Fat Quantification with an Interleaved Bipolar Acquisition

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Target Audience: This work targets researchers in chemical-shift based water/fat separation in all anatomies.

Introduction: Chemical-shift based water/fat separation has gained increasing use in clinical practice. It can be achieved with multiple gradient echo acquisitions using either unipolar [1] or bipolar readout gradients [2]. Typically, fat quantification is performed using at least 6 unipolar echoes separated with fly-back readout gradients [3]. Multiple shots are required to achieve optimal echo-spacing within the recommended range that provides the best SNR performance [4]. This increases the scan time. On the other hand, in a bipolar acquisition data is acquired with positive and negative readout polarities, potentially resulting in 1) shorter echo-spacing, 2) shorter scan time, and 3) higher SNR efficiency [2]. However, phase errors are produced between positively and negatively acquired data; if uncorrected, severe artefacts are produced in water and fat components. We propose a new bipolar acquisition scheme that overcomes this problem without requiring direct correction of the phase errors.

Theory and Methods: Bipolar multi-echo sequences acquire odd and even echoes with positive and negative polarities respectively (all k-space lines +,-,+,-,+,-) [2, 5]. In this work, the readout gradients also alternate their polarities every other k-space line (odd lines +,-,+,-,+,- vs. even lines -,+,-,+,-,+). By grouping k-space lines with same polarity, parallel imaging reconstruction can be used to obtain two full k-spaces with opposite readout polarities. By complex averaging, the inconsistent phase errors between odd and even echoes are removed [6] and water/fat separation techniques employed with conventional unipolar sequences can be performed. This approach does not attempt to directly correct the phase errors like previous phase correction techniques [2, 5]. Instead, the complex averaging adds a fixed phase term to all the echoes [6], removing the inconsistency between even and odd phase errors.

Phantoms and in-vivo experiments were performed on a 3T MR (Discovery MR 750, GE Healthcare, Waukesha, WI) using a knee T/R 8-coil array. A 3D IDEAL-SPGR sequence was modified to acquire data in an interleaved bipolar readout scheme. To achieve similar echo-spacing for a 6-echo acquisition, 2 shots of three echoes were used in the unipolar experiments. In phantom experiments, TR/TE1/ΔTE = 5.74/0.88/0.69 and 5.65/0.84/0.704 ms for unipolar and interleaved bipolar respectively. BW=142.86 kHz, acquisition matrix=128x128x28, FOV=35 cm for both sequences. For in-vivo experiments, TR/TE1/ΔTE = 8.09/1.11/0.87 ms and 6.74/1.02/0.86 ms for unipolar and interleaved bipolar, respectively. BW=142.86 kHz, acquisition matrix=128x128x28, FOV=25 cm for both sequences. Conjugate-gradient SENSE [7] was used for parallel imaging reconstruction. T_2^*-corrected water/fat separation was performed using Max-IDEAL [8]. SNR efficiency $\left(\mathrm{SNR}/\sqrt{\text{acquisition time}}\right)$ was calculated using the method described in [9].

Results: The aim is to compare the proposed method with the well-established unipolar technique as a reference. Table 1 shows fat fractions from selected ROIs in Fig. 1. Fat fraction maps from a healthy volunteer are shown in Fig. 2 (a-b), with the corresponding SNR efficiency maps of water images shown in Fig. 2 (c-d). The proposed method demonstrated accurate fat fraction and higher SNR efficiency compared to the unipolar sequence. Overall scan times were 58s for unipolar and 31s for interleaved bipolar.

Discussion: Although additional reference lines were acquired to map the coil sensitivities, the overall acquisition time is still less than a unipolar sequence with similar echo-spacing, particularly at higher bandwidth. This approach is not vulnerable to residual phase errors that might occur in previous phase correction methods employed in bipolar reconstruction [2, 5]. Moreover, the number of acquired reference lines does not affect the accuracy of the correction as in Yu *et al.* [5]. This method is limited to coil-arrays as the reconstruction pipeline implicitly decimates the data by a factor of 2 and uses parallel MRI to reconstruct two fully sampled data sets. However, this limitation is not significant given the widespread usage of coil-arrays in clinical practice.

Conclusion: Fat quantification using a new bipolar sequence was demonstrated. The interleaved acquisition scheme allows accurate fat measurement in shorter scan time, with higher SNR efficiency, compared to unipolar acquisitions.

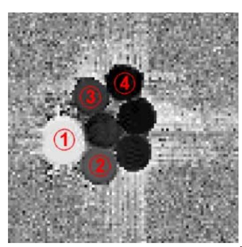

Fig.1: Selected ROIs on a fat fraction map from a phantom experiment with its corresponding fat fractions shown in Table1.

Table.1	*Unipolar*	*Interleaved Bipolar*
ROI #1	95.93 ± 0.7	95.36 ± 0.7
ROI #2	22.21 ± 1.1	20.78 ± 1.3
ROI #3	10.81 ± 1.1	10.59 ± 1.0
ROI #4	1.53 ± 0.7	1.50 ± 0.7

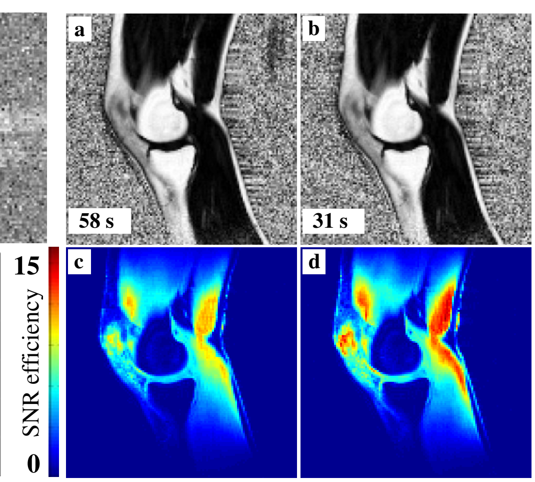

Fig.2: Fat fraction and SNR efficiency maps of water images from unipolar (a, c) and interleaved bipolar (b, d) sequences, respectively.

References:
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