The Effect of B_0 Inhomogeneity on The SSFP Dixon Technique: A Comaprison of Variants

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Introduction

Images of fat-water separation can be obtained by combining the Dixon method [1] and the balanced steady-state free precession (bSSFP) sequence [2], which is termed as SSFP Dixon method [3]. The application of this method was successful at regions of relatively homogeneous B_0 [3]. Another variant of this method is the dual-TR method, which was anticipated to have a better immunity to the shimming condition [4]. In this study, we validate this concept with experiments of both methods at regions with significant B_0 inhomogeneity.

Theory

The phase behaviors between fat and tissue water (e.g. muscle) at a 3.0T environment using steady-state bSSFP sequence is shown in **Fig. 1.** Here "ip" and "op" stands for in-phase and out-of-phase behaviors between the two tissues. The original SSFP Dixon method use a single TR = 3.4 ms and acquire two images with center frequency adjusted to ± 80Hz (the two green spots in Fig. 1) [3]. At the on-resonance condition (i.e. off-resonance frequency = 0 Hz), the choice of TR = 3.4 – 5.4 ms can also lead to in phase of the two tissues, or out of phase when TR < 3.2 ms or TR > 5.8 ms. Using this property, we can acquire in-phase and out-of-phase bSSFP images using two different TR's without altering the system's center frequency. This was then termed as Dual-TR method [4].

Also from Fig. 1, the tolerance to the B_0 inhomogeneity varies in accordance with TR. In the original method, the two images are acquired already with center frequency shifted to ±80 Hz. The tolerance to resonance frequency drift will be at most ~80 Hz in each image (the two green bars). Meanwhile, an image acquired at TR = 4.5ms is anticipated to be in-phase with a frequency tolerance ~ 200 Hz (the central red bar). The out-of-phase image can be acquired at TR = 2.8 ms or TR = 6.8, while the former has a much wider shimming tolerance (the left red bar) than the later does (the right red bar). However, using a TR as short as 2.8 ms inevitably requires the application of the partial-echo function, which may arouse one's suspicion about the effect of an extra phase offset.

Materials and Methods

We investigated the tolerance to the B_0 inhomogeneity by performing scans at head-and-neck regions, where the B_0 inhomogeneity is regarded as significant. The images were acquired on a 3.0T system (Siemens Trio, Erlangen, Germany). We used a set of TR/TE, including 3.4/1.7, 4.5/2.25, 2.8/1.26 (partial echo), 6.8/3.4 ms. Image matrix size was 128×128. Raw data were processed off-line with MATLAB software to get the calculated "water images" and "fat images". A gradient-echo phase image of the same slice was also obtained to give an estimation of the B_0 drift across the imaging plane. TrueFISP with built-in fat suppression (FS-TrueFISP) was also performed for comparison of the fat suppression effectiveness to SSFP Dixon methods.

Results

The SSFP Dixon water image **(Fig. 2a)** exhibits superior fat-suppression effectiveness than that in the FS-TrueFISP image **(Fig. 2c)**. **Fig. 3** shows the image results of a female volunteer. Note that the erroneous assignment of the tongue signals mainly to the fat image in the original TR = 3.4 ms method. **Fig. 4** is the gradient-echo phase image corresponding to the same slice in Fig. 3 for a rough estimation of the B_0 distribution. The dental repair with amalgam on the right side has influence on B_0 inhomogeneity.

Discussion and Conclusion

We have demonstrated that for body regions with significant B_0 inhomogeneity, both the two dual-TR variants had a better performance than the original method in Ref. [3]. For the dual-TR methods, to shorten TR to 2.8 ms requires the use of partial echo function, or one has to use 3D slab scan to circumvent the limited gradient switching and the possible physiological stimulations. This situation is thus somewhat unfavorable. Also, an extra phase offset may bring along some complexities into the image data when partial echo is used. Using TR = 6.8 ms for the dual-TR method is therefore considered to be more desirable. In conclusion, we compared three variants of the SSFP Dixon techniques, and validate the anticipation that dual-TR methods have a better immunity to B_0 drift.

