Model for Pre-Surgical Intracerebral Hemorrhage Planning

Client: Dr. Walter Block

Advisor: Dr. Paul Campagnola

Team members: Joe Kerwin, Payton Parmett, Alex Truettner, Evan Ryser, Kurt Vanderheyden

Overview

- Problem Statement
- Background and Prior Work
- PDS
- Design Alternatives
- Design Matrix
- Future Work: Stages 1-4
- References
- Acknowledgements

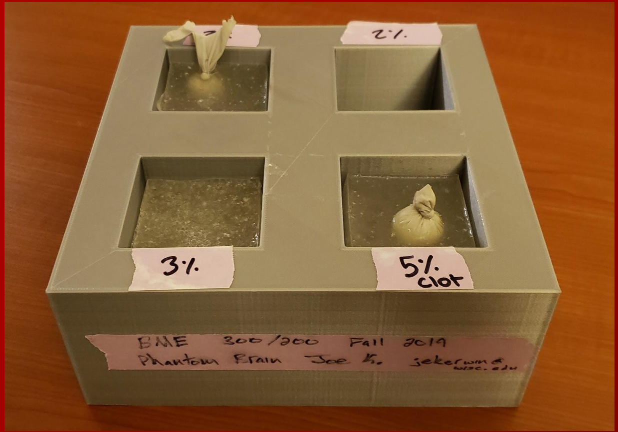
Problem Statement

- In the past, very little could be done for patients with intracerebral hemorrhaging
- Recent efforts being made to remove as much clot as possible to prevent damage
- Characteristics of different clots vary - differences in rigidity affect removal approach
- Research being done to map rigidity of clots before operation

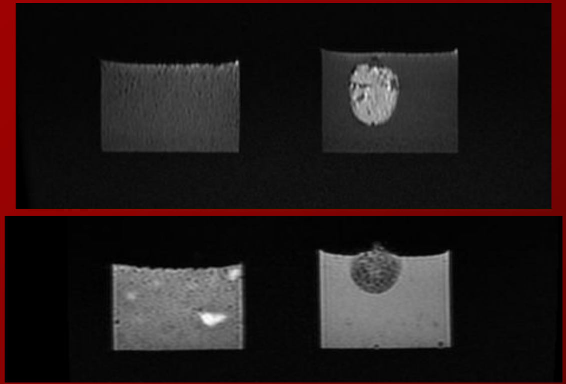
Goal is to create a gel model to simulate interior of brain with various clots to image and validate the effectiveness of mapping techniques

Background

- Recently two methods to remove cerebral clots have been developed
- The method used is dependent upon the stiffness of the clots
  - Suction
  - Drug treatment then suction
- A phantom brain is needed to acquire a range of stiffness measurements to be used in a database
- First semester
  - Gel making protocol
  - Proof of concept completed



