Model for Pre-Surgical Intracerebral Hemorrhage Planning

Alex Truettner, Joseph Kerwin, Payton Parmett, Kurt Vanderheyden
Client: Prof. Walter Block Advisor: Dr. Aviad Hai

Abstract

Intracerebral hemorrhaging (ICH) is an extremely dangerous condition that without intervention can ultimately lead to death. Recently, new methods have been developed for evacuating clots formed as a result of ICH. However, the stiffness of the brain clots can be very different from patient to patient, which complicates the decision of what method of evacuation to utilize. Professor Walter Block presented the team with the challenge of designing a brain phantom that will eventually be used to generate a database that allows neurosurgeons to compare MRE phantom images to MRE images of ICH patients. By comparing the patient's scan to the database of phantom images, the surgeon is able to determine the stiffness of the clot prior to surgery, and decide on the best method of evacuation. Other brain phantoms have been created, but none target ICH specifically or include a gel-gel interface. Our solution is to create an alginate phantom with "clots" inside of base gels to prove materials of different stiffness can be differentiated in MRE images.

Problem Definition

- Intracerebral hemorrhaging occurs when blood vessels burst in the brain, resulting in blood clots.
- Choosing a treatment for blood clot evacuation can be difficult because it is based on the material properties of the blood clot.
- Surgeons need a control that can be imaged with an MRI to create a standard of measurements that can be used to determine the surgical approach.
- A brain phantom database will be used by neurosurgeons to compare the MRI scans of the phantom with a scan of their patients' brains. The phantoms purpose is to illustrate the stiffness of the patient's clot.
- Our model seeks to create an environment where there are two alginate gels of known, different compositions. The gels will then be imaged by MRI and the difference in stiffnesses between the gels will be distinguishable.

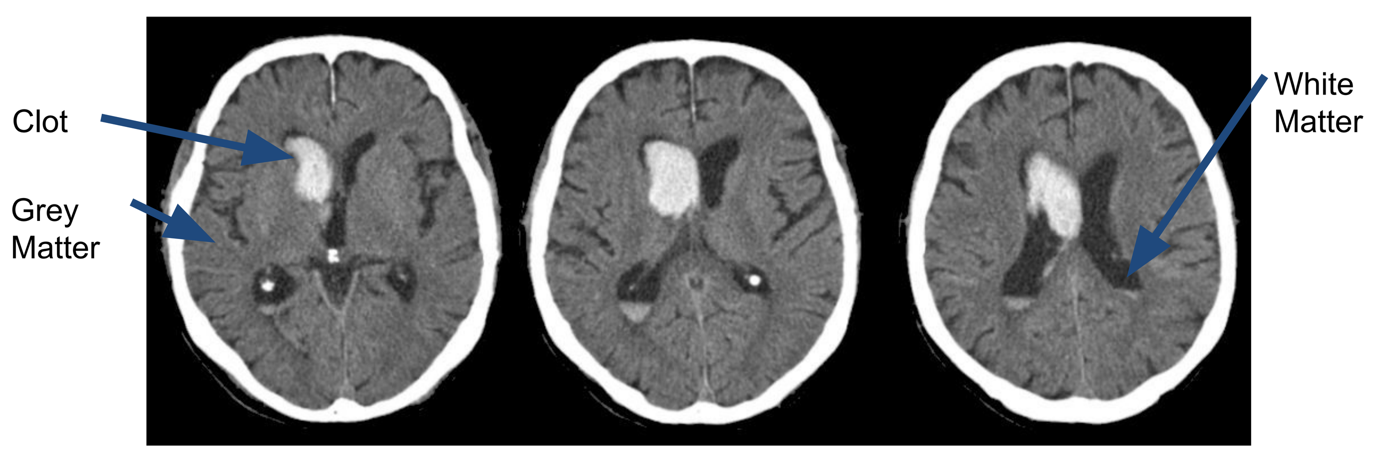

Figure 1.1 Intracerebral Hemorrhage MRI Scan [1]. The white mass in the image indicates a blood clot.

Final Sample Holder Design

- Simple design to allow for easy implementation of base gels as well as clot gels
- Clot gel suspended in base gel to avoid gel-air interface
  - Prevents distortion of MR images
- 3D printed with PLA gray
- 17 x 17 x 7 cm overall
- Four 5 x 5 x 5 cm cavities for samples

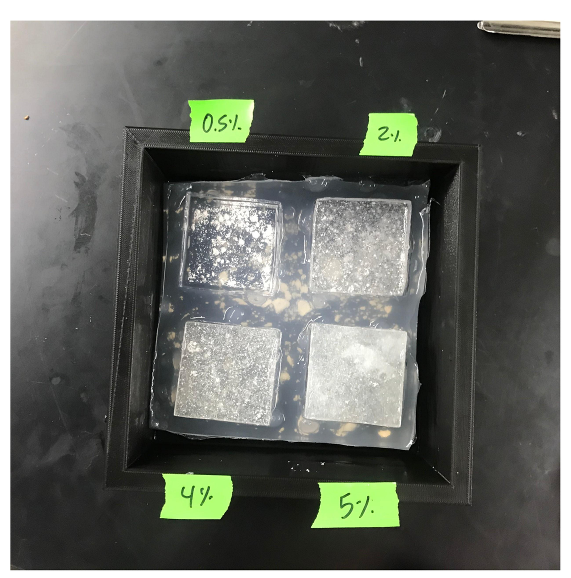

Figure 2.1 Sample holder containing three alginate gels samples

Imaging Timeline

Stages 1 and 2

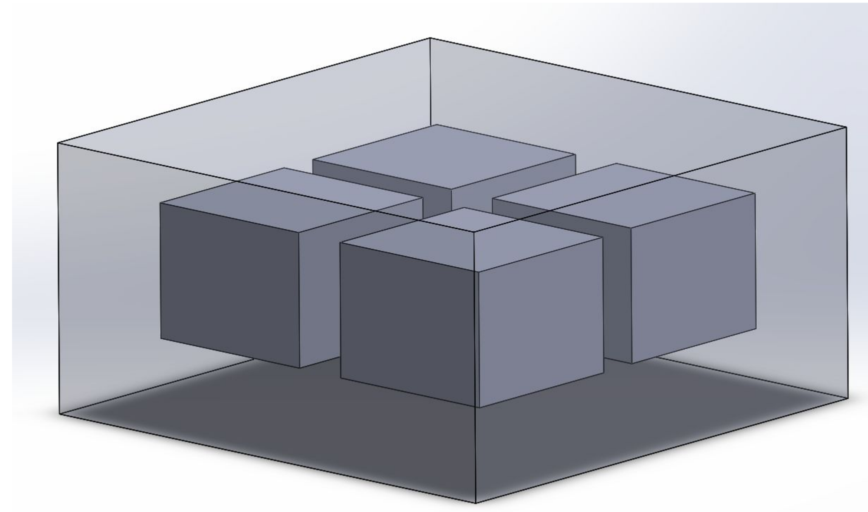

Figure 3.1 Sample holder containing different stiffness clots

- Stiffer alginate gels suspended in base gel
- "Clot gels" all the same size
- Both have the same gel sizes and specifications
- Stage 1 consists of a wide range of gel rigidities
- The stiffest gel in stage 2 will be the highest from stage 1 that had the best image quality
  - The other 3 gels will be lower rigidities based of the optimal gel

