Interleaved T_1- and T_2-weighted imaging

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Introduction: Diagnosis with MRI often requires the acquisition of T_1- and T_2-weighted images. In many cases specific signals (e.g. fat, blood, CSF) have to be suppressed. Inversion recovery (IR) sequences are often used either for T_1-weighting and/or signal suppression. These require long inversion times and additional time delays after each acquisition. To improve scan efficiency these times can be utilized to acquire multiple images with different contrast in one scan [1]. In this abstract, we propose a new interleaved dual contrast sequence that takes advantage of the long inversion times and time delays to obtain T_1- and T_2-weighted images in one scan. To demonstrate this we simultaneously acquire T_1- and fluid attenuated inversion recovery (FLAIR) T_2-weighted brain images in healthy volunteers. We also applied the sequence to patients with deep vein thrombosis (DVT) using the phase sensitive T_1-weighted images for direct thrombus visualization [2] and T_2-weighted images to distinguish arteries from veins.

Methods: All experiments were performed on a clinical 1.5 T scanner (Achieva, Philips Medical Systems) equipped with 32 receive channels. The proposed sequence consisted of an interleaved 3D gradient echo sequence with two different magnetization preparation pulses to acquire T_1- and T_2-weighted images in one scan (Fig. 1). In the first interval a non-selective inversion pulse was employed for T_1-weighting, whereas the second interval contained a T_2-preparation pulse (90-180-180-180-180-90) for T_2-weighting. The timing of the sequence was adapted for brain imaging and DVT imaging. For the brain scan the sequence was used to obtain T_1-weighted (first interval) and T_2-weighted FLAIR images (second interval). In particular, an inversion time of 500 ms (TI_1) was used in the first interval (total 1000 ms) to acquire a number (32) *k*-space profiles with TR/TE = 7.6/3.8 ms and α = 30º. In the second interval a T_2-preparation pulse with TE_{T2}=120 ms was applied and a number (32) of *k*-space profiles (low-high order) were acquired (TR/TE = 7.6/3.8 ms, α = 30º) at TI_2 = 1630 ms to ensure nulling of the CSF-signal. A delay of 2000 ms was employed after the second acquisition to allow recovery of the longitudinal magnetization (esp. CSF). Using this sequence, we acquire a 3D dataset of the brain of a healthy volunteer with a resolution of 1 x 1 x 6 mm. Furthermore, the phase of the T_2-weighted images was used to reconstruct phase sensitive T_1-weighted images providing a higher dynamic range [3]. For DVT imaging ECG-triggering was employed for each interval to ensure the acquisition was at end diastole where the flow in the femoral artery is slow [4]. In the first interval an IR-sequence with TI_1 = 500 ms was used to suppress the blood signal (T_1 = 1200 ms). During the second interval a T_2-preparation pulse with TE_{T2} = 80 ms was applied. Furthermore, fat suppression was used for both acquisitions. In each interval 32 gradient echoes were acquired (TR/TE = 5.2/2.5 ms). We obtained a 3D dataset with 80 axial slices (voxel size: 1.36 x 1.36 x 3.5 mm^2) in 3 patients with known DVT of lower extremities. A 32-channel coil was used to reduce the scan time to 3.5 min by using SENSE in two direction, with R = 4.

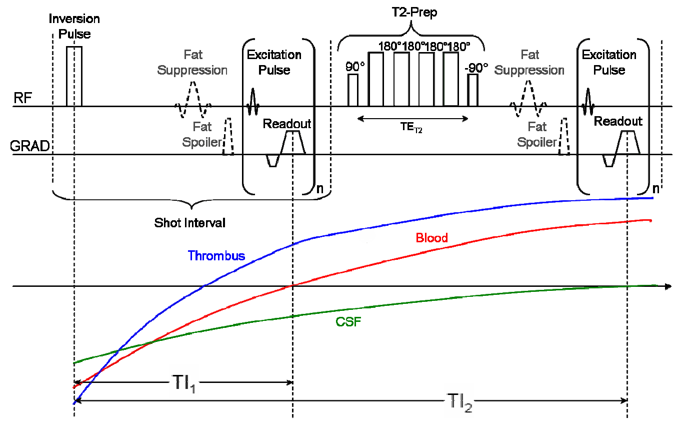

Figure 1: 3D gradient echo sequence for interleaved acquisition of T_1- and T_2-weighted image.

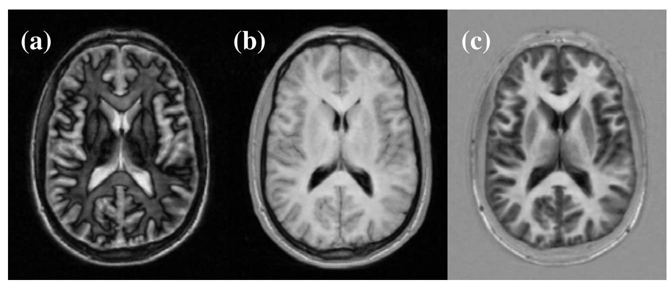

Figure 2: Selected slice from the 3D dataset of the brain of a healthy volunteer showing a (a) T_1-, (b) T_2-weighted image and (c) a phase sensitive T_1-weighted image.

Results and Discussion: Figure 2a shows one slice of the T_1- and the FLAIR T_2-weighted interleaved brain scan. The phase information of the second dataset (Fig. 2b) was used to calculate a phase-sensitive T_1-weighted image (Fig. 2c), thus improving the classification of the different tissues. Figure 3 and 4 depict the results of the interleaved T_1- and T_2-weighted sequence on patients with known DVT in the lower extremities. The T_1-weighted images (Fig. 3a, 4a) allow direct visualization of thrombus that has a higher signal (T_1 = 781 ± 61 ms) while allowing simultaneous suppression of the surrounding blood. The T_2-weighted images allow differentiation of venous and arterial blood due to different T_2 relaxation times (Fig. 3