Executive Summary: Design Excellence Award, BME 402

Model for Pre-Surgical Intracerebral Hemorrhage Planning

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Intracerebral brain hemorrhaging (ICH) is a dangerous condition that affects thousands of Americans annually. The blood clots that form from this condition have a wide range of material properties that impact the surgical method of choice for removing them. Currently, there is no way to determine the stiffness of clots prior to surgery. A phantom that can provide images where a clot environment of known stiffnesses would be used to create a large database that surgeons can utilize to compare the MR images of their patients to those of the phantom's in the database, allowing them to determine the stiffness of their patients' clots and therefore the appropriate surgical method of extraction. This project proposes a phantom consisting of a 3D-printed polylactic acid (PLA) skull containing polyacrylamide (PA) gels to mimic blood clots and the brain, the stiffnesses of which will be verified via rheometric analysis and cross-checked with MR elastography, which works by applying low-frequency vibrations to the phantom and imaging the wave diffusion properties to obtain a shear modulus value.

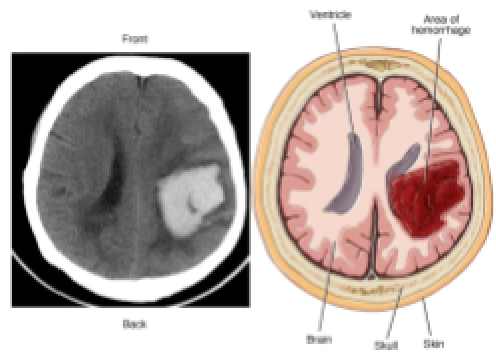

Figure 1: Image of intracerebral hemorrhage on left with cartoon breakdown of components on right.

Any existing related devices/IP serve a different purpose and as a result have different design features catered toward those purposes. For example, a team created an MRI brain phantom out of a silicone mold and agar gels with the goal of achieving the highest detail in brain shape and texture (Altermatt et al., 2018). This model did not put focus into material accuracy or stiffness change like this project.

The creation of the phantom requires two parallel processes focusing on both the container and material fabrication and testing. The PLA container was created from CT images of a skull, which was hollowed, halved, and prepared for 3D printing in MeshMixer software (Autodesk, 2018). Polyacrylamide was gelled using photoinitiator and UV light at a wavelength of 365 nm to promote cross-linking and gelation. The stiffness of the gels are then analyzed with a rheometric frequency sweep to obtain the storage and loss moduli, as well as an approximate shear modulus. Finally, the gels are placed in the PLA shell and the phantom may then be analyzed via MRE by the client, which also yields a shear modulus of the gels for comparison with the rheology data. Future work for this project includes refining of material stiffness and further comparison analysis with MRE data, which has been limited thus far. In addition, anatomical features to more accurately represent the brain (such as air pockets to represent sinuses and fluid pockets to represent CSF) will be incorporated into the model to make the images as accurate as possible.

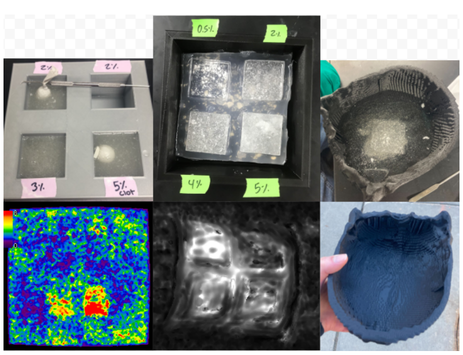

Figure 2: Three variations of gel containers throughout four semesters. Each has its respective MR scan below, except for the final on the far right, as we are awaiting scan results. The first model created MR results showing the base gels stiffer than the "clot" gels. The second container created phase issues for not properly fitting in the MR head pillow.