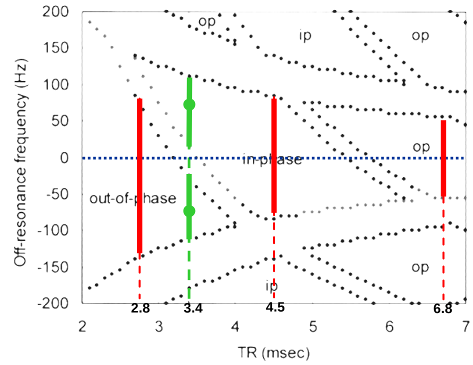

FIG. 1. Phase behavior of fat and tissue water (e.g. muscle) as a function of TR and center frequency. "ip" and "op" stands for "in-phase" and "out-of-phase", respectively. The green line stands for the original method, while the red lines are for the dual-TR methods.

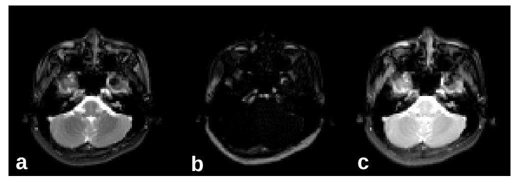

FIG. 2. Comparison of SSFP Dixon images and a fat-suppressed TrueFISP image, (a) the Dixon water image (b) the Dixon fat image (c) FS-TrueFISP. Fat suppression effectiveness is better in the Dixon water image.

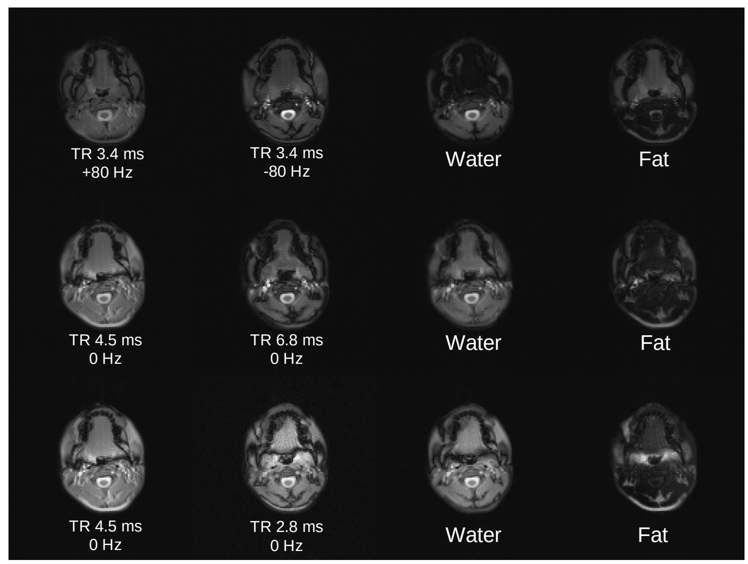

FIG. 3. The axial images of a female volunteer at the tongue level, showing the **original method** (upper row: TR = 3.4 ms with ±80 Hz adjustment), the **dual-TR method version 1** (middle row: TR = 4.5 ms and TR = 6.8 ms) and the **dual-TR version 2** (lower row: TR = 4.5 ms and TR = 2.8 ms using partial echo). In all three calculated water image, the tongue signals are lowest in the original method, where they are mostly assigned to the fat image. The signal intensities in the water image of dual-TR version 1 are a bit more homogeneous than those in the version 2. As seen, there are some bright signals around oropharynx in the fat image of dual-TR version 2. This is related to hyperintensity at the same region in the TR = 2.8 ms image, of which the cause is unclear.

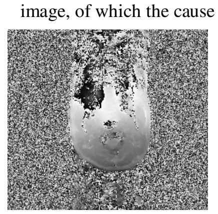

FIG. 4. A gradient-echo phase image (TR/TE = 1000/12.46 ms) of the same slice in Fig. 3 demonstrates the B_0 distribution across the image plane. The dental repair with amalgam on the right side shows its influence on B_0 inhomogeneity.

References

1. Dixon WT, *Radiology* 1984;153:189 **2.** Oppelt A, *Electromedia* 1986;54:15 **3.** Huang TY, *MRM* 2004;56:1328 **4.** Huang TY, *ISMRM* 2007 #1626