Let's cook a realistic brain for science

7/17/2014

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If you happen to have to deal with medical device testing and validation, it may be difficult to escape from either getting the real body tissues from animal or human (yes, tissues from our own species) or making a fake one that resembles the real deal.

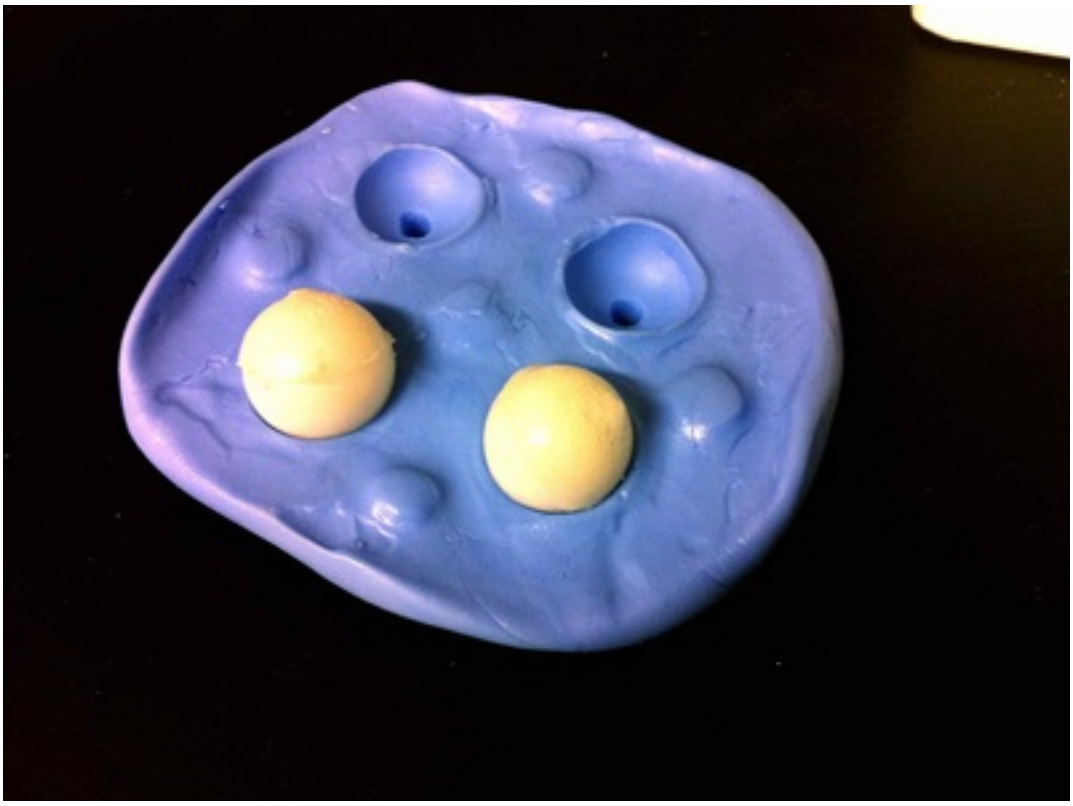
For the purpose of brain surgery, I have bought real animal brains in the past, and the experience really was not as nice as I thought. Hunting for the freshest possible brains which preserve the best mechanical and imaging properties in the city of Montreal was quite a journey, and often it won't serve a long term for investigation. In rare occasions, I have heard at some more fancy courses/demos, real human heads were used for training, but how rare will you get into this type of situation?

Another convenient option will be making a fake brain. If you search the relevant key words in Youtube, it is likely that you will get many tutorials on how to make fake jello brains for special occasions. Surprisingly, for disposable brain phantoms, these tutorials will very likely to work for the scientific needs. However, if you intend to keep the brain for longer time and better simulate the mechanical and medical imaging properties, we need to do some more sophisticated cooking. I happened to need to make a brain phantom this week, and let me show you how to cook half a realistic brain for science!

In general, I followed the recipe introduced in this paper [1], and the associated medical images (MRI, CT and Ultrasound) can be found in here. Instead of getting the brain mold from the dollar store, I did get a fancier version - a 3D printed mold made from one of the most famous brains in the field, the Colin27 template. Yet, the dollar store mold works fine if you don't have access to brain data or a 3D printer. If you ask anyone in the brain imaging field, nearly everyone has heard about Colin27. I suppose now he is a bit of a rock star in the field, not for the music, but for his brain (check out his interview here). The main material for the brain is called PVA-C or polyvinyl alcohol cryolgel, which is commonly used in making body tissue phantoms. When the gel is frozen and thawed (each process for 12 hours), it will be transformed into a material that feels much like a piece of meat (minus the sticky part and smell). Depending on the concentration and the freezing-thawing cycles, the mechanical properties can be manipulated to resemble different body tissues. For our brain phantom, we choose a PVA concentration of 6% with one freezing-thawing cycle. In addition, we will also put some "implants" to resemble different tissue types and to mark the internal location of the phantom in the MRI/US images, and for the implants, we chose a PVA concentration of 8% with two freezing-thawing cycles. To obtain the US contrast, talcum powder (or simply baby

powder..ask your friends with babies) was used. For the implants, 5% concentration is used, and 1% was applied for the main brain phantom. If you also need to have some CT contrast, certain concentration of $BaSO_4$ is required. Although $CuSO_4$ may be required for MRI contrast, often the MRI scanner will be able to differentiate PVA with different concentrations. These will really depend on your specific needs.

OK. Now let's make the implants first. You may be creative on this. I personally made some spheres, stars and hearts. For the spheres, I used the marbles as the models, and made the mold with the mold putty, which is a really nice material for fast (only 5 min for hardening) and easy casting work, and lasts for a long time for re-uses. Otherwise, using silicone is the standard choice...



After the implants are ready, make the gel with the appropriate PVA concentration for the main brain. Put the implants inside and fill the brain mold with the gel. To save your time and material, it is suggested to fill the mold with water first, and measure the volume of the water to know how much PVA you will need to make the phantom. However, if you don't want to wet your mold, some couscous will work the same.

The most difficulty I had with the cooking is really dissolving the PVA crystals into water. To melt the crystals while not burning them into some yellow colour, you should prepare your water to be between 70 ~90 degrees Celsius, and keep stirring. In this sense, a nice water bath and a thermometer will be very instrumental. Also, watch out for the loss of H2O through the cooking process. Too much water loss may mean that your concentration will go up, resulting in a harder material.

Now let's take a look what the brain will look like in the ultrasound image.

We can clearly identify the implants in the brain phantom when imaged with

ultrasound, as well as the cortex. In a real brain, there are many different structures, and their imaging properties vary as well. If you need to make even more realistic brain, more complex casting techniques are the only limit you will face in production. However, if you are interested, you are more than welcome to give it a try.

Reference:

[1] Chen SJ, Hellier P. Marchal M., Gaufrait JY, Carpenteir R, Morandi X, and Collins DL, "An anthropomorphic polyvinyl alcohol brain phantom based on Colin27 for use in multimodal imaging," Medical Physics, 39(1):554-61, 2012.