OPTIMIZED ENCAPSULATION OF NEURAL TISSUE FOR SE AND EPI IMAGING

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Purpose This research aims to develop an encapsulation methodology for neural tissue to reduce susceptibility artifacts in EPI images and preserve contrast in SE images. This effort is in support of a study that requires spin echo (SE: T1, T2, and proton density (PD)), and echo planar (EPI: diffusion tensor) imaging of resected pig brains coregistered for correlation with physical measurements.

Methods Yorkshire and Yucatan pig brains were acquired from swine carcasses under a tissue sharing protocol.[1] Four encapsulation geometries were tested to determine their effect on artifacts and image contrast: 1) a bare brain, 2) a brain encapsulated in a cylindrical mold, 3) a brain encapsulated in a 7.5 inch diameter sphere, and 4) a brain encapsulated in a 4 inch diameter sphere. Criteria for an appropriate encapsulant are low signal on T1, T2, and PD images so it can be easily distinguished from tissue and firm mechanical properties to provide tissue support. T1 values of grey matter, white matter, and encapsulating materials were measured using multiple inversion recovery experiments with signals fit to the TI signal model.[2] T2 values were estimated using T2 and PD weighted signals with a two-point fit to a monoexponential T2 model.[2] (It is understood that our measurement of T1 and T2 were not absolute values, but they were useful to estimate and to better understand relative signal). An initial phantom study was done using encapsulating substances in centrifuge tubes (Table 1). T1, T2, PD, and inversion recovery images were acquired of each phantom to visualize the relative signals and for estimation of T1 and T2 values.

Table 1. Substances in phantom study

1. 5% Gelatin
2. 4% Agarose
3. 5mM CuSO4 in 5% Gelatin
4. 10mM CuSO4 in 5% Gelatin
5. 1mM NiCl2 in 4% Agarose
6. 2mM NiCl2 in 4% Agarose
7. 5mM NiCl2 in 4% Agarose
8. 1mM GdCl3 in 5% Gelatin
9. 5mM GdCl3 in 5% Gelatin
10. 5mM MgCl in 5% Gelatin
11. 10mM MgCl in 5% Gelatin

Results Imaging of different geometries revealed a number of artifacts that can be corrected by appropriate encapsulation (Fig 1).

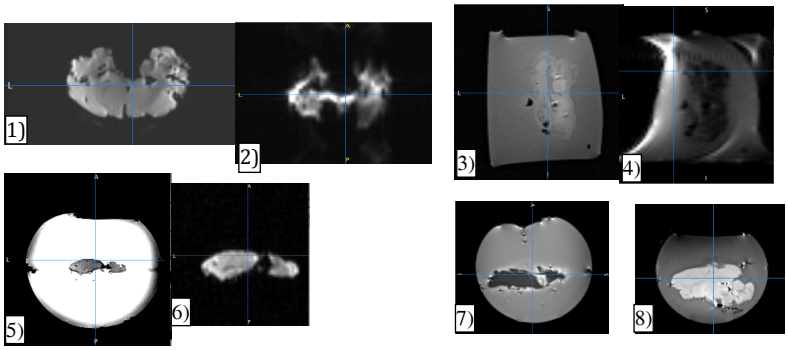

Figure 1. 1) bare brain T1 image, 2) bare brain EPI image showing significant geometric distortion from susceptibility artifact, 3) T1 image of brain encapsulated in 10% gelatin showing significant signal from the encapsulating region, 4) EPI image of brain encapsulated in 10% gelatin showing significant geometric distortion at the end of the cylinder, 5) T1 image of brain encapsulated in 7.5 inch sphere of gelatin containing 30mM copper sulphate, 6) EPI image of brain encapsulated in 7.5 inch sphere showing lack of geometric distortion, 7) T1 image of brain encapsulated in 4 inch sphere containing 30mM copper sulphate, 8) T1 image of brain in 4 inch sphere encapsulated in 4% agar.

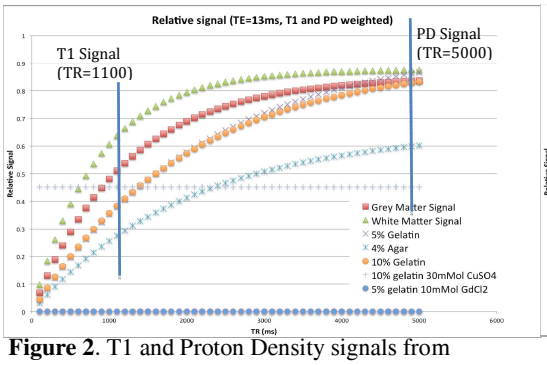

Figure 2. T1 and Proton Density signals from neural tissue and encapsulating substances.

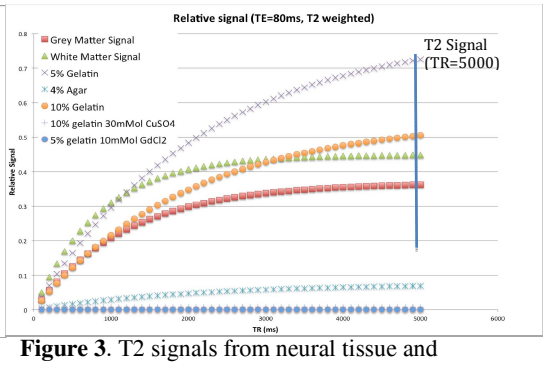

Figure 3. T2 signals from neural tissue and encapsulating substances substances.

Based on estimates of T1 and T2, signals were predicted for brain tissue and selected encapsulating media (Figs 2,3).

Discussion The geometry of the encapsulating material and prevention of air-tissue interfaces is important to minimize susceptibility and geometric distortion artifacts, respectively. Maximum T1 contrast between white and grey matter occurs at approximately TR=1100ms based on the models in Figures 2. In the predicted T1 image, the signal from pure gelatin and agar are smaller than signals from brain tissue. In the PD image, pure gelatin looks very similar to tissue. $CuSO_4$-doped gelatin looks very similar to grey matter in T1 images. In predicted T2 images, 5% gelatin is much brighter than brain tissue and 10% gelatin is similar to brain tissue (Figure 3). Four percent agar has very low signal in the T2 image and is sufficiently different from brain tissue in the T1 and PD images to make segmentation convenient. $GdCl_2$ is a good dopant, but it leached into the tissue and reduced the signal unacceptably.

Conclusion Based on the substances tested, encapsulation in 4% agar provides the lowest signal in all images without leaching into tissue, and it provides a stable substrate for physical measurements of brain tissue.

References [1]AFRL Exempt Protocol 12-05; [2]McRobbie DW et al (2007). *MRI from Picture to Proton* (2nd ed). Cambridge University Press