Contrast-Enhanced Single-Echo Acquisition Imaging Using Single-Point Dixon

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Introduction

Single-Echo Acquisition (SEA) using a parallel array of many localized coil elements can acquire an entire slice-image only with a single echo, leading to extremely high frame-rates up to 1/TR frames per second [1]. However, at high frame rates, SEA imaging may suffer from reduced contrast due to the strong T1 weighting. This poses a potential problem for future clinical applications (such as dynamic MRI) of SEA because the fats have short T1 and the strong fat signals can limit the image contrast of the interested water protons. In this project, a single-point Dixon method was integrated with SEA imaging to improve image contrast (or to acquire separate water/fat images). For imaging structures with smooth phase variations, the method normally does not take additional pulses or reference acquisitions as required by the conventional chemical saturation or multi-point Dixon methods [2]. Thus, it allows fat suppression while maintaining high frame rates of SEA imaging.

Methods

The SEA slice-image is acquired using a 64-channel parallel array coil and receiver systems. Each single-point Dixon SEA image line can be modeled as

$$I(x, y_c) = (W(x, y_c) + jF(x, y_c))S_c(x, y_c)e^{j\theta_c(x,y_c)}e^{j\phi(x,y_c)} \qquad (1)$$

where y_c is the position of the *c*-th channel, *W* and *F* are the water and fat signals with 90^o phase-difference induced by time shift of data window in the Dixon acquisition [2,3], $S_c(x, y_c)$ is coil sensitivity magnitude, $\phi(x, y_c)$ is the background phase shift common to all channels (such as those due to B0 field inhomogeneity and eddy current), and $\theta_c(x, y_c)$ is the coil-dependent phase shift (such as those due to the complex coil sensitivity). For simple processing, it is assumed that: 1) coil-sensitivity is localized to the voxel size; 2) all channels are equalized to have the same maximum gain/sensitivity, $S_c(x, y_c)$. Stacking all 64 complex image lines forms a complete SEA image. Based on the above assumptions, the complex image pixels of the SEA image can be modeled as $I = (W + jF)e^{j(\phi+\theta)}$ (2) . To account for the channel-dependent phase term θ_c, an 8 x 64 image stripe in the SEA image was extracted and a vector sum of all 8 points were used to remove relative channel phase θ_c, by making SEA image to have smooth phase along y_c direction. Assuming that the background phase contains only smooth spatial variations, a region-growing algorithm can be used to estimate ϕ using the orthogonality of water and fat signals and sooth phase constraint as prior knowledge [3-5]. Except some rare degenerated cases, the algorithm works with the single acquisition data without need for additional references. Once the phase term is estimated, fat-only and water-only SEA images can be decomposed using the regular single-point Dixon technique [5], as such:

$$I' = Ie^{-j\phi} \quad (3), \qquad W = \text{Re}\{I'\} \quad (4), \qquad \text{and } F = \text{Im}\{I'\} \quad (5)$$

Results

To test the proposed methodology, a phantom was constructed using a 13cm-diameter box with compartments filled with (1) vegetable oil (fat), (2) distilled water, and (3) water doped with 1g/L $CuSO_4$ (see Fig.1a). A regular spin-echo protocol was modified to acquire only a single echo data with the acquisition window shifted by 186 us to create a 90^o phase difference between water and fat signals at 4.7 T. Single-point Dixon SEA images were acquired on a 4.7 T Bruker Scanner with 64-channel linear array (2 mm by 8.1 cm planar-pair elements). Scan parameters were: TE = 20 ms, TR = 250 ms, RBW = 50 kHz, ST = 3 mm, and FOV = 14 cm. Fig. 1 (b) and (c) show magnitude and phase of the single-echo acquisition image after correcting channel-dependent phase. Using the estimated background phase map shown in Fig. 1 (d), water-only (Fig. 1(f)) and fat-only (Fig. 1(g)) images were reconstructed using Eqs. (3-5).

Discussion

Because SEA imaging uses coil sensitivity for spatial localization and no multiple phase encodings are acquired, the SEA images are different from the conventional Fourier images. Using the channel and spatial correlations of the image phase in a single-point Dixon method, we showed that it is possible to produce clearly decomposed fat-only and water-only SEA images. For the objects with smooth phase variations, phase correction can be accomplished without additional phase reference. This technique is unique in that it does not perform coil-by-coil water/fat reconstruction, as in conventional water/fat imaging with array coils. The technique is expected to be useful to improve tissue-contrast in clinical applications, especially when very fast frame-rates in the regime of 1/TR is used, by suppressing unwanted strong fat signals.

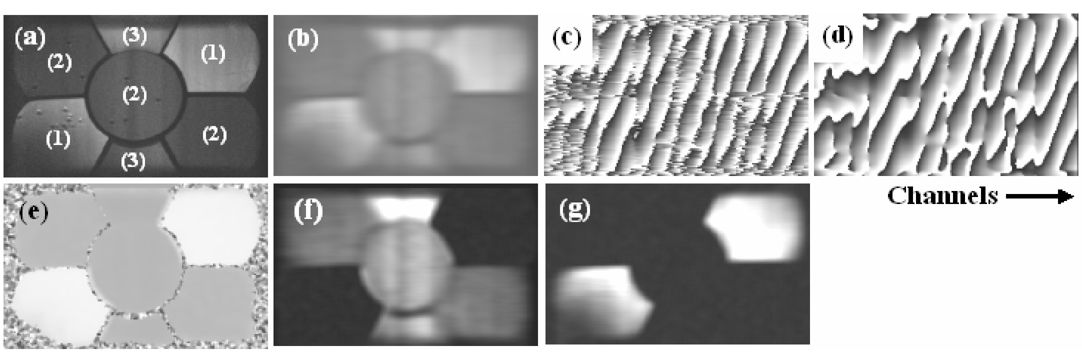

Fig. 1 (a) High resolution image (256 encodings); (b) SEA magnitude image; (c) SEA phase image (after relative channel phase correction); (d) Estimated background phase; (e) Phase map after phase-correction; (f) Reconstructed water-only SEA image; note the improved contrast as comparing to (b); and (g) Reconstructed SEA fat-only image.

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