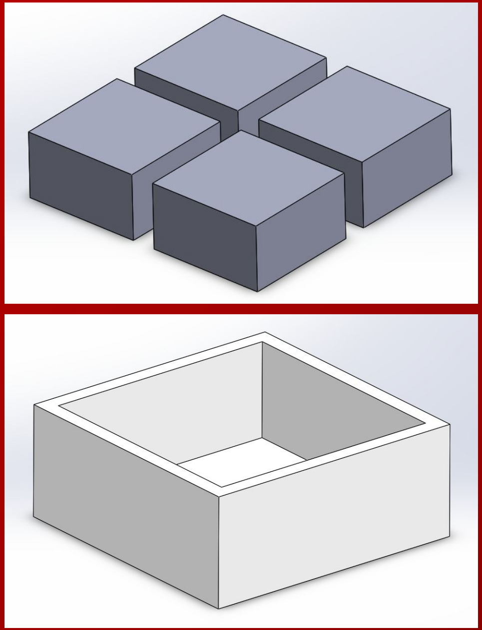
Sample Holder from Fall 2019

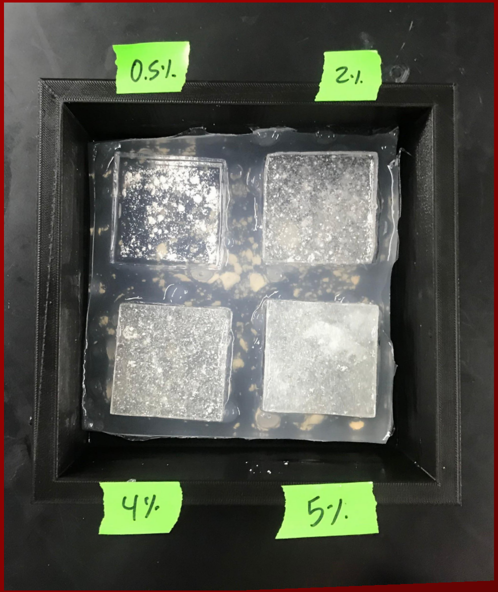


T1 and T2 imaging results from Fall 2019

Prior Work - Stage 1 Updated Design

- Separate inserts to make holes for clots
- Testing resolution of MRI - clot stiffness range
- Stage 1 complete and dropped off to WIMR in March
- Ready for stage 2





Sample Holder from Spring 2020

PDS

- Final stiffness should be comparable to brain matter
- Size of “clots” must test the accuracy of MRI
- Must be resilient to handling and transport
- The phantom must be able to handle powerful magnetic fields (no metal)
- Must be sharp contrast between stiffnesses

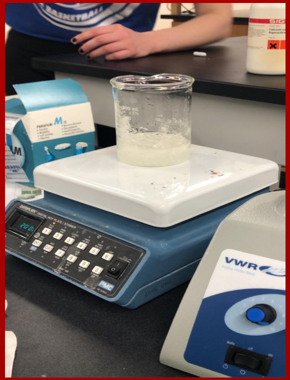
Biomaterial Decision

Criteria	Alginate		Agarose		Gelatin	
Ease of Fabrication (25)	4/5	20	4/5	20	5/5	25
Biomimicry (25)	5/5	25	4/5	20	2/5	10
Cost (15)	4/5	12	4/5	12	5/5	15
Duration (15)	2/5	6	3/5	9	1/5	3
Thermostability (10)	5/5	10	3/5	6	1/5	2
Safety (10)	4/5	8	4/5	8	5/5	10
Total (100)	81		75		65	

Gel Fabrication Protocol

Protocol:

1. Dissolve alginate in water
2. Add $CaCO_3$ and Glucono-δ-lactone
3. Mix gel thoroughly
4. Pour base gel evenly into the holder
5. Place “Clot Holders” into gel before it sets
6. Allow the base gel to set in a fridge
7. Remove “Clot Holders”
8. Repeat steps 1-3 for clot gels
9. Pour clot gels into the holder space
10. Allow clots to set in fridge
11. Repeat steps for a second base gel layer
12. Pour second base layer over top and allow time to set.

