Improved Frequency Selective Fat Suppression in the Cervical Spine and Neck with Tissue Susceptibility Matched Pyrolytic Graphite Foam

Gary Lee[1], Caroline Jordan[2,3], Jeff McCormick[4], Pamela Tiet[5], Brian Hargreaves[2], and Steven Conolly[1,5]

[1]Berkeley/UCSF Bioengineering Joint Graduate Group, Berkeley, CA, United States, [2]Radiology, Stanford University, [3]Bioengineering, Stanford University, [4]Molecular Environmental Biology, University of California, Berkeley, [5]Bioengineering, University of California, Berkeley

Introduction: Frequency selective fat suppression methods exploit the 3.5 ppm chemical shift between fat and water to suppress the fat signal in MRI [1]. B_0 field homogeneity must be within ~1 ppm for robust fat suppression. Unfortunately, the field homogeneity near the skin is typically ten times worse than 1 ppm (±5 ppm) due to air near the skin. Field shimming methods cannot reliably shim out the steep field patterns induced near certain parts of the body (e.g., breast, foot, or shoulder). Here we target more robust fat suppression using pyrolytic graphite (PG) foams for contrast-enhanced musculoskeletal, body, and brain MRI. We have previously demonstrated that the PG foams are nonconductive and do not heat, so they are safe for patient use [2]. Here we demonstrate that the foams do not affect SNR, improved *in vivo* susceptibility matching in the cervical spine and posterior neck, and enabled improved frequency selective fat suppression.

Methods: A PG foam neck cushion (Fig. 1) was created by dispersing PG powder (3.9% by volume) into two-part polyurethane foams [2]. PG foam is magnetically isotropic and matches the susceptibility of water, fat, or tissue [2-3]. Signal and noise measurements of water phantoms (N=15) with/without >3.5L of packed PG foam in a standard head coil were acquired with a standard gradient echo (GRE) sequence to test no SNR loss. *In vivo* 3T field maps in the cervical spine were acquired with/without PG cushions with a standard Siemens field mapping sequence to verify susceptibility matching. T_1-weighted 3T GRE images (256x256 matrix, FOV 22.4x22.4 cm^2, 3.75 mm thick TR/TE = 600/3.5 ms) with and without frequency selective fat suppression were compared for 6 healthy volunteers.
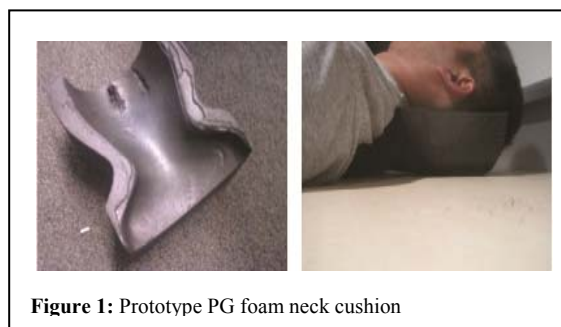

Figure 1: Prototype PG foam neck cushion

Results: The PG foam packed phantoms lead to virtually identical SNR to the unpacked phantoms, 101 ± 4.6 compared to 102 ± 4.8 (mean ± SD), indicating that no noise was added by the PG foams. A representative set of experimental field maps and the corresponding histograms is shown in Fig. 2. The static field homogeneity was significantly improved with the use of the susceptibility matching PG foam neck cushion. The use of PG foam reduces the percentage of voxels outside of the critical ±1 ppm threshold from 15.7% to 2%. Representative T_1-weighted, fat suppressed GRE images of one of the volunteers are shown in Fig. 3. The frequency selective fat suppressed image showed signal dropout, reduced SNR, and failed fat suppression in the region of poor static field homogeneity. The susceptibility matching PG foam neck cushion demonstrated robust fat suppression and fewer susceptibility-induced artifacts.
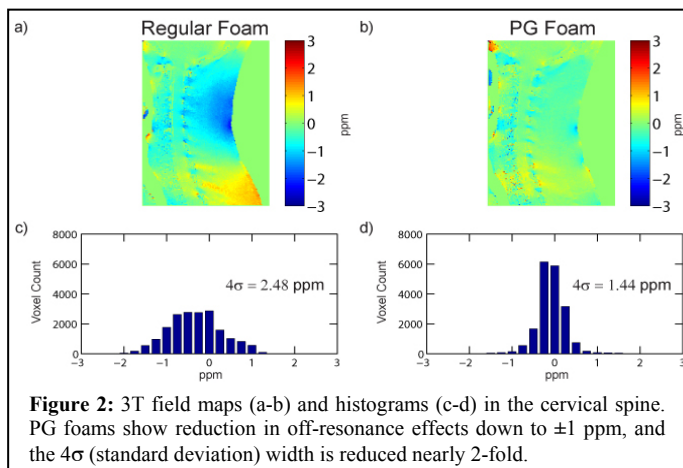

Figure 2: 3T field maps (a-b) and histograms (c-d) in the cervical spine. PG foams show reduction in off-resonance effects down to ±1 ppm, and the 4σ (standard deviation) width is reduced nearly 2-fold.

Discussion: PG foams added no extra noise to the receiver coil, demonstrated excellent susceptibility matching, showed improved fat suppression and produced no MRI signal. Compared to other potential fluid matching agents, PG foams are safe for patient use [2], inexpensive, lightweight, and compatible with embedded RF coils. PG foams could have many important practical applications, such as improved fat suppression in dynamic contrast-enhanced breast MRI, bSSFP applications, EPI-based protocols (including BOLD fMRI), and diffusion-weighted MRI [1].

References: [1] F. Sardanelli et al. Radiol Med 112:1244-1251 (2007). [2] G. Lee et al. JMRI 32:684-691 (2010). [3] J. Schenck. Med Phys 23:815-50 (1996).
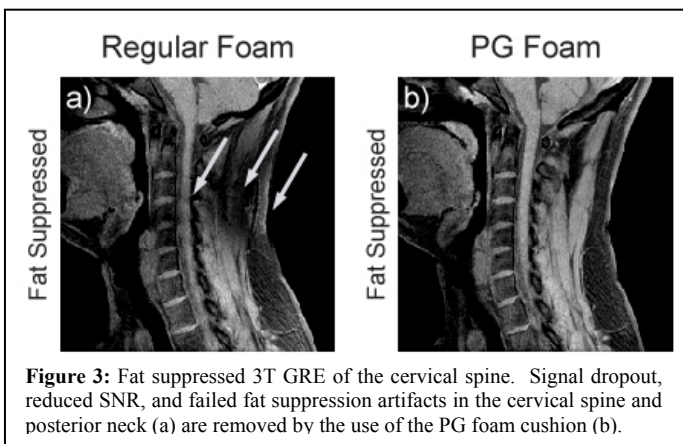
Figure 3: Fat suppressed 3T GRE of the cervical spine. Signal dropout, reduced SNR, and failed fat suppression artifacts in the cervical spine and posterior neck (a) are removed by the use of the PG foam cushion (b).