Stage Three

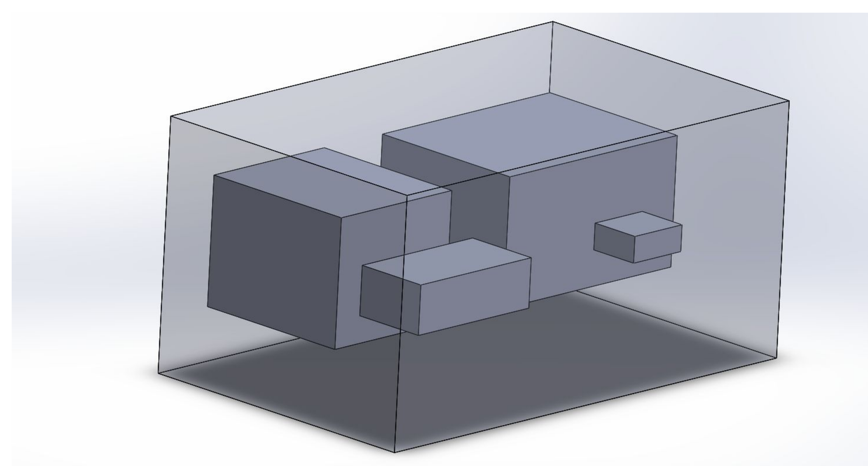

Figure 3.2 Sample holder containing different size, same stiffness clots

Stage Four

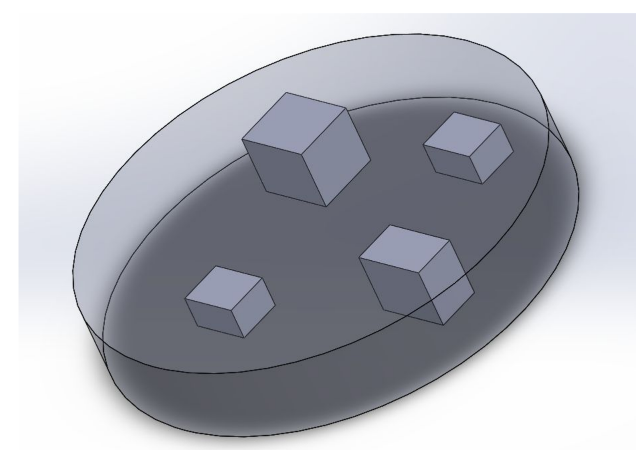

Figure 3.3 Sample holder mocking anatomy, containing different size and stiffness clots

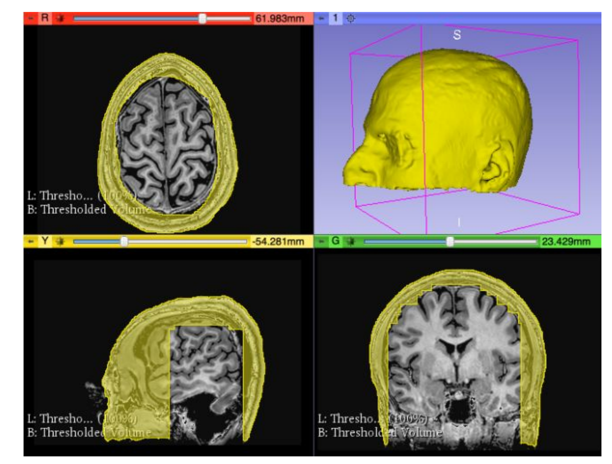

Figure 3.4 Sample brain shell creation on 3dSlicer

MRI Testing Results

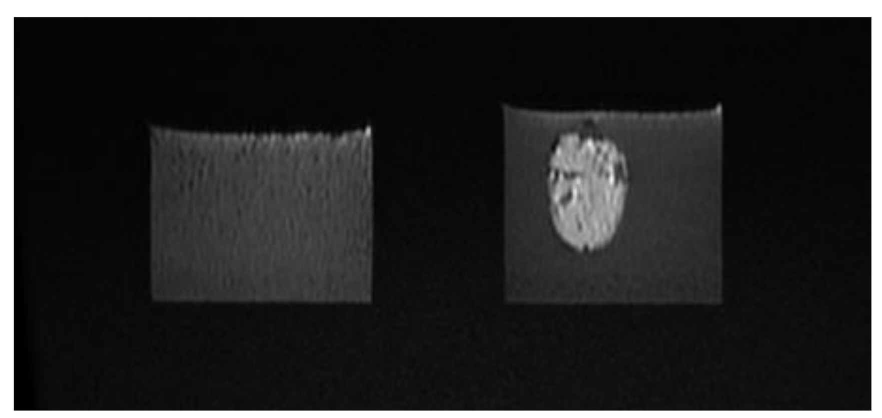

Figure 4.1 T1 Imaging Result

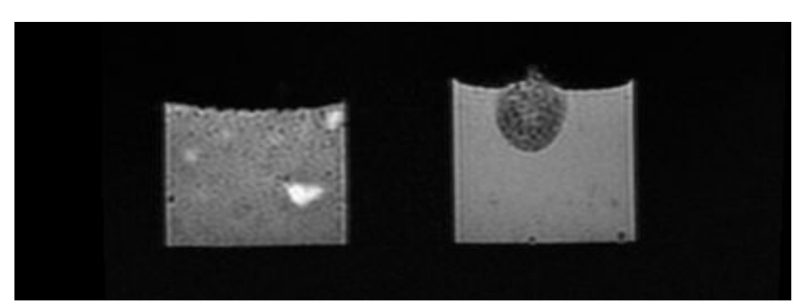

Figure 4.2 T2 Imaging Result

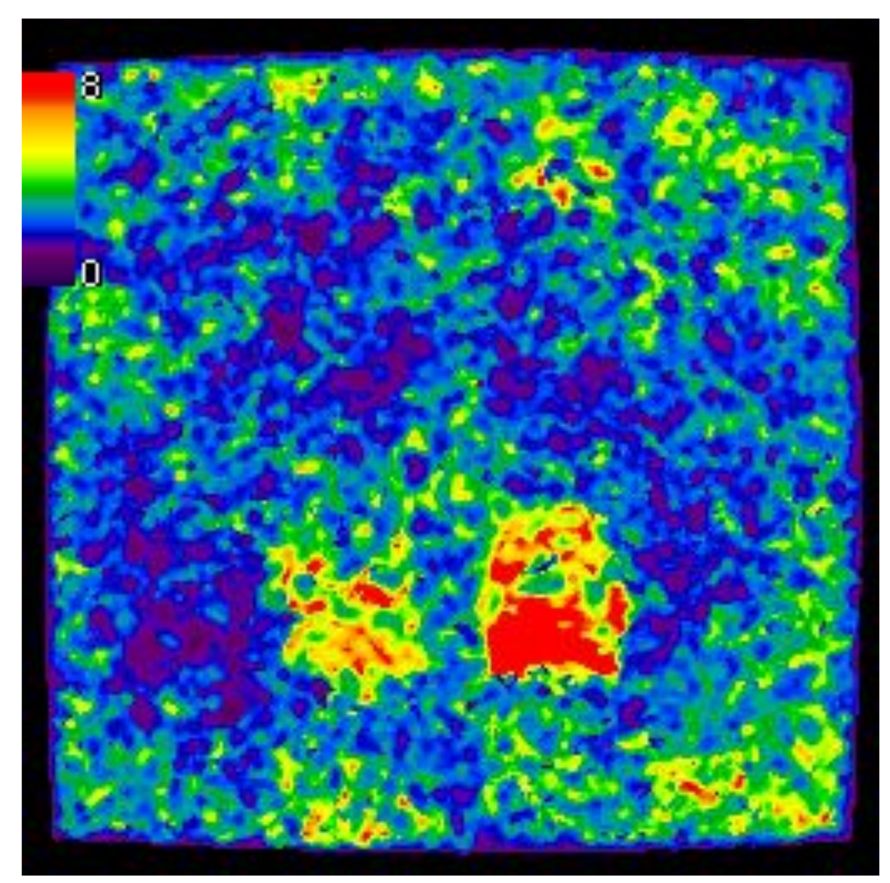

Figure 4.3 Results showing more minute variation in density of gels

- The three images show the difference in stiffnesses between the clots and the surrounding gels
- Figure 4.1 and 4.2 show T1 and T2 imaging respectively, resulting in a definite clot surrounded by homogeneous gel
- Figure 4.3 shows minute variation in stiffness in two of our gels
- Interestingly, the clots, 5% alginate, were less stiff on the images then the base 2% alginate gel

References

[1] "Figure 2f from: Irimia R, Gottschling M (2016) Taxonomic revision of Rochefortia Sw. (Ehretiaceae, Boraginales). Biodiversity Data Journal 4: e7720. https://doi.org/10.3897/BDJ.4.e7720."

[2] K. Y. Lee and D. J. Mooney, "Alginate: properties and biomedical applications," *Progress in polymer science*, Jan-2012. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223967/. [Accessed: 04-Dec-20

[3] Figure 1 from L. Q. Wan, J. Jiang, D. E. Arnold, X. E. Guo, H. H. Lu, and V. C. Mow, "Calcium Concentration Effects on the Mechanical and Biochemical Properties of Chondrocyte-Alginate Constructs," *Cellular and Molecular Bioengineering*, vol. 1, no. 1, pp. 93–102, Mar. 2008.

Gel Making Procedure

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.