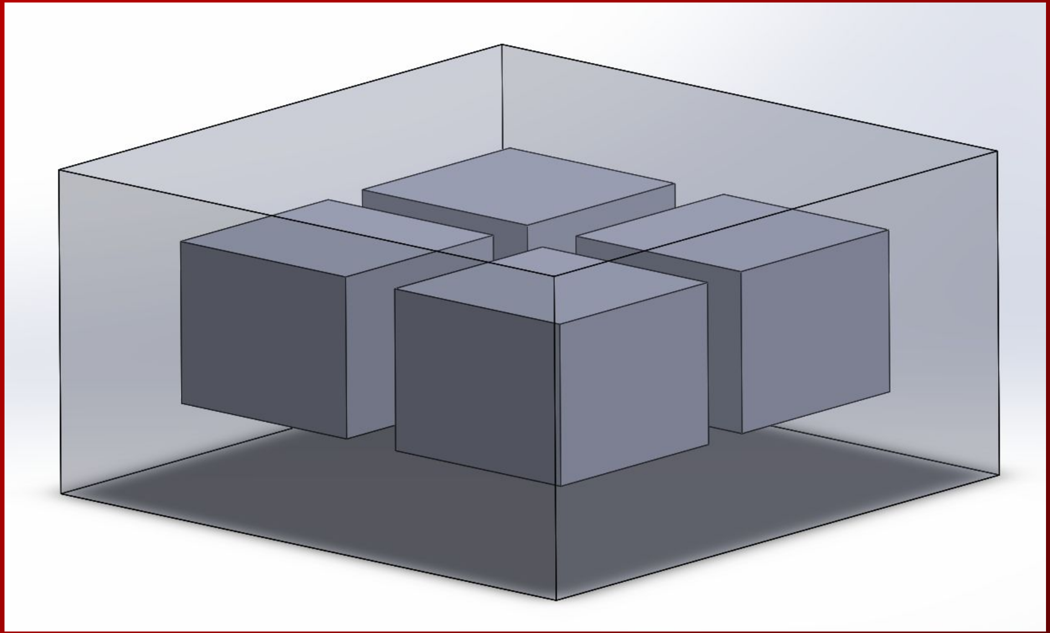


Dissolving alginate

Alginate powder being stirred

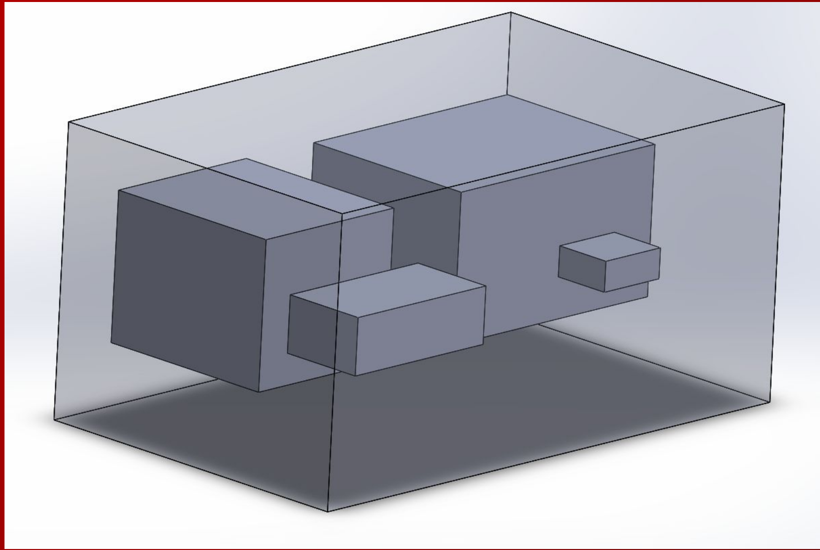
Current Work - Stage Two

- Same setup as previous work
- Refined range of varying “clot” rigidity
  - 0.5%, 2%, 4%, and 6% to compare imaging
  - Make smaller range: reference and 50%, 75%, 125% of optimal
- Goal is to find imaging threshold



