Evaluation of Commonly Available Materials for MR Elastography Phantoms

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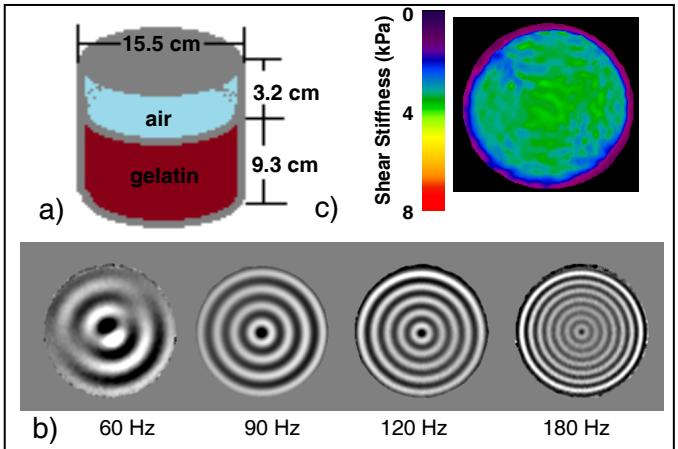

Figure 1: a) Flavored gelatin phantom schematic. b) MRE wave images. Notice the concentric wave pattern ideal for MRE stiffness measurements. c) Elastogram of gelatin phantom at 60 Hz. The stiffness was 2-3kPa at 60Hz, the stiffness of a healthy liver.

Introduction: MR Elastography (MRE) is an MRI-based technology for evaluating tissue stiffness [1]. Recent research has shown that for some patients MRE offers a safer, more comfortable, less expensive and more reliable alternative to invasive biopsy for assessing liver fibrosis [2]. Commercial phantoms for system calibration and validation are common for imaging modalities like CT and MRI, including resolution and flow phantoms. However, there currently are no commercial sources for a suitable liver-mimicking test phantom for MRE. The purpose of this study was to identify and test readily available and inexpensive materials that might be useful as simple test phantoms for hepatic MRE. This study will benefit clinical radiologists and MRI scientists interested in evaluating the quality of MRE procedures.

Methods: Phantoms: Among commonly available semisolid materials, we found 11 possible materials for use as a phantom: flavored gelatin mix, packaged pudding, "marshmallow cream", tofu, jam, jelly, cranberry sauce, pie filling, a mixture of cornstarch and water, a mixture of absorbent polymer and water, and a material obtained by combining vegetable fiber supplement (Metamucil) and water. When possible, the materials were imaged in the containers they were purchased in. The gelatin mix was prepared using a 60% concentration of gelatin powder and water (80-90 °C) in a container with a diameter of 15.5 cm and a height of 12.5 cm. The container was filled so that 3.2 cm of air remain at the top when the lid was on (Figure 1).

MRE scans: All phantoms were scanned to evaluate the homogeneity and stiffness of the material using MRE at four mechanical frequencies: 60Hz, 90Hz, 120Hz, and 180Hz. For the gelatin mix, the effects of time, temperature and repeatability of a recipe were evaluated at 60 Hz. MRE was performed on each phantom using an acoustic passive driver positioned underneath the phantom inside a single-channel birdcage head coil at 1.5T (GE, Wisconsin, USA) (Figure 2). A 2D GRE MRE sequence was used with the following imaging parameters: FOV = 20 cm; 4 phase offsets; coronal imaging plane, motion-encoding gradient (MEG) amplitude = 3.2 G/cm. TR = 50-55.5 ms, TE = 18-23 ms; flip angle = 30°, BW = 31.25 kHz, acquisition matrix = 256X64, reconstruction matrix = 256X256, NEX = 1. Wave images were analyzed with the same inversion algorithm used for hepatic MRE to generate shear stiffness maps (elastograms) [1]. The mean stiffness was reported from ROIs drawn on the elastograms.

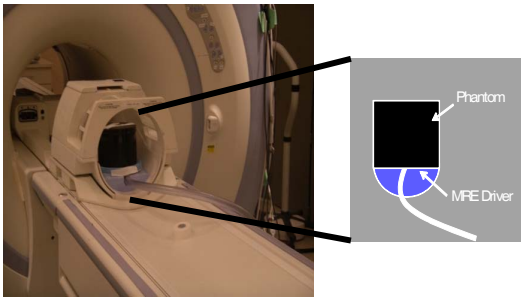

Figure 2: Each phantom being tested was placed on top of an acoustic driver placed inside a single-channel head coil.

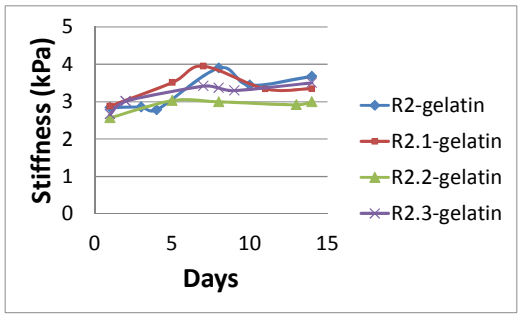

Figure 3:. Stiffness of the gelatin phantoms increased with time (R.#.# denotes recipe #, and individual #, that prepared the phantom.)

Results and Discussion: The stiffness obtained for the flavored gelatin mix was in the range of 2-3kPa at 60Hz (Figure 1). Medium firmness tofu had a higher stiffness value (5.5 kPa at 60 Hz) and had the benefit of requiring no preparation prior to scanning as the packaging was found to be MRI compatible. The remaining materials were either too heterogeneous, too stiff, or lacked MR signal. Healthy liver tissue has a shear stiffness in the range of 2-3 kPa at a shear wave frequency of 60 Hz, which is much softer than most off-the-shelf materials regarded as solids. Therefore, the flavored gelatin mix was found to be the best liver-mimicking phantom material among those tested. The reproducibility of this gelatin preparation was tested by having three different individuals prepare the phantom material according to the recipe described above. The range of stiffness values was 2.6 kPa to 2.9 kPa with a mean of 2.8 kPa. This range is acceptable for use as a simple test phantom for validating the performance of an MRE system. As expected, an inverse relationship between temperature and stiffness was observed as theses phantoms were warmed from approximately 7 °C to room temperature (approximately 22 °C). Also, the stiffness of the gelatin phantoms increased with time over a two week period (Figure 3).

Conclusion: In conclusion, a phantom suitable for basic testing of an MRE system can be prepared using a widely available packaged flavored gelatin mix. Preliminary testing indicated that the stiffness of the material is comparable to the stiffness of healthy liver tissue, though its value does fluctuate with temperature and age.

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References: [1] Yin M, Clinical Gastroenterology and Hepatology 2007; 5: 1207-1213. [2] Yin M, Topic in MRI, 2009; 20: 79-87.