Materials & Costs

1. Alginic Acid - $ 46.53
2. Glucono-δ-lactone - From Dr. Masters Lab
3. $CaCO_3$ - From Dr. Masters Lab
4. Sample Box - $28.49

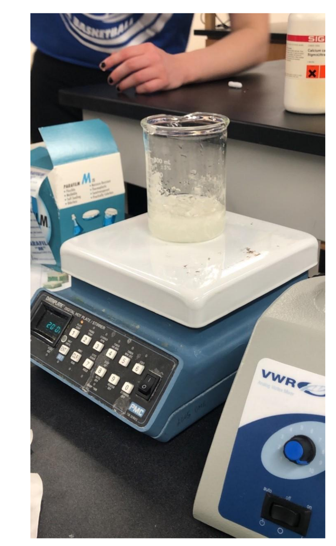

Figure 5.1 Dissolving Alginate

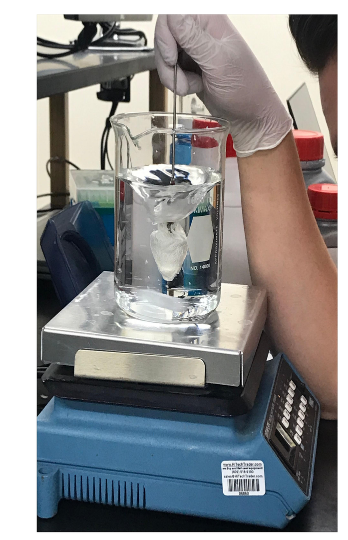

Figure 5.2 Alginate powder being stirred

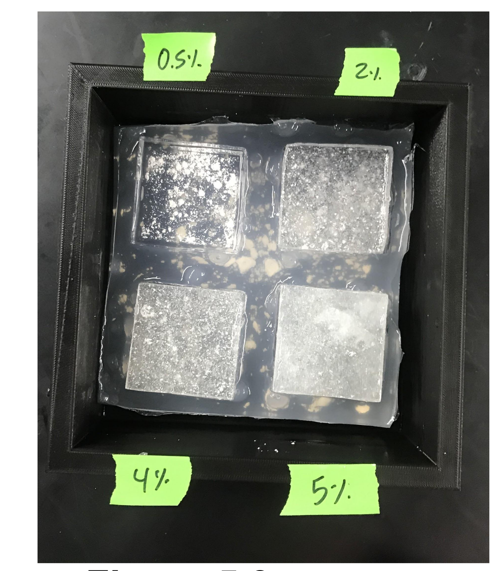

Figure 5.3 Gel setting after being poured

Future Project Development

- Mechanical testing of gels
- Integrate clots into anatomical model
- Create array of different stiffnesses
- Fine tune clot accuracy
- Incorporate materials that simulate white/gray matter as well as CSF

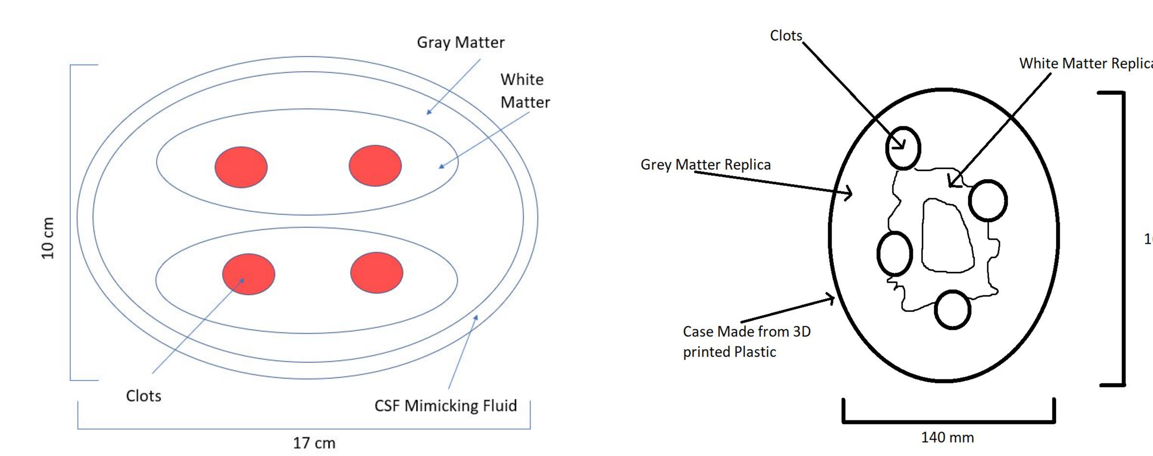

Figure 6.1 Two proposed anatomically correct brain phantom models

Acknowledgements

- Dr. Aviad Hai
- Dr. Kristyn Masters
- Prof. Walter Block
- Kristen Schill
- Zayn Kayali
- Cate Fitzgerald
- Robert Moskwa
- UW-Madison Makerspace
- Dept. of Biomedical Engineering

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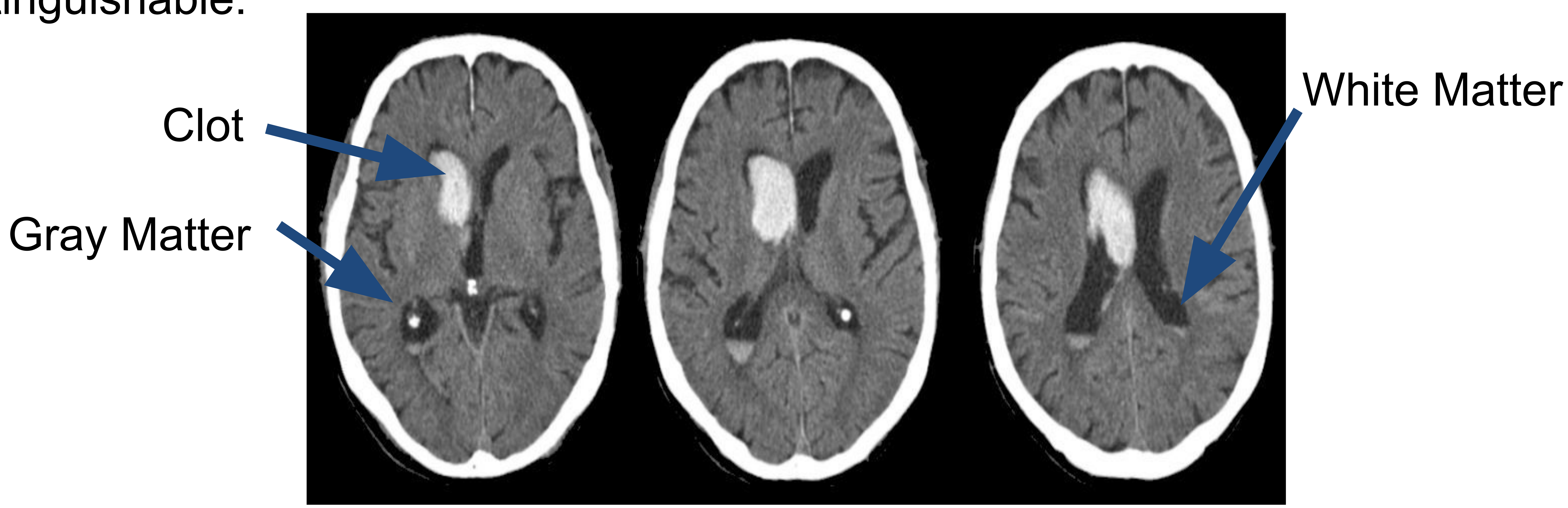

