Model for Pre-Surgical Intracerebral Hemorrhage Planning

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Client: Prof. Walter Block Advisor: Dr. Kristyn Masters

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.

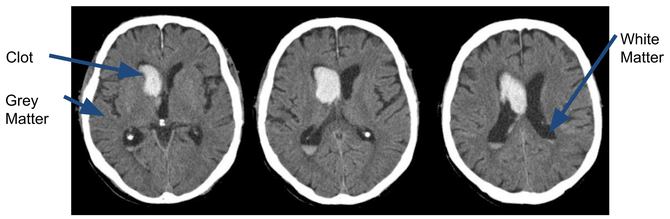

Figure 1.1 Intracerebral Hemorrhage MRI Scan [1]. The white mass in the image indicates a blood clot.

Design Specifications

Function:

- The clot gels must be 3cm x 3cm in order to be properly imaged by the MRI
- Gels must be of obviously different stiffnesses
- Gels must be homogenous in order to create a cohesive image
- Clots need to be suspended in outer gel layer to avoid air interfaces

Usability:

- Gel holding container must fit on an MRI "pillow"
- Metal must not be present in order to get proper images

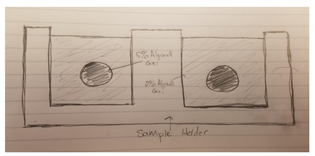

Figure 2.1 Goal of the design with suspended gels

Final Sample Holder Design

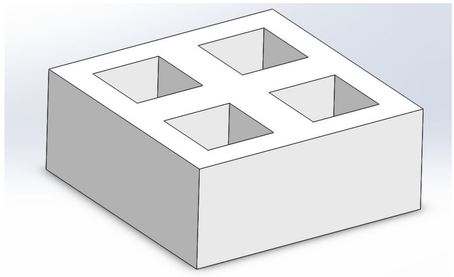

Figure 3.1 Solidworks rendering of sample holder design

- 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

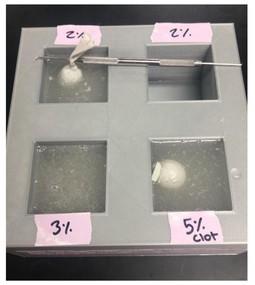

Figure 3.2 Sample holder containing three alginate gels samples

MRI Testing Results

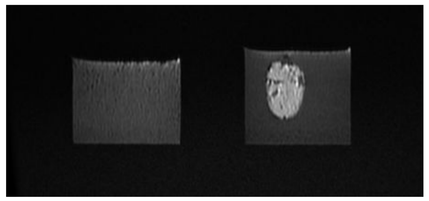

Figure 4.1 T1 Imaging Result

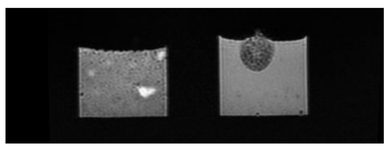

Figure 4.2 T2 Imaging Result

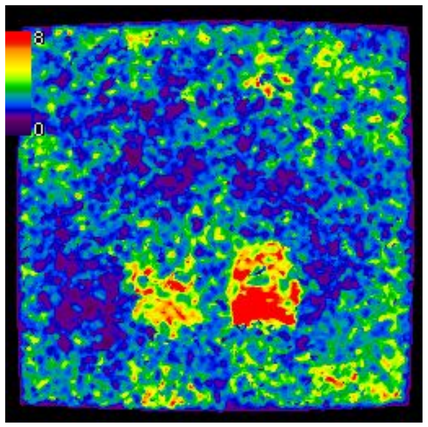

Figure 4.3 Results showing more minute variation in density of gels

- 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

The Chemistry of Alginate Gels

- Alginate gels form from intermolecular cross-linking of divalent cations
- The gel forms its structure when the guluronate blocks of adjacent polymer chains form bonds to one another (egg-box model of cross-linking)
- The buffer Glucono-δ-lactone is added to dissociate the calcium ions from our cross linker by lowering the pH
- The buffer is used to allow the gelling process to be more gradual
- Stiffnesses of gel will be varied based on alginate percentage

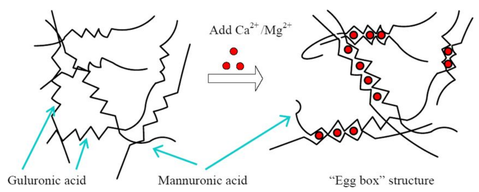

Figure 5.1 Alginate Gelation Mechanism [3]

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. Before the gel sets, scoop it into the finger-tip of a latex glove
5. Tie the top of the latex glove off, ensuring no air gets in the glove
6. Allow the clot gel to set in a fridge
7. Repeat steps 1-4 for 2% base gel
8. Suspend the clot using a wooden stick in the cavity of the container
9. Pour the base gel into the cavity and allow the gel to set in the fridge

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 6.1 Dissolving Alginate

Figure 6.2 Centrifuged Gels

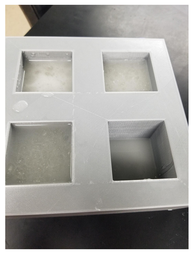

Figure 6.3 Gel setting after being poured

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

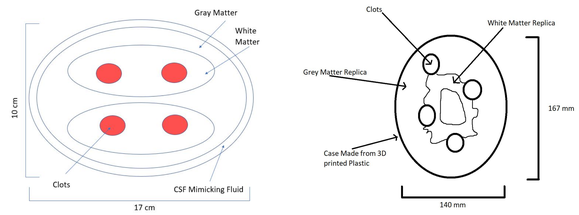

Figure 7.1 Two proposed anatomically correct brain phantom models

Acknowledgements

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