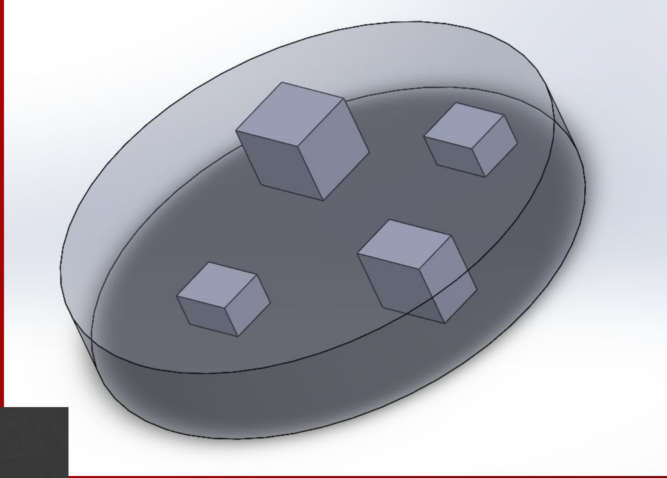
Future Work - Stage Three

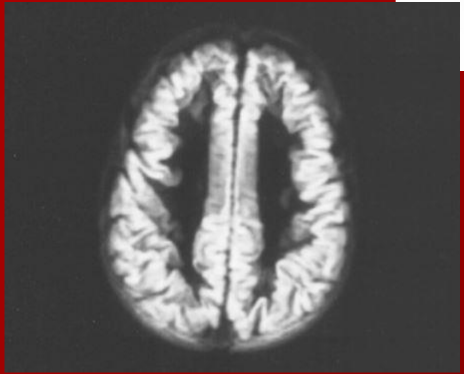
- Same setup as previous stages
- One "clot" rigidity - whatever was found to be threshold in stage two
- "Clots" of varying sizes
- Testing for smallest detectable "clot"



Future Work - Stage Four

- New sample holder - brain model
- Same constant threshold "clot" rigidity
- Different "brain" gels to model gray and white matter
  - Different depths of clots
  - Different sizes of clots