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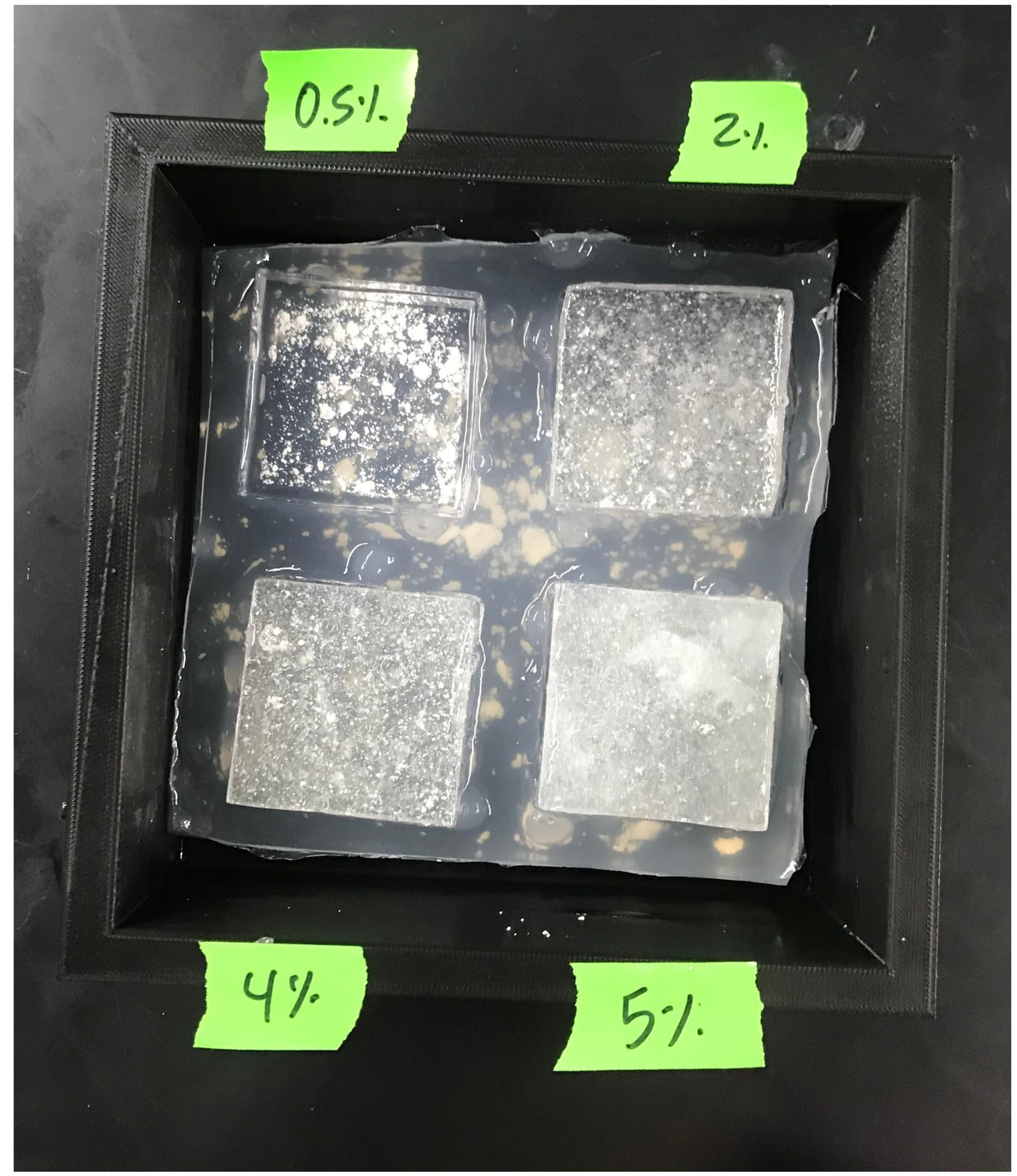

Figure 2.1 Sample holder containing four alginate gel samples suspended in "brain" reference gel

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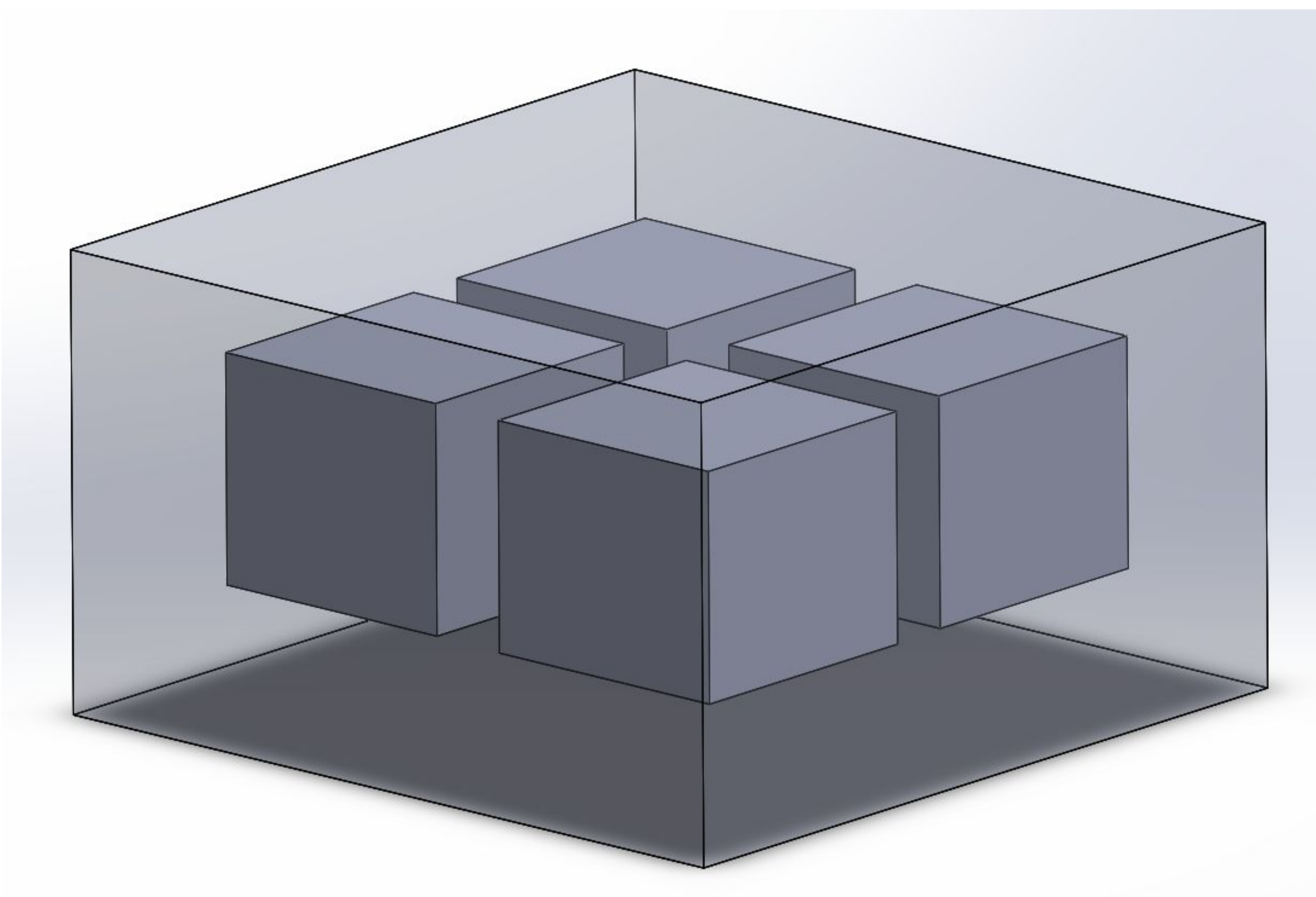

