• Smaller surface area for clamp • Parts can slide

Concept Generations for the Negative Mold

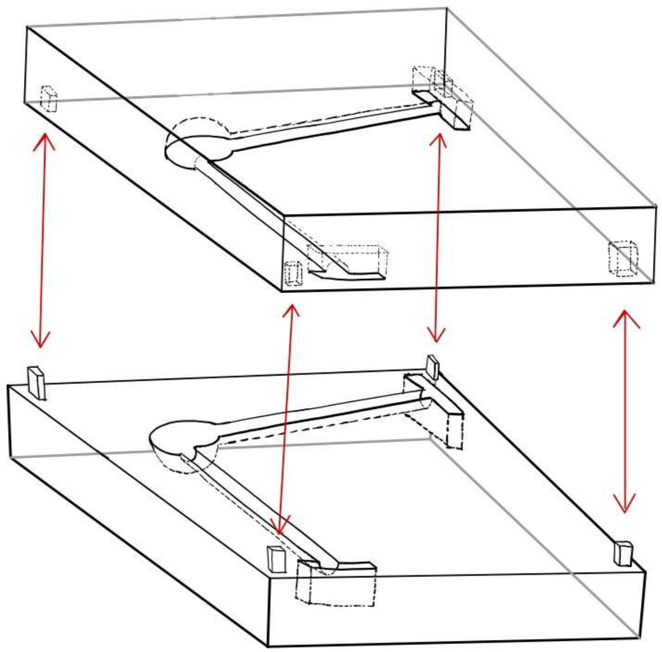


Figure 10: Mold with keys

Advantages	Disadvantages
• Sturdy • Parts will stay aligned	• Tolerances for keys must be considered • More difficult to separate after silicone has dried

Concept Generations for the Negative Mold

Advantages	Disadvantages
• Less silicone leakage	• Harder to apply silicone evenly • Silicone tubes will have to be cut off of the end result making a smaller leg

