Sliding Phase Encoding in Table Motion Direction for 3D Continuously Moving Table Imaging

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Introduction

Various continuously moving table (CMT) imaging methods are developed for whole body imaging. Kruger et al. describe CMT imaging with longitudinal (superior-inferior (S/I)) frequency encoding[1]. This maximizes the longitudinal field of view on each echo (FOVsub) and increases signal to noise ratio (SNR). Aldefeld et al. describe CMT imaging with lateral frequency encoding[2]. This minimizes the number of phase-encoding steps required and achieves a shorter scan time because FOVsub is likely to be smaller than lateral FOV length (FOVlat) due to magnetic field inhomogeneity and gradient nonlinearity. However, the excitation slab must track the same region while each series of phase encoding is done in the direction of table motion. Therefore, the slab varies from maximum to half thickness according to the encoding order. A thinner slab results in a lower SNR.

We proposed a CMT imaging method called sliding phase encoding (SPE)[3] in previous research. SPE enables lateral (left-right (L/R)) frequency encoding without slab tracking. Scan time is minimized with lateral frequency encoding, and SNR is maximized using maximum slab thickness. We apply SPE to 3D imaging with fixed axial slab excitation, and 3D gradient echo images are successfully reconstructed.

Method

Figure 1 shows the typical encoding order and table motion direction used for SPE imaging. The last encoding (sliding phase encoding) is set in the longitudinal direction of the table motion. The slab position is fixed to a magnet. This means the slab relatively moves against moving patient. Figure 2 shows the relationship between sliding phase encoding and table position. The sliding phase encoding value changes from -pi to pi each time the table traverses the slab thickness. In this case, the excitation region of the patient completely changes during each series (-pi to pi) of encoding. The table motion tears the relationship between MR signals and the reconstructed images away from the Fourier transform. The MR signals, s(n), acquired by SPE are written as

$$s(n) = \int_{r=0}^{FOV_{total}} m(r)\exp(-2\pi(r - r_{table}(n))k(n))w(r - r_{table}(n))dr \, , \tag{1}$$

where n is the echo number, m(r) is the magnetization at position r, $r_{table}(n)$ is the table's displacement at echo n, k(n) is the SPE value shown in Fig. 2, and w(r) is a system parameter such as the slab excitation profile. The image, m(r), is reconstructed by solving for m(r) using Eq. 1. Though this equation is in ill condition, we can find m(r) by solving for the real and imaginary parts of m(r) independently using approximation.

Experiment

The proposed method was tested using phantom experiments. Three bottle phantoms were put in the table motion direction. A T/R body coil fixed to a magnet was used. The slab excitation profile was obtained by imaging a uniform phantom. The profile is shown in Figure 3. Frequency search, gain setting and shimming were performed once at the center of the phantom. The table velocity was 20mm/s. The imaging sequence was RF spoiled steady state acquisition with a rewound gradient echo (RSSG). The other imaging parameters were imaging matrix= 128 x 6 x 300 (A/P x L/R x S/I), signal matrix= 128 x 6 x 450(A/P x L/R x S/I), FOV= 240 x 120 x 600 mm^3, slab thickness (S/I)= 200 mm, TR= 12 ms, TE= 6 ms, and FA= 30°.

Results & Discussion

Figure 4 shows the SPE reconstruction results, which indicate that the proposed methods successfully reconstructed images. However, the signal matrix size was 1.5 times larger than the imaging matrix size in the S/I table motion direction for stable image reconstruction. This may be caused by blur slab profile. Due to blur slab profile, there are poorly excited regions. Extra data may be needed to compensate for insufficient signals. Although a slab selective 3D imaging needs extra echoes to prevent aliasing or signal loss, the signal matrix is still large. An optimal slab profile for SPE is needed to improve scan time.

Conclusion

SPE enables lateral frequency encoding without slab-tracking. We applied SPE to 3D imaging with fixed axial slab excitation, and 3D gradient echo images were successfully reconstructed. However, large signal matrix was needed for stable reconstruction in current setting. An optimal slab profile for SPE is needed to improve scan time.

Reference

[1] David G. Kruger, Stephen J. Riederer, Roger C. Grimm, and Phillip J. Rossman. Magn. Reson. Med. 2002; 47:224-231.
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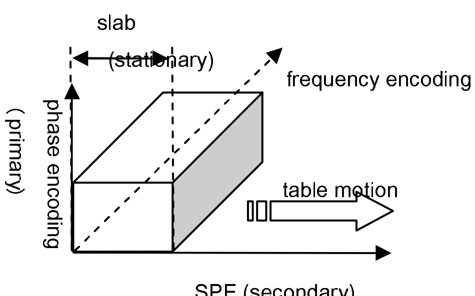

Fig. 1. Sliding phase encoding and table motion. Axis used for SPE runs in same direction as table motion.

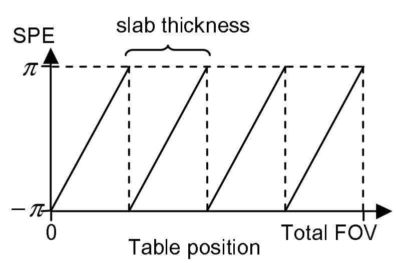

Fig. 2. Sliding phase encoding vs. table position: SPE value changes from -π to π each time table traverses slab thickness.

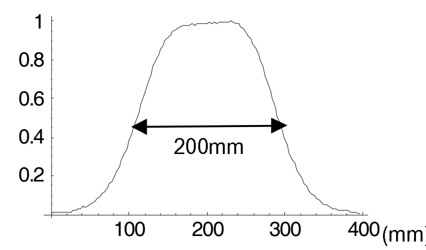

Fig. 3. Slab profile obtained by uniform phantom imaging.

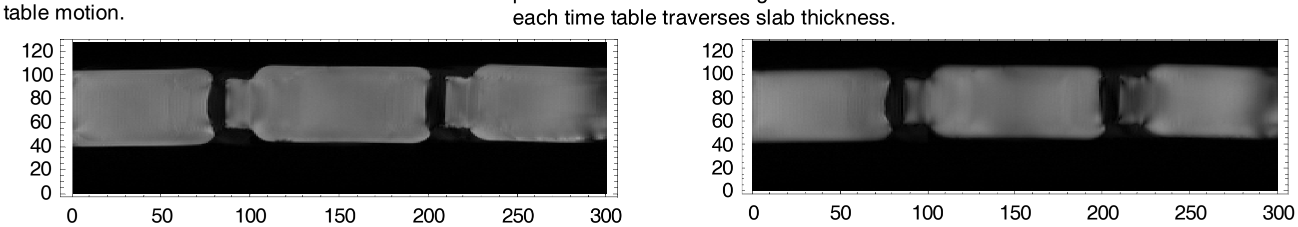

Fig. 4. Phantom images, showing 2 out of 6 sagittal planes.