SSFP single point fat water separation

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Abstract

Steady State Free Precession provides strong signal, high contrast images in a short scanning time. However, strong fat signal contaminates image. This paper is to separate fat signal by applying single point fat water separation method.

Introduction

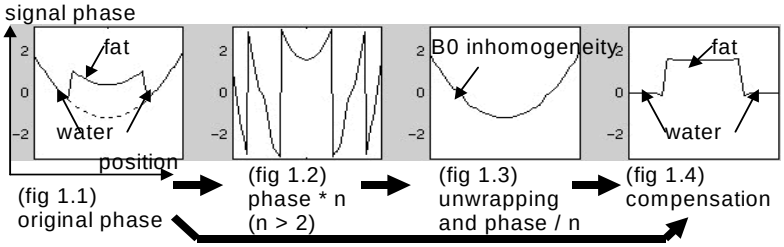
Steady State Free Precession (SSFP, FIESTA, True FISP, balanced FFE) provides high SNR image rapidly. But it suffers from a bright fat signal. Current techniques to reduce the fat signal are Fat Saturation RF pulse [1], Fluctuation Equilibrium MR (FEMR)[2], Linear Combination SSFP (LCSSFP)[3]. In ISMRM 11th meeting, some post-processing fat separation methods are presented; that is out-of-phase TE [4], multi point Dixon [5] and Phase cycling single quadrature Dixon [6]. However, FEMR, LCSSFP, multi point Dixon and Phase cycling increases number of TR and Fat Sat pulse breaks steady state. Although out-of-phase TE does not increase scan time, high resolution is required to avoid partial volume effect and this method is very sensitive to B0 inhomogeneity.

This paper is a following job of Phase Cycling single quadrature Dixon [6] and demonstrates single point fat water separation method without Phase Cycling. Steady State is kept because this method does not require Fat Sat pulse. This method does not require additional data acquisition and very robust to partial volume effect and B0 inhomogeneity.

Theory (Single point fat water separation)

This method is to separate fat and water signals by using signal phase offset information. Not like multi point Dixon method, this requires only one phase offset data.

This requires TR to be in-phase time. TR is 5.0msec in 1.5T system and 9.9msec in 0.7T system. TE must be TR/n where n must be natural number more than 2. For example, TE is 1.67 (n=3) in 1.5T system and 3.33 (n=3) in 0.7T system. In the case of n = 2, this is same as reference [4].



If n is more than 2, the fat signal phase is "water phase+π/n". Conceptual 1D signal phase image is like (fig1). The water signal phase suffers from B0 inhomogeneity (ex. parabolic line). By multiplying the signal phase by n, fat signal phase offset is canceled (fig1.2). By unwrapping and dividing the signal phase by n, only B0 inhomogeneity element is extracted (fig1.3) and phase data is compensated by it (fig1.4). In this way, this method is robust to B0 inhomogeneity. In fig. 1.4, 0 and π/n phase parts indicates water and fat respectively. As n is not 2, fat and water are separated correctly even in partial volume pixel.

In former job [6], Phase cycling is required. However, TR of this paper is in-phase time and water and fat signals have same phase at Excitation timing and only TE determines phase difference between water and fat. So single acquisition is enough.

Method

SSFP is scanned with Signa Open Speed 0.7T scanner (GE Yokogawa Medical Systems) with 3D FIESTA pulse sequence. The protocol in fig.2 is TE 3.3 ms, TR 9.9 ms, flip angle 90, slice thick 3.2 mm, #slice 20, 224*160 matrix, 30sec breath hold. Fat signal is separated from water very clearly. Fig 3 indicates 3D FIESTA water image of leg without Contrast Agent. Fat signal of bone marrow and surface fat is rejected from artery and vein signal.

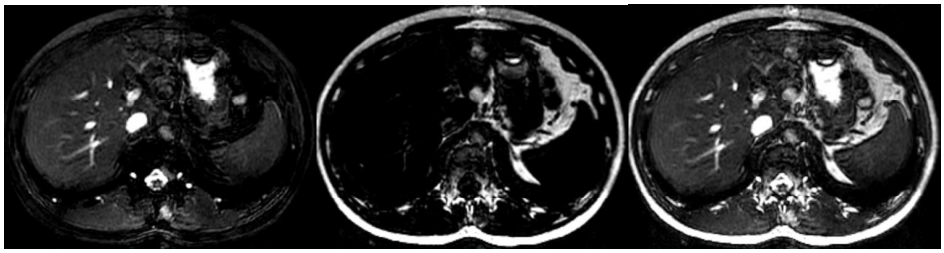


fig 2 Liver;Fat signal(center) is separated from water(left). Right is a combined image.

Result and Discussion

Fat and water signal are separated with only single data acquisition. As this method does not use Fat Sat pulse, Steady state is kept completely. Band artifact is very few because TR is short enough.

However, as TE is not half of TR, SSFP uses fractional echo and this causes flow artifact from aorta in fig.2. Slow artery signal in fig 3 does not cause flow artifact. So flow compensation from fast motion needs to be considered.

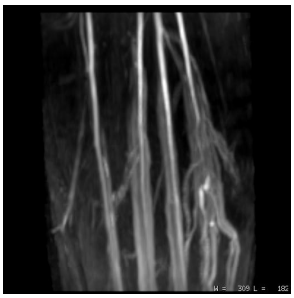


fig 3 Leg w/o contrast agent

Reference

[1]Scheffer K, et al. Magn Reson Med 2001; 45:1075-1080.
[2]Vasanawala S.S., et al. Magn Reson Med 1999; 42:876-883.
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[4]Hargreaves B.A., et al. 11th ISMRS 2003, p.548.
[5]Reeder S.B., et al. 11th ISMRS 2003, p.698.
[6]Miyoshi M, et al. 11th ISMRS 2003, p.981.