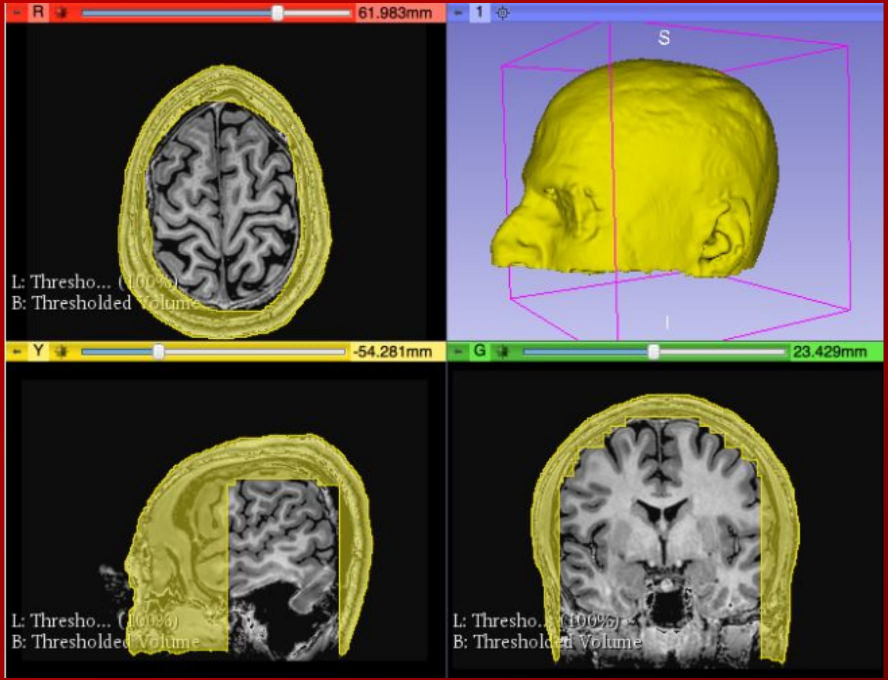




https://onlinelibrary.wiley.com/doi/full/10.1002/

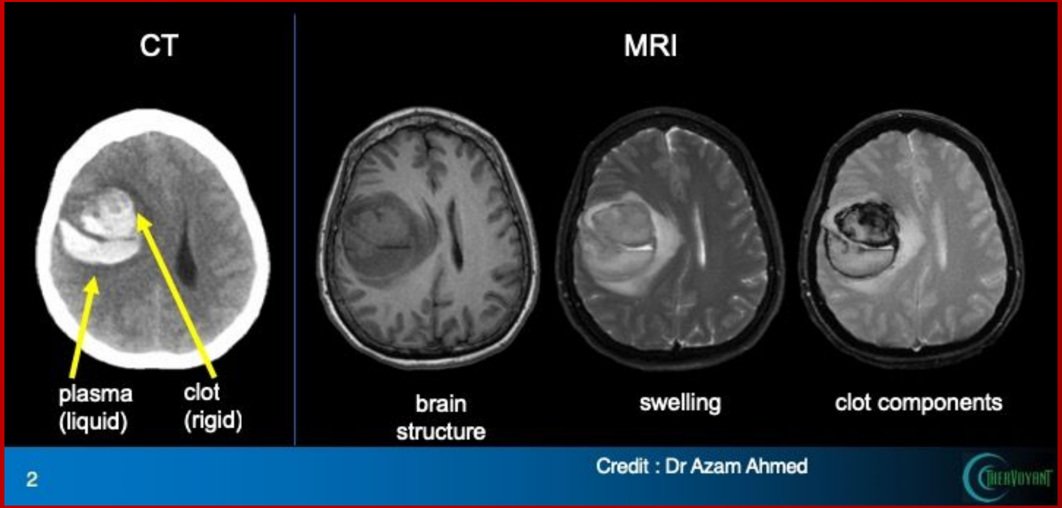
Future Work - Stage Four

- Create 3D print of brain from MRI data to make brain
    - Use brain as outer shell
- Put gels within the brain shell to explore different geometries
    - More realistic location and depth of clots

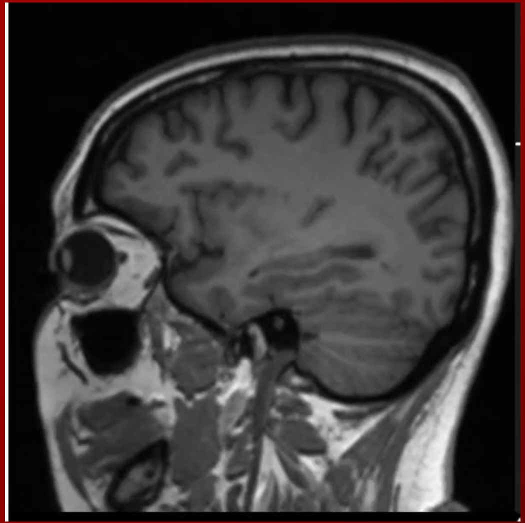


Future Work - Stage Five

- Explore geometric differences - air/fluid pocket
  - Sinuses, internal acoustic canal, CSF



https://news.wisc.edu/mr-guidance-next-frontier-in-hemorrhagic-stroke/



Case courtesy of Assoc Prof Craig Hacking, Radiopaedia.org, rID: 41613

Acknowledgements

Thank you for all of your guidance!

Dr. Walter Block

Dr. Paul Campagnola

<u>Previous advisors:</u>

- Dr. Kristyn Masters
- Dr. Aviad Hai
- Robert Moskwa

Dr. Puccinelli

The UW-Madison BME Department

References

[1] M. McLean, F. Woermann, G. Barker and J. Duncan, "Quantitative analysis of short echo time1H-MRSI of cerebral gray and white matter", *Magnetic Resonance in Medicine*, vol. 44, no. 3, pp. 401-411, 2000. Available: 10.1002/1522-2594(200009)44:3<401::aid-mrm10>3.0.co;2-w [Accessed 9 February 2020].

[2] Csun.edu. (2019). [online] Available at: http://www.csun.edu/~ll656883/lectures/lecture10.pdf [Accessed 3 Oct. 2019].

[3] Lee, K. and Mooney, D. (2019). *Alginate: Properties and biomedical applications*.

[4] Leibinger, A., Forte, A., Tan, Z., Oldfield, M., Beyrau, F., Dini, D. and Baena, F. (2014). *Soft Tissue Phantoms for Realistic Needle Insertion: A Comparative Study*. [online] NCBI. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4937066/ [Accessed 3 Oct. 2019].

[5] Martinez, J. and Jarosz, B. (2015). *3D perfused brain phantom for interstitial ultrasound thermal therapy and imaging: design, construction and characterization*. [online] IOPscience. Available at: https://iopscience.iop.org/article/10.1088/0031-9155/60/5/1879 [Accessed 3 Oct. 2019].