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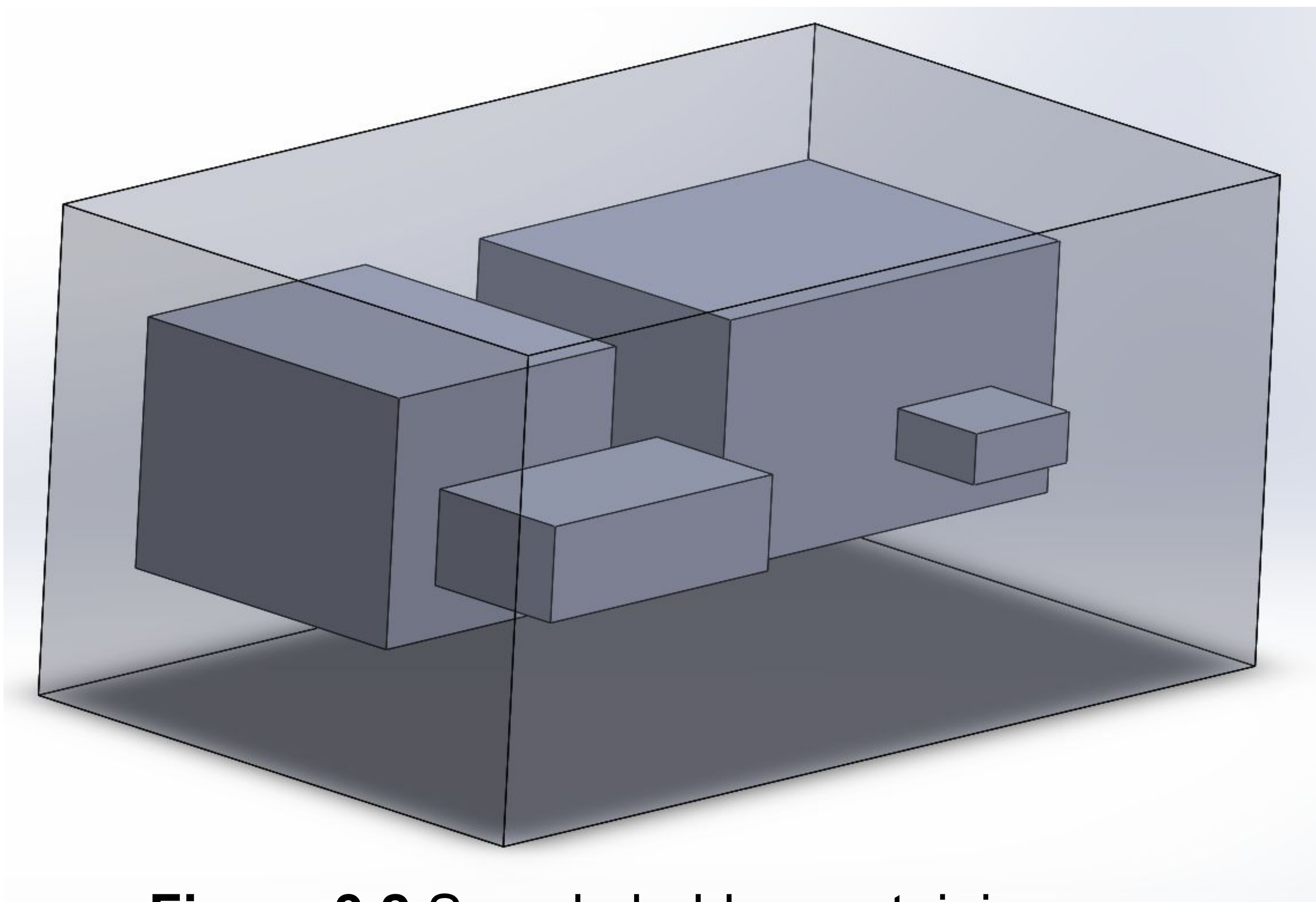

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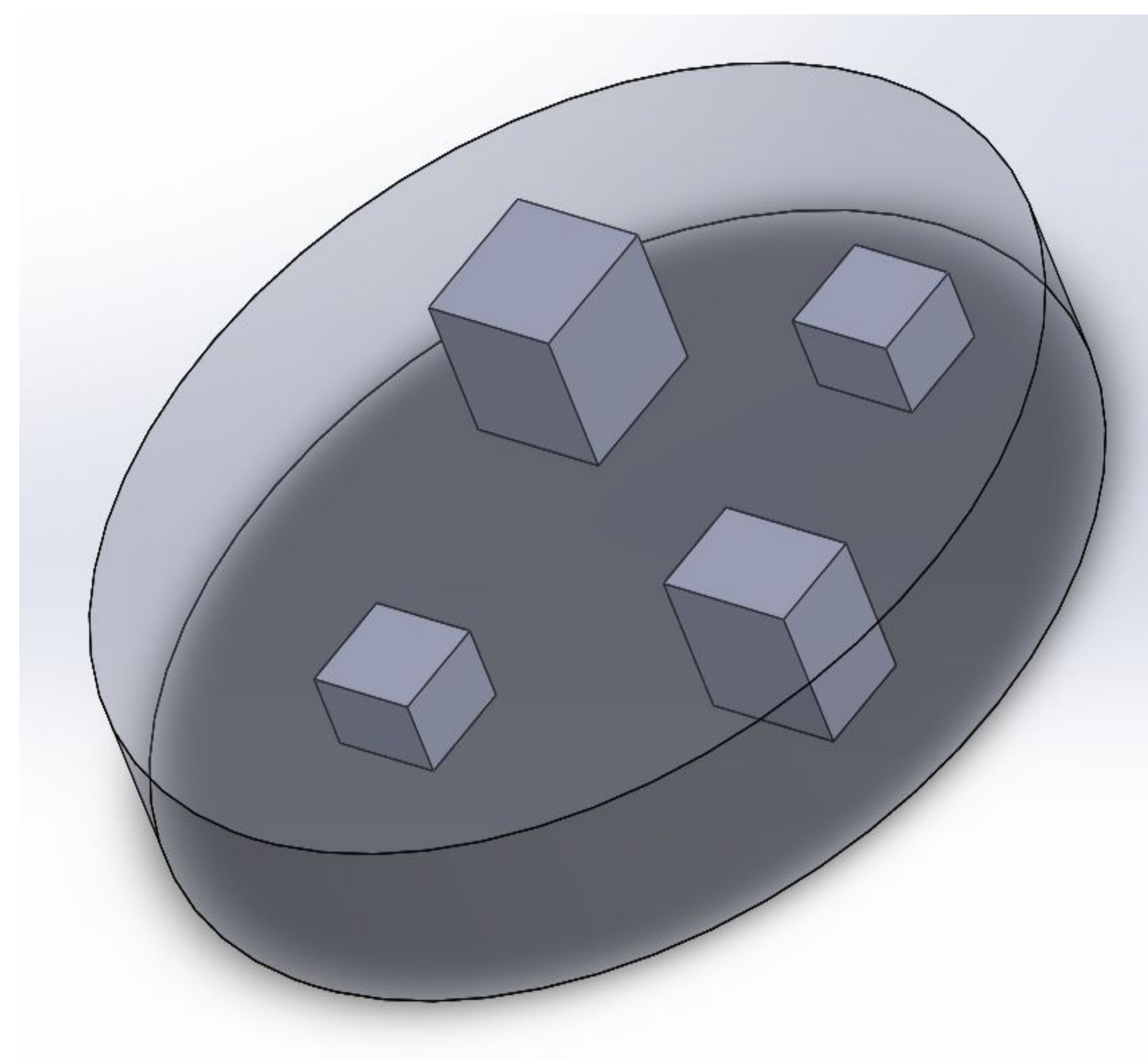
Stage Three

- "Clot" gels all the same stiffness determined in previous stages
- Size is varied to find resolution constraints of MRI

Stage Four

- "Clot" gels of varying sizes and rigidity at varying depths
- Phantom mocks anatomical model
- Dimensions achieved from imaging bag of water in MRI coil
- Phantom can be shelled and shaped via 3DSlicer



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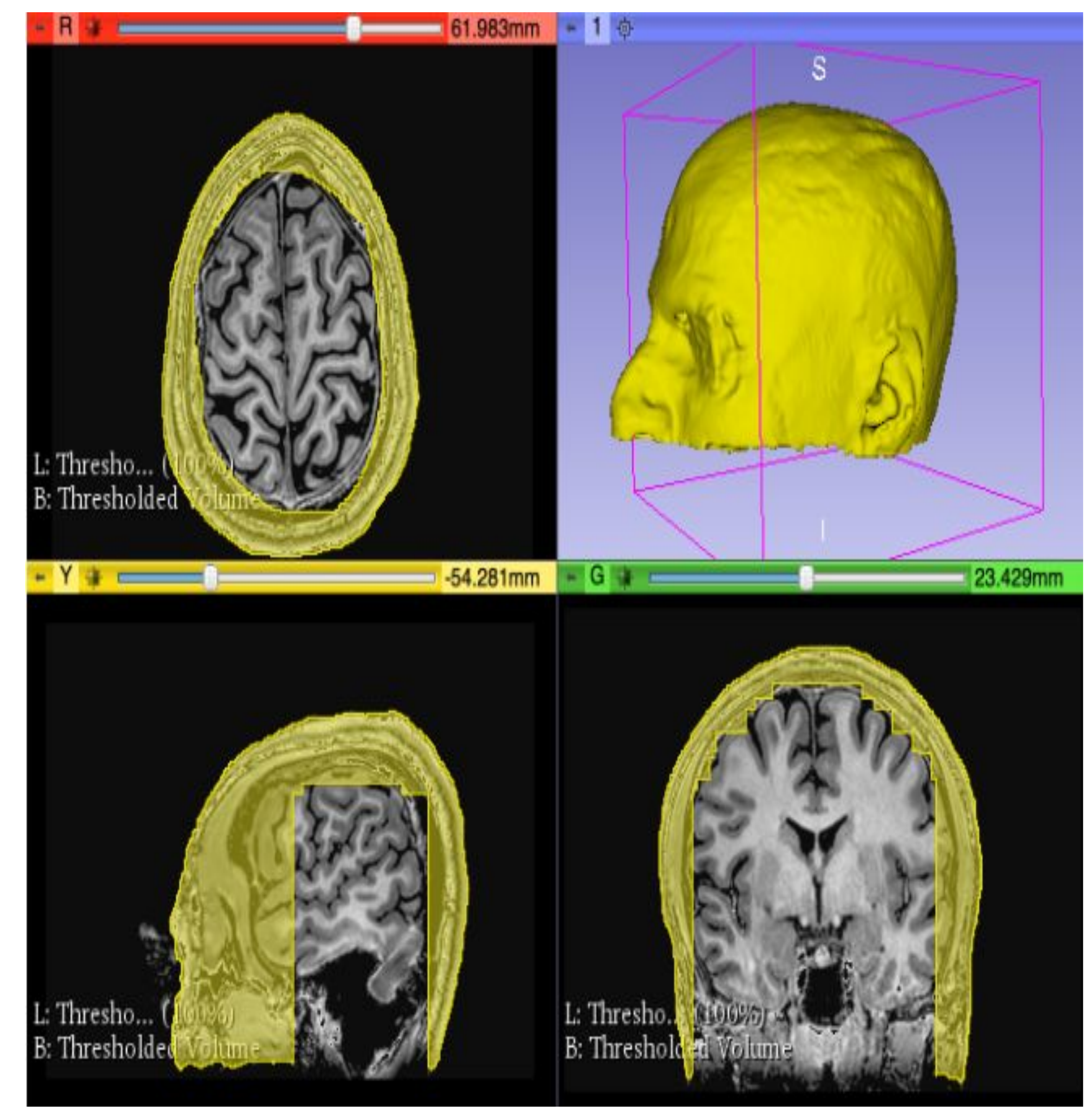

