ZTE for Whole Heart Imaging - Initial Results, Limitations and Challenges at 1.5T

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Target audience MR methodologists, cardiologists and musculoskeletal

Introduction

Ultrashort echo time (UTE) imaging [1] is an MRI technique that allows the depiction of highly ordered structures with very short T_2. Zero echo time imaging (ZTE) [2] is an emerging variant of UTE, which involves very low acoustic noise levels, and therefore improves patient comfort. Both techniques have some potential in cardiac MRI for the assessment of pathologic alterations such as plaque formation [3, 4] and fibrosis [5], but intrinsically do not provide sufficient contrast for a good visualization of the cardiac anatomy and vessel structure. Therefore, before addressing the ability to visualize very short living T_2 species, a fat-suppressed and T_2 contrast-prepared whole heart ZTE sequence has been implemented and was evaluated in healthy adult volunteers in this study. This method can combine good contrast, volumetric coverage and short echo times in one single scan with very low acoustic noise.

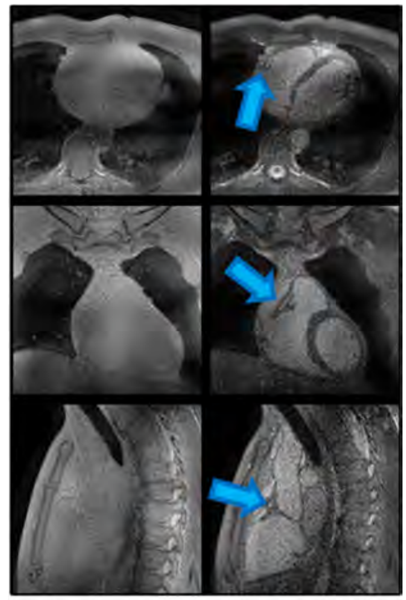

Fig.1. Reformatted whole heart ZTE images. (left column) PD contrast - no magnetization preparation. (right column) Fat suppressed, T_2-prep.- prepared ZTE images. Arrows indicate location of a coronary artery, voxel size: $(1.4mm)^3$.

Methods

In vivo experiments were performed on 6 healthy volunteers on a clinical 1.5T MRI system (Achieva, Philips Healthcare) using a dedicated 32-element cardiac coil array. No hardware modifications were required. Two ECG-triggered, volumetric ZTE sequences (FOV: $(320mm)^3$ / $(450mm)^3$ voxel size: $(1.38mm)^3$ / $(1.8mm)^3$, α: 5°, cardiac acquisition window: 150ms at late diastole) were combined with respiratory navigator gating (pencil beam, acceptance window: 6mm), spectral pre-saturation inversion recovery (SPIR), and T_2-preparation (TE: 50ms) to improve contrast between blood and myocardium, and to suppress epicardial fat and venous blood signal. In the ZTE read-out sequence, a short RF excitation block pulse (12.8µs duration) was applied in the presence of the "constant" readout gradient, which was altered in direction in each TR (2.4ms), following a trajectory on the surface of a sphere from the pole to the equator. Due to the finite transmit / receive switching time on this clinical system, a TE of 60µs was realized, and extra data sampling was used to fill the missing samples at k-space center [6]. The total scanning time was approximately 8 minutes during free breathing. A clinical balanced SSFP (bFFE) sequence [7] (α: 90°) and a T_1-weighted gradient dual-echo mDixon (FFE) sequence [8] (α: 15°), both using identical/comparable magnetization preparations and similar total scan durations like the ZTE sequence, were acquired for comparison in one volunteer.

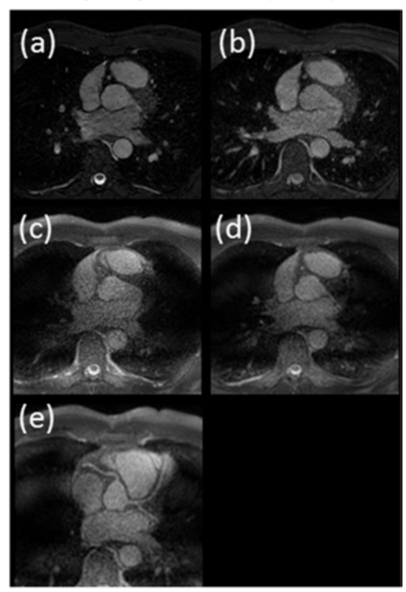

Fig.2. Comparison of whole heart CMRA. (a) bFFE result, (b) Dixon water image, (c) ZTE image, voxel: $(1.4mm)^3$, (d) ZTE image, voxel: $(1.8mm)^3$, (e) RCA-LAD-RCX reformat of data shown in (d).

Results and Discussion

Figure 1 shows selected reformats of a volunteer scan performed with ZTE without magnetization preparation, exhibiting poor, mainly proton density dominated contrast (left), and data from the same volunteer using SPIR and T_2 preparation (right). An improved depiction of the coronaries and the other anatomical structures is obvious. However, although parallel reception was employed, the SNR in the images needs further improvements. For illustration, Fig. 2 shows a comparison of clinical routine protocols such as bFFE (a), T_1-Dixon (b), with ZTE (c), where lowest SNR was observed with the ZTE sequence (c). SNR may be recovered by an increase of the flip angle; however, the ZTE flip angle is restricted by the maximum available B_1^+ and limitations of the pulse duration, since a large bandwidth is required for excitation in the presence of the readout gradient. High bandwidth frequency modulated RF pulses could be a potential solution for this problem in the future [9]. On the other hand, the Cartesian data in Fig.2 shows a better fat suppression quality than the ZTE scans. This can be a consequence of the long cardiac sampling window used and the fact that each radial spoke updates the center of k-space [10]. Despite potential SNR issues, a comparable image contrast was observed for all sequences, including contrast prepared ZTE. It is important to note that the fast T_2-relaxing species are mostly unaffected by the magnetization preparation. Due to their very short T_2, they lose coherence quickly during the long RF pulses involved in the magnetization preparation, and thus contribute to the ZTE signal. This is a significant difference of the ZTE method compared to other conventional sequences. This may provide diagnostic information that should be investigated in future studies.

Conclusion

ZTE provides very short TE, and therefore allows depicting short T_2 components at isotropic spatial resolution and a greatly reduced noise level. Although the basic feasibility of whole heart ZTE imaging has been shown in this study, much further work is necessary to prove its clinical potential.

References

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