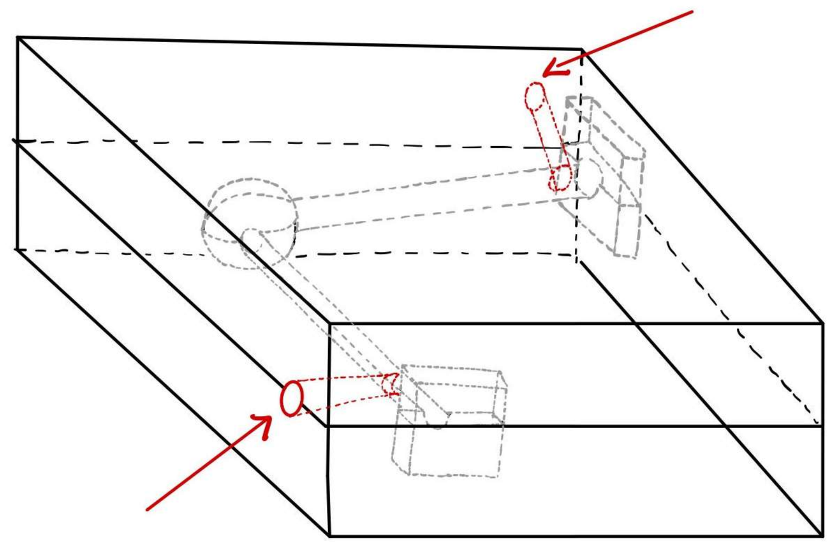
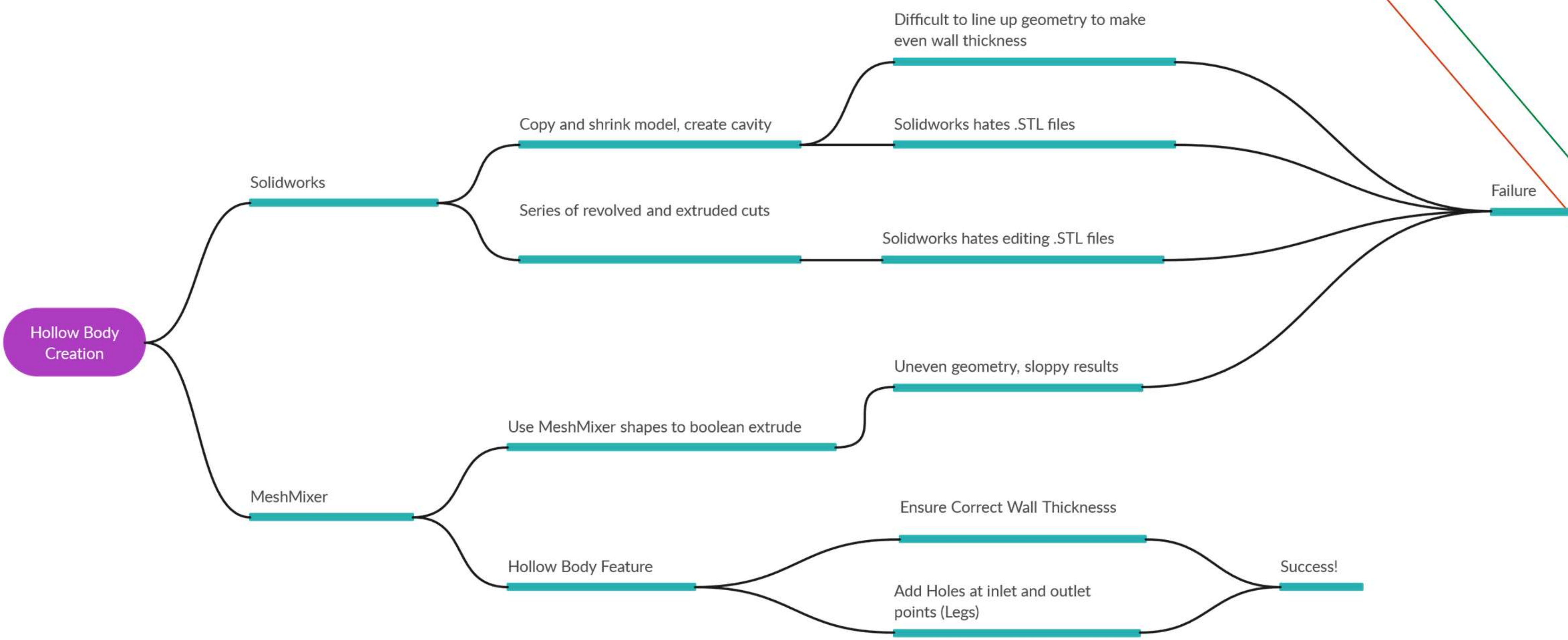


Figure 11: Mold with silicone injection holes

Concept Generations for the Hollow Core (Patient Specific)



C Adams

Concept Generations (Idea 1)

Advantages	Disadvantages
• Solidworks is fun	• Solidworks makes joining STL files a pain. • Direct Editing does not work

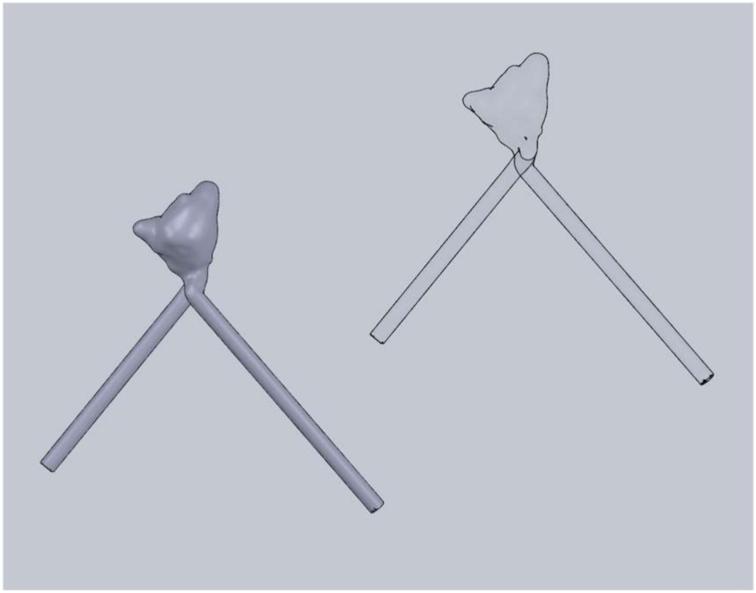


Figure 12: SolidWorks concept w/ 0.75 scaled down model (Right)

Concept Generations (Idea 2)

Advantages	Disadvantages
• N/A	• Look at this thing. • What was I thinking.