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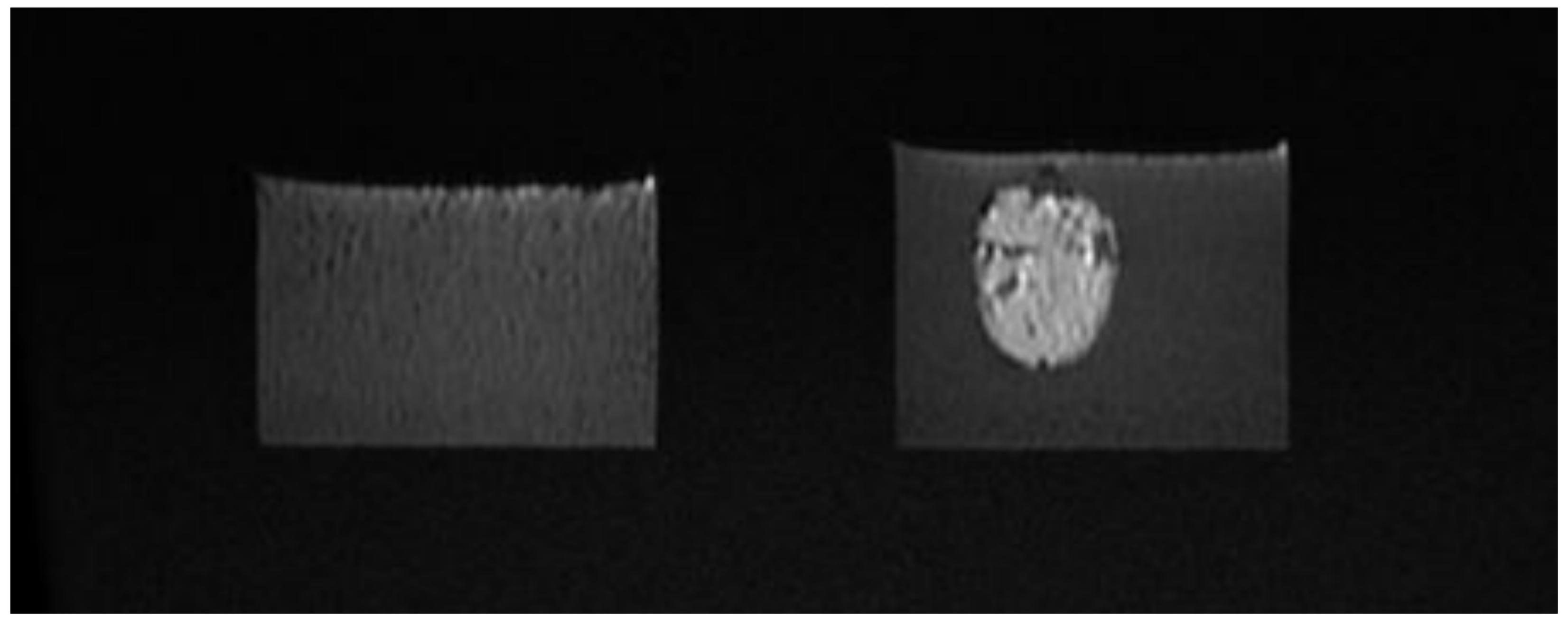

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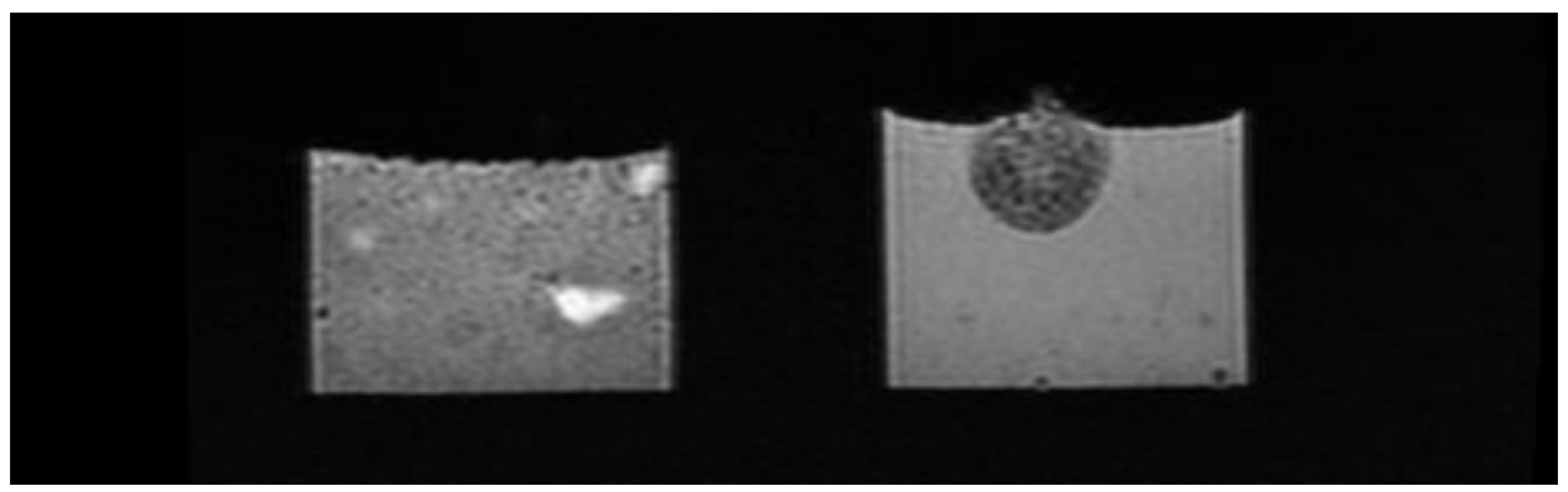
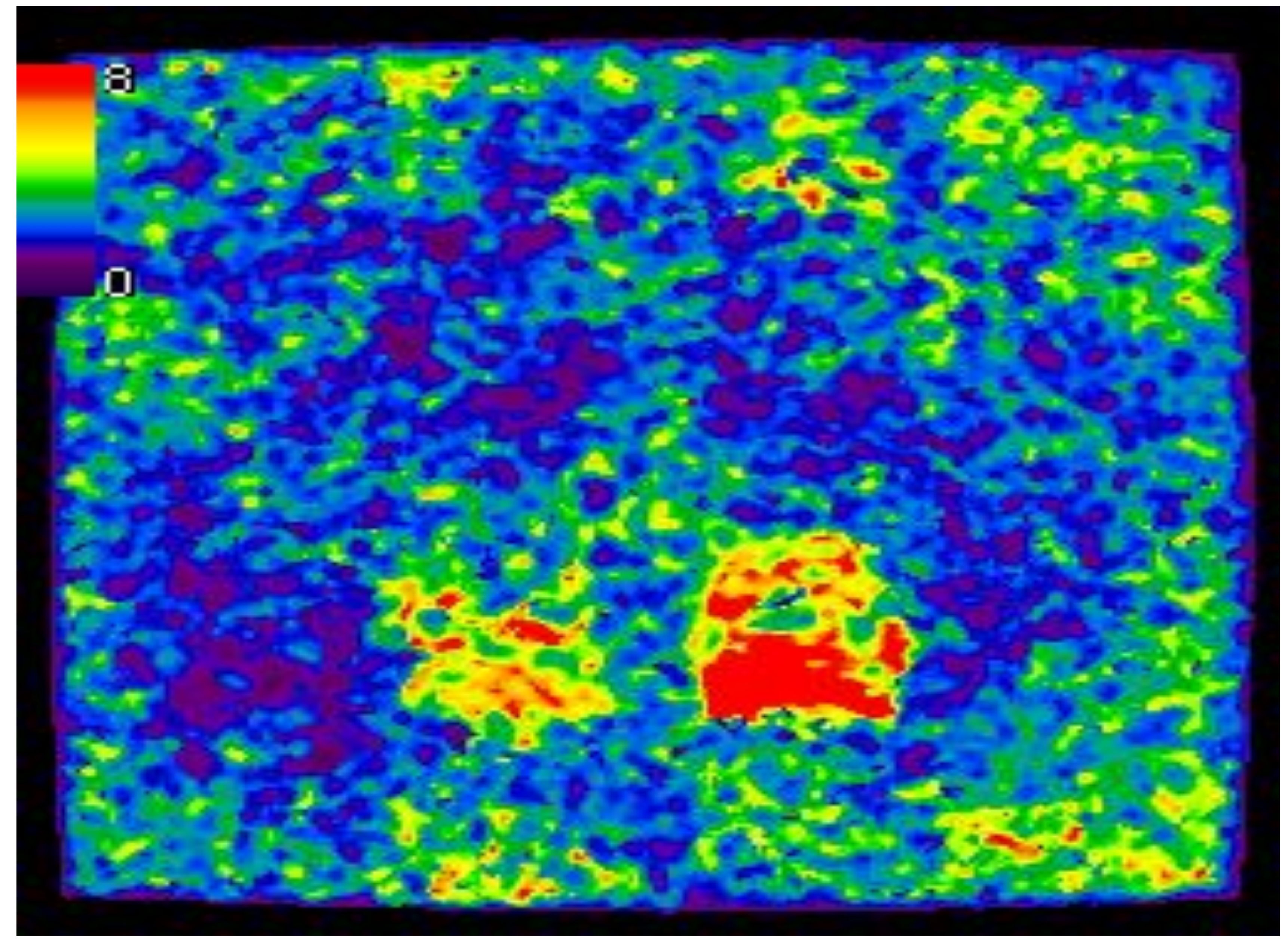


