Fast Single Breath-hold 3D Abdominal Imaging with Water-Fat Separation

P. Koken[1], H. Eggers[1], and P. Börnert[1]
[1]Philips Research Europe, Hamburg, Germany

Introduction

In abdominal MRI, it is important to achieve large volume coverage and robust water/fat separation with in a short total scan time. To avoid respiratory motion artifacts of the organs under study, the complete data acquisition has to take place in a single breath-hold, typically shorter than 25s. Three-point chemical-shift encoding was found to achieve high quality water/fat separation, even in the presence of considerable B_0 inhomogeneity [1]. This approach needs at least three separate gradient echoes, sampled at different echo times, which is detrimental to the desired short scan time. Parallel imaging [2] helps to reduce the scan time significantly, allowing to perform such a water/fat resolved scan in a single breath-hold [3]. However, using a gradient echo sequence that acquires only one echo per TR is not very efficient. In order to speed up the data acquisition, a multi-echo sequence using fly-back gradients can be employed [4], which avoids the odd/even echo problems known from EPI. In this feasibility study, an EPI-like readout samples echoes at both polarities of the readout gradient to further increase the sampling efficiency. Appropriate signal correction in combination with highly accelerated parallel imaging allows water/fat resolved abdominal imaging during one breath-hold.

Methods

Data were acquired in healthy volunteers on a 1.5T clinical scanner (Achieva, Philips Medical Systems) using a 32-element cardiac coil with sufficient feet-head (FH) coverage. A 3D EPI-like sequence was used to sample three gradient echoes. After each excitation, phase encoding was applied only once, such that the alternating readout gradient encodes the same *k*-space line at three different echo times as fast as possible (Figure 1). The first TE was adjusted to 2.6 ms, the TE increment to 1.5 ms, TR to 9 ms, the flip angle was 15°, and sampling was performed with a bandwidth of 883 Hz/pixel. The FOV was $370 \times 260 \times 210$ mm^3 (RL×AP×FH), and the voxel size was $1.65 \times 1.65 \times 3.0$ mm^3. A SENSE factor of 6 (3FH × 2AP) was used resulting in an overall scan time of 24s. Coil sensitivity maps were acquired in a preceding reference scan. During reconstruction, first, the inconsistencies between the odd and the even echoes were corrected using reference data measured just before the scan, similar to Reeder et al. [5]. Using odd and even echoes, the chemical shift appears in opposite directions along readout. However, with high acquisition bandwidth, this shift is in the sub-pixel range and can be neglected in the first order. The bandwidth of 883 Hz chosen for the examination, results in a shift of 0.25 pixels between water and fat images. After image reconstruction, an iterative water/fat separation was performed using a region-growing algorithm for local B_0 inhomogeneity estimation, similar to the method described by Yu et al. [1].

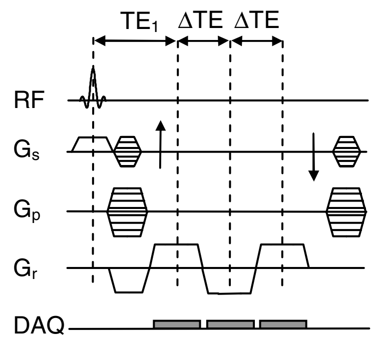

Figure 1: Schematic pulse sequence for water/fat chemical shift encoding using odd and even gradient echoes.

Results

Figure 2 shows different axial slices and a reformatted coronal slice from a 3D data set of a volunteer. Due to optimized coil geometry, no SENSE artifacts were observed. All images show very good water/fat separation. No artifacts due to the use of data acquired with opposite gradient polarity are noticeable. Without the phase correction, the water/fat separation fails, mainly in the outer body regions.

Discussion and Conclusion

The feasibility of highly efficient 3D multi echo scanning with three-point water/fat separation in one breath-hold has been demonstrated. With a proper odd/even phase correction, it is possible to use echoes acquired with opposed readout gradient polarity. Therefore, fly-back gradients are dispensable, and scan time is further reduced compared to scanning approaches using only readout with identical gradient polarity. When using a lower bandwidth, the error due to the different direction of the water fat shift could lead to artifacts or failure of the water-fat separation. Future work has to integrate a proper handling of the different shift of fat in odd and even echo images.

The single breath-hold acquisition may enable more comfortable, fast and accurate diagnosis. The more efficient sampling can be used to either increase the spatial image resolution or reduce the breath-hold duration.

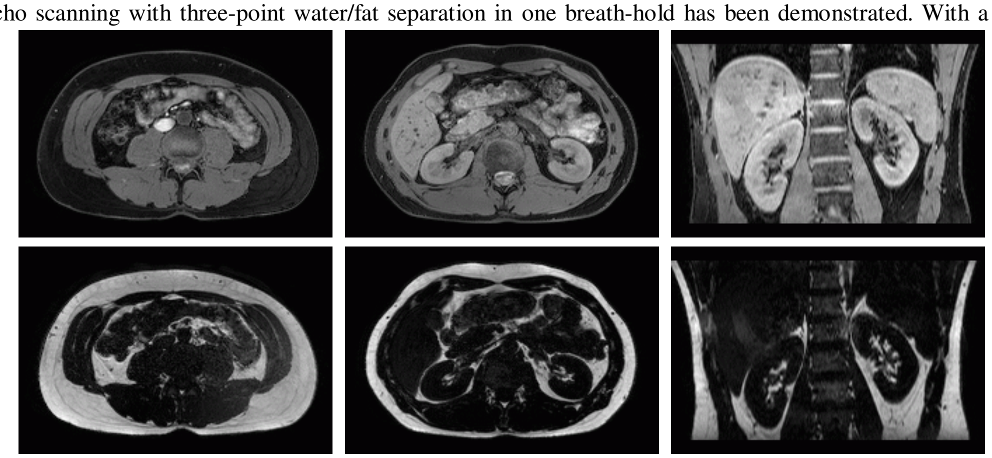

Figure 2: Selected slices of a 3D abdominal image volume. Top: water images, bottom: fat images. FOV: $370 \times 260 \times 210$ mm^3 (RL×AP×FH). Left and middle: axial slices, right: reformatted coronal slice.

References

1. Yu H. et al., Magn Reson Med. 54: 1032-1039 (2005) **2.** Pruessmann K. et al., Magn Reson Med. 42: 952-962 (1999) **3.** Shankaranarayanan A. et al., ISMRM, Seattle, 2453 (2006) **4.** Reeder S. et al., ISMRM, Seattle, 2444 (2006) **5.** Reeder S. et al., J Magn Reson Imaging 9:847-852 (1999)