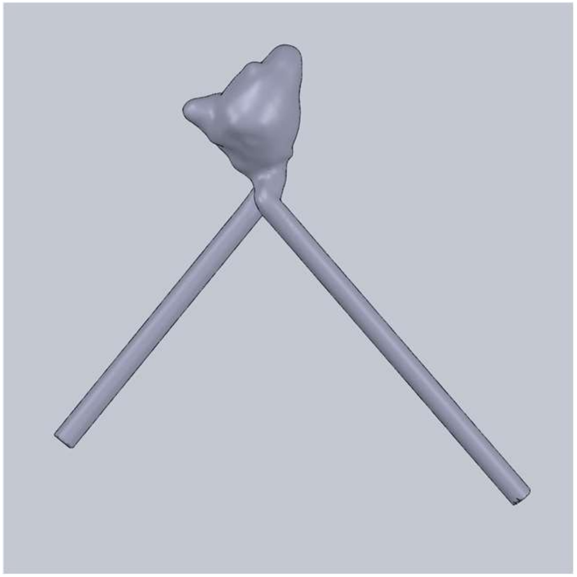


Figure 13: Solidworks 3D render of difficult geometry

Concept Generations (Idea 3)

Advantages	Disadvantages
• MeshMixer subtraction is easy and repeatable.	• There isn't a meshmixer shape or series of shapes long enough or precise enough to cut through aneurysm and legs.

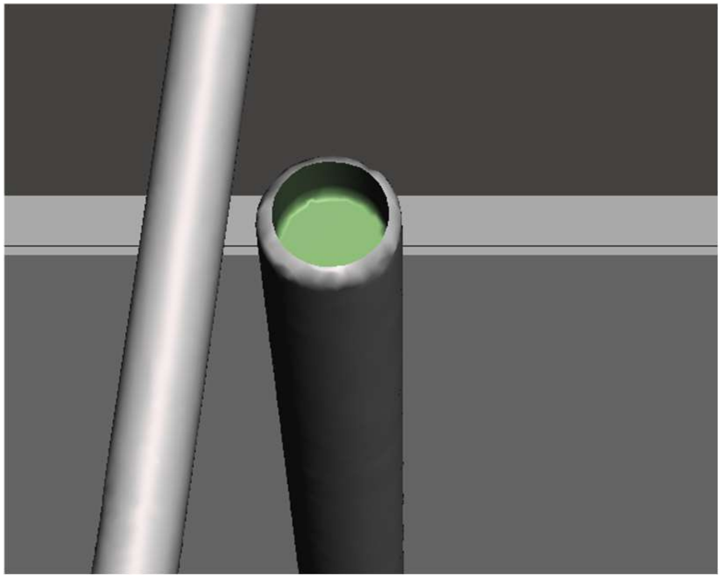


Figure 14: MeshMixer demonstration of lack of depth

Concept Generations (Idea 4)

Advantages	Disadvantages
• MeshMixer does all the work • Set offset distance (accurate)	• Doesn't clear the inlet/outlet

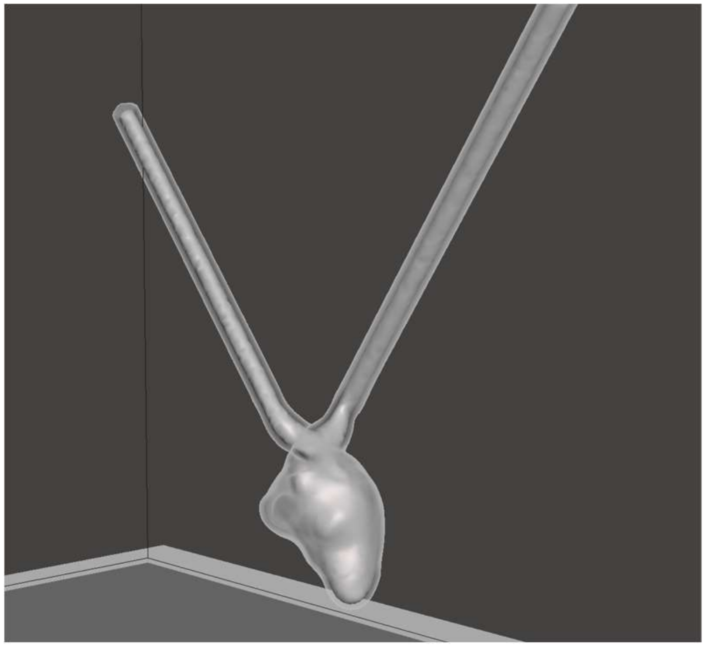


Figure 14: Hollow body (dark gray) inside 3D render (translucent)

Concept Evaluation

Criteria	Weight	No supports	Cylinder Support	Cylinder supports along structure	Square supports
Cost	4	0	-	--	-
Simplicity	2	0	-	--	-
User Friendly	3	0	0	-	0
Reusability	5	0	0	0	0
Precision	5	0	0	--	++
Effectiveness	5	0	0	-	++
Plus			0	0	2
Minus			2	5	2
Zero			5	2	2
			-2	-5	0

Figure 15: Support Evaluation

Criteria	Weight	Basic Square	Excess removed	With keys	Silicone injection holes
Cost	4	0	++	-	+
Simplicity	2	0	+	-	-
User Friendly	3	0	0	+	-
Reusability	5	0	0	0	0
Precision	5	0	0	+	0
Effectiveness	5	0	0	0	0
Plus			2	2	1
Minus			0	2	2
Zero			4	2	3
			2	0	-1

Figure 16: Negative Evaluation

Engineering Calculations

Noyes-Whitney Equation

$$\frac{dM}{dt} = \frac{D \times A \times (C_s - C)}{L}$$

DM/dt = rate of mass dissolved per unit time
D = diffusion coefficient
A = Surface area
Cs = saturation concentration
C = concentration of solute in solvent at time
L = thickness of boundary layer

- Assuming diffusion coefficient of $D \approx 1\times10{-}9 m2/s$ and saturation concentration of 0.1 g/mL, it would take approximately 40 hours for resin prints to completely dissolve in water

A Ortiz-Velazquez

Engineering Calculations

Laplace's Law

Wall tension: $T = \frac{PR}{2}$ [2]

- $T = \frac{13333.52Pa \times 0.010m}{2} = 66.67Pa \times m$

T = tension
P = internal pressure
R = radius

Wall Stress: $\sigma = \frac{Pr}{2w}$ [3]

- $\sigma = \frac{13333.52Pa \times 0.010m}{2(0.0075m)}$
- $\sigma = 4444.51Pa$

P = internal pressure
r = radius
w = wall thickness

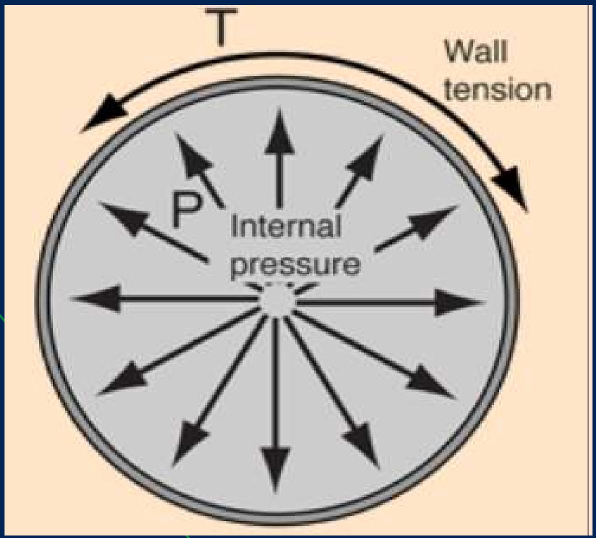


Figure 17: Laplace's Law for a sphere

Engineering Calculations

Poiseuille Flow (assuming laminar flow):

$$\tau_w = \frac{4\mu Q}{\pi R^3}$$

- μ = Dynamic Viscosity (of fluid $Pa * s$)
- Q = Volumetric flow rate of blood ($\frac{m^3}{s}$) = 342$\frac{mL}{min}$
- R = Blood Vessel Radius (m)

$$\tau_w = \frac{4 \times 0.0035 \text{ Pa·s} \times 5.713 \times 10^{-6} \frac{m^3}{s}}{\pi \times (0.005195m)^3}$$

$$\tau_w = 0.182\ Pa$$

- Areas with low shear stress ($\tau_w < 0.4\text{Pa}$) are more prone to enlargement and potential rupture.