Figure 4.2 T2 Imaging Result



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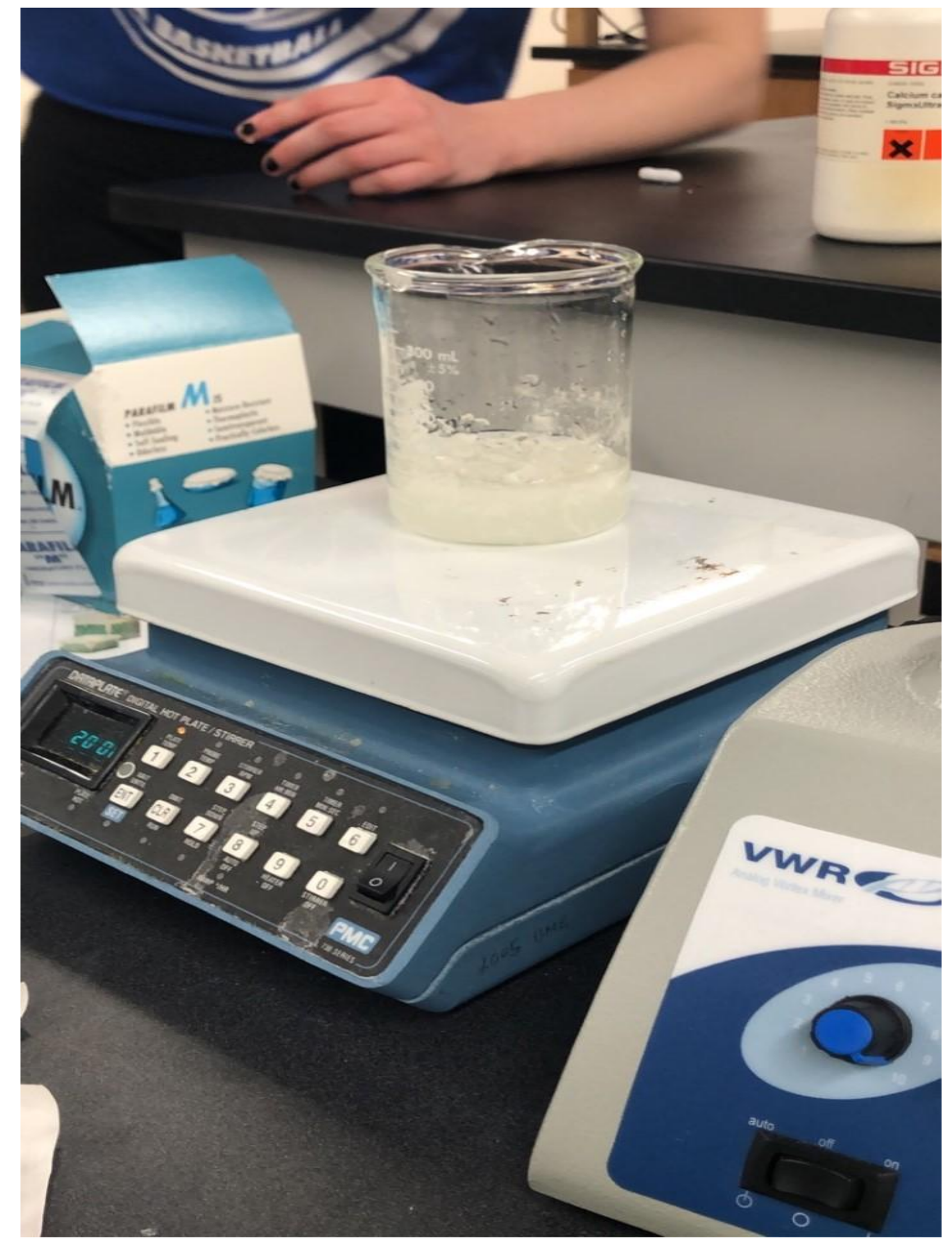

