Fat Suppression with Independent Shims for Bilateral Breast MRI

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Introduction: There exists a significant static field inhomogeneity for breast MRI related to the shape of the breast and susceptibility difference at air/tissue interfaces [1]. Field inhomogeneity can cause imaging artifacts or failure in fat suppression when spectral-selective fat suppression methods are used. For bilateral breast MRI, the large field variation over the two breast volumes makes robust fat suppression more difficult. Conventionally, a constant and linear shim correction is conducted by the scanner to remove field inhomogeneity, but optimal shim values can differ between the two volumes. A dual-band spectral-spatial pulse [2,3], which excites two slabs in a time-interleaved manner, allows independent selection of both center frequency and linear shims for each slab. Here we incorporate independent shims to our bilateral protocols and compared fat suppression between standard shims and independent shims for spectral-spatial excitation.

Methods: A dual-band spectral-spatial pulse [2] (Fig. 1) excites one slab on positive gradient lobes and other slab on negative gradient lobes. This time-interleaved excitation allows the center frequency and shims to be alternated during excitation between optimal values for each slab. For practical implementation, an average shim in each axis over the two slabs was set using the shim channels of the scanner and an additional oscillating shim was applied with the gradient waveform as explained in [2] (Fig. 2).

Five healthy volunteers were scanned using a 1.5T GE Excite scanner and an 8-channel phased-array breast coil. For acquisition, flyback EPI [4] with the echo train length (ETL) of four was used with a 20º flip angle, a 20 x 20 cm FOV and 256 x 192 matrix (in-plane), half-Fourier, 1.6 mm slice thickness with 64 sagittal 3D sections per breast (total 128 sections). The independent slab-phase modulation technique [5] was incorporated with the dual-band pulse to avoid encoding the empty space between the breasts. For each subject, the center frequency and linear shim values of the x, y, and z axis for the left breast and right breast are separately measured by the scanner and used for experiments with different shim methods as follows: (1) apply the left breast shim values to both breasts, (2) apply the right breast shim values to both breasts, (3) apply the average shim values to both breasts (standard shims), (4) apply the left breast shim values to the left breast and right breast shim values to the right breast (independent shims).

Results: Figure 3 shows axial reformatted images of inferior breasts from one volunteer with the four shim methods. When the optimal left shim values or the optimal right shim values are used for the both breasts (a, b), the ipsilateral breast shows excellent fat suppression, while the contralateral breast shows bright fat or suppressed water as shown by arrows. Using average shim values to both breasts (c), failure in fat suppression can be still seen in the right breast. With independent shims (d), the fat suppression in both breasts is as good as the best case of (a) and (b). Figure 4 shows sagittal slices from the right breast corresponding to the dashed line in Fig. 3. By using the standard shims, fat suppression fails in the inferior edge of the breast, which typically possesses significant field inhomogeneity, yielding partially-suppressed water and unsuppressed fat signal; however, the independent shims provide excellent fat suppression in this region.

Discussion: For bilateral breast MRI, use of the same center frequency and linear shims for the right and the left breasts can cause failure in fat suppression. The independent shim method, which uses optimized shim values for each breast separately, can provide more homogeneous fat suppression and better delineation of breast tissue over the two breasts.

References
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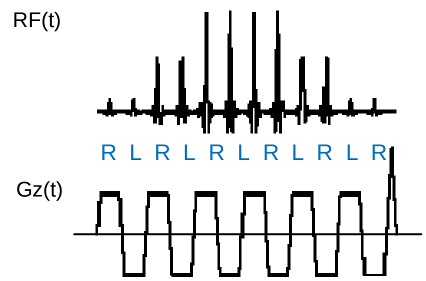

Fig. 1. Dual-band spectral-spatial excitation.

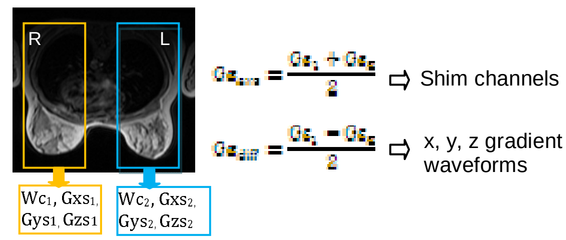

Fig. 2. Independent shim implementation. Shims for the right breast and left breast are separately measured and then average and difference values are calculated, and used to apply independent shims.

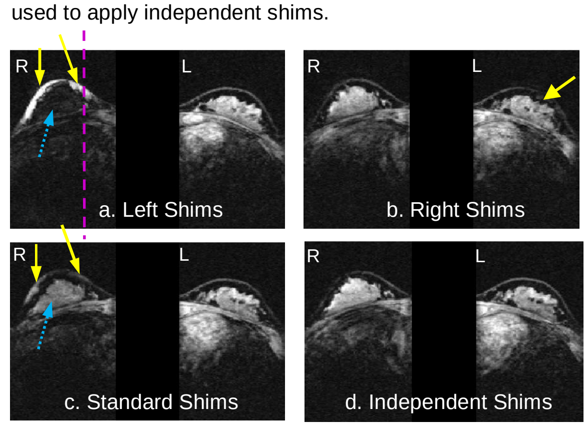

Fig. 3. (a-d) Axial reformatted images from the four different shim methods. The regions of failure in fat suppression are shown by arrows (solid yellow: unsuppressed fat, dashed blue: suppressed water). With independent shims, fat suppression was done robustly over the two breasts.

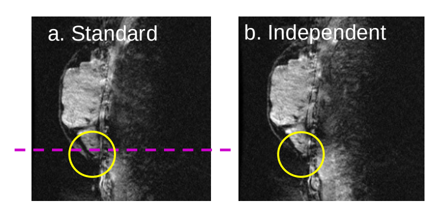

Fig. 4. Sagittal slices from the standard shims (a) and independent shims (b). With using the standard shims, fat suppression fails in the inferior edge of the breast; however, independent shims provide robust fat suppression in this area. The dashed line in (a) corresponds to the axial position in Fig. 3.