1

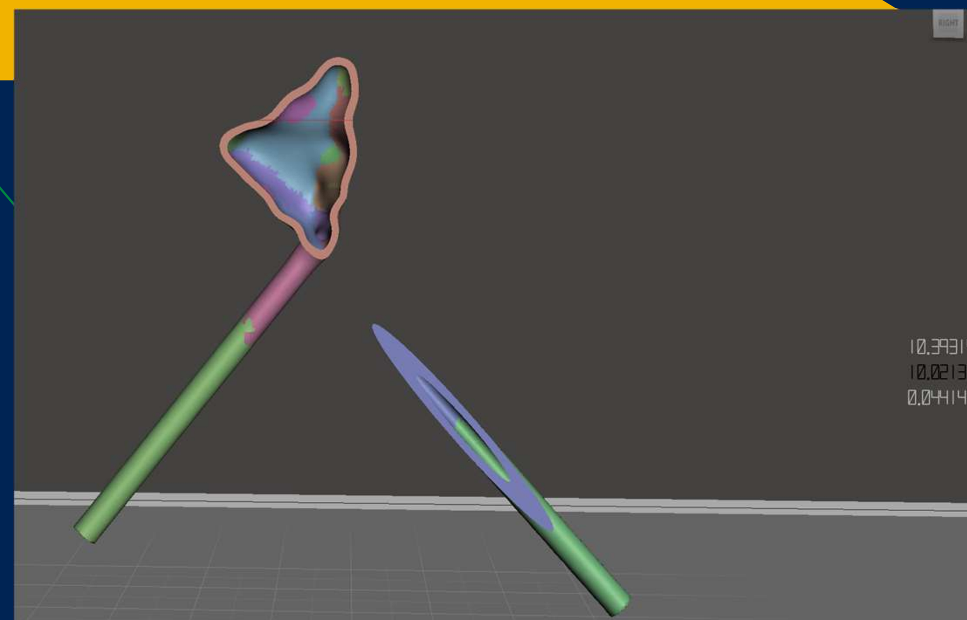


Figure 18: Cross section of Patient Specific aneurysm to find diameter

SimVascular

- Simulation program useful for mapping and measuring blood flow.
- Will be useful to do hemodynamic calculations involving velocity gradients and vectors once program is fully set up and running.
- Program also works for MRI scan files.
  - Useful for directly mapping and measuring flow from patient aneurysms for quick risk diagnosis turnaround.

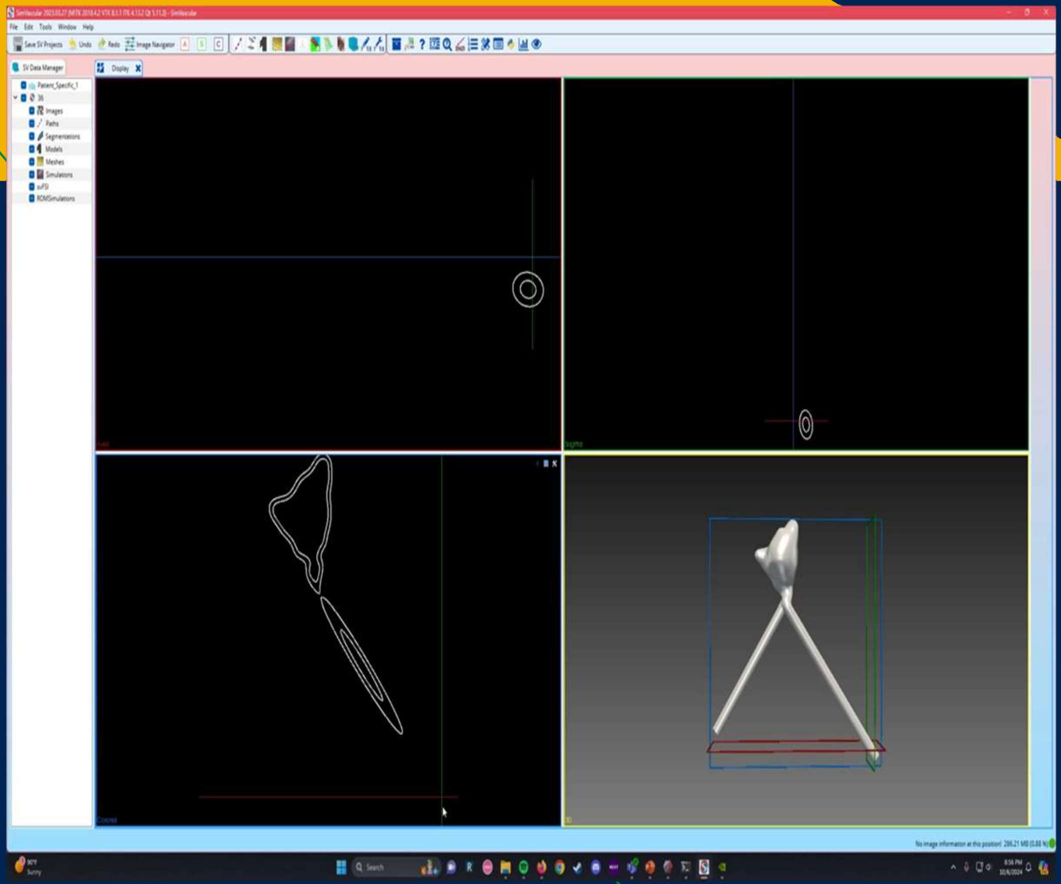


Figure 19: SimVascular Screen

C Adams

Schedule

Cerebral Aneurysm Rupture Project Schedule

Northern Arizona University Team F24toS25_02

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	Sun 11/10/24	35	60%	43
1.1.1	Obtain Core Models		Wed 9/11/24	Wed 9/18/24	7	100%	6
1.1.2	Add supports to models		Thu 9/19/24	Tue 9/24/24	5	100%	4
1.1.3	Create model negatives		Thu 9/19/24	Tue 9/24/24	5	70%	4
1.2	Perfect Casting model and rapid produce		Mon 11/11/24	Wed 1/08/25	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	100%	1
1.5	Develop 3D Printed model		Thu 9/26/24	Tue 10/15/24	20	60%	14
1.5.1	Create Hollow Model		Thu 9/19/24	Tue 9/24/24	5	100%	4
1.6	Perfect 3D Printed model		Tue 10/15/24	Thu 12/12/24	59	10%	43

Figure 20: Gantt Chart Additions

A Mellin

Budget

Budget	$1,000
Fundraising Needed	$100
Fundraising Obtained	$771.25
Expenses	$150
Total	$850

Figure 21: Budget

Donation	From Who	Amount
3D Printer	Dr.Dou (Pheatt Award)	$271.25
Pump	Dr.Dou	$500
Total		$771.25

Figure 22: Donations

Expected Future Expenses	$370
Total Left For Budget After Expected Expenses	$480

Figure 23: Expected Future Expenses

- Total does not include donated material
- Future expenses are estimations for future 3D prints as well as a cart purchase

A Ortiz-Velazquez

BoM

BOM Level	Part Name	Unit Cost	Quantity	Total Cost
1	Water Soluable Resin	$0.75/G of material	50G per iteration for vessels, 150G per iteration for molds	$150 per iteration
2	Soft material print from idea lab	$31.35	2	$62.70
3	Silicone	$500	1	$500
				712.7

Figure 24: Bill of Materials

C Adams

THANK YOU

References

[1] J. X. Lu, “Biochemistry, dissolution and solubility,” StatPearls [Internet]., https://www.ncbi.nlm.nih.gov/books/NBK431100/ (accessed Oct. 6, 2024).

[2] R. Nave, “Pressure,” *hyperphysics.phy-astr.gsu.edu*.

[3] E. Debevec-McKenney and S. Ladhani, “Law of Laplace: Video, Anatomy, Definition & Function | Osmosis,” *osmosis.org*. Aug. 14, 2019.

[4] “SimVascular,” *simvascular.github.io*.

[5] The Engineering Toolbox, “Dynamic Viscosity of common Liquids,” *Engineeringtoolbox.com*, 2019.

[6] F. M. White, *Fluid Mechanics*, 7th ed. McGraw Hill, 2011.