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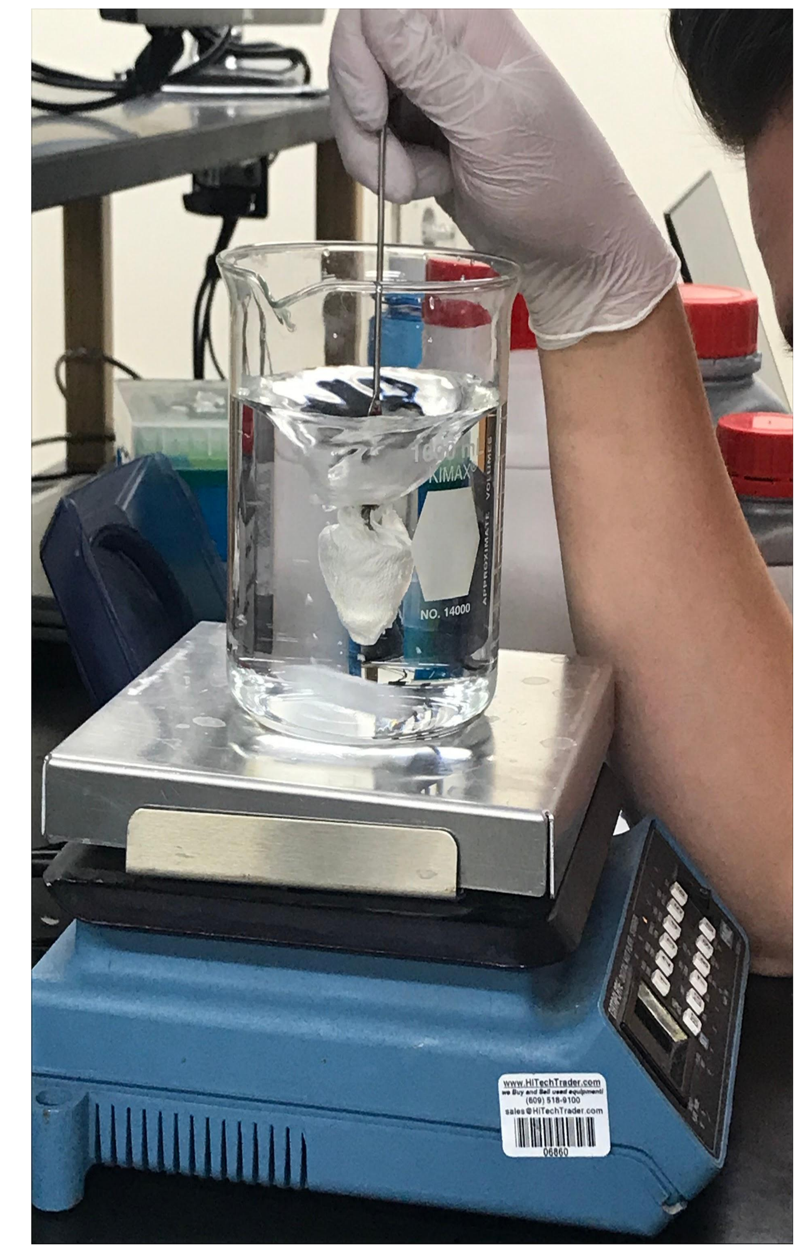

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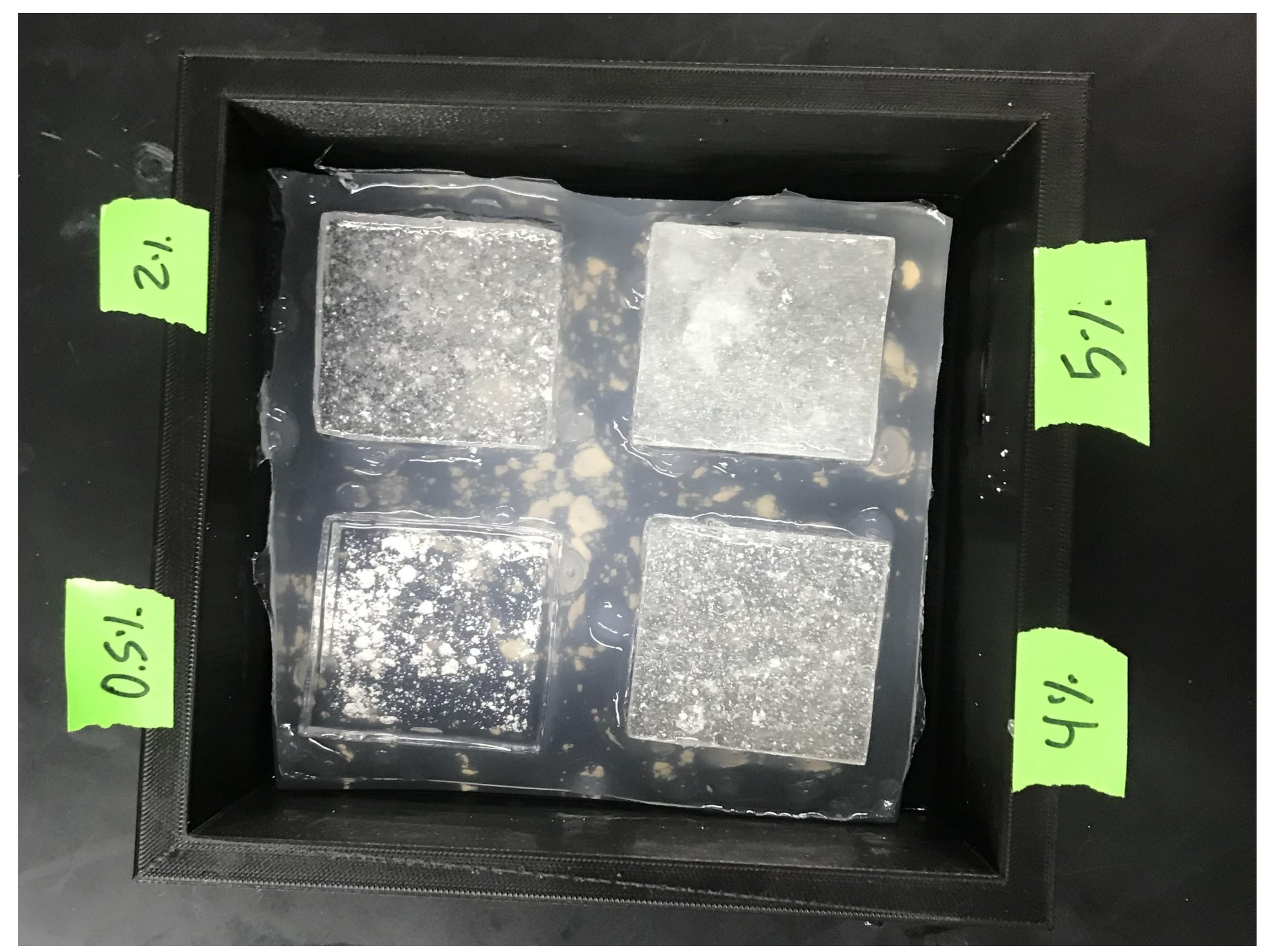

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Gel setting after being poured

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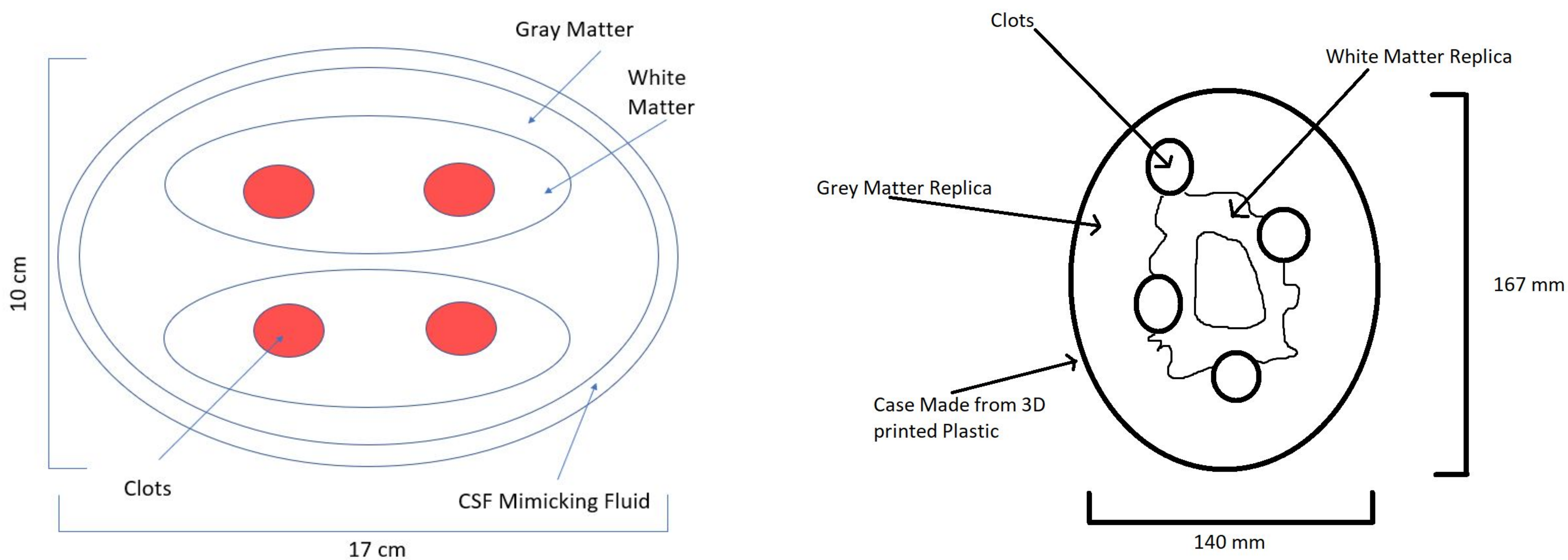

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- **Last Semester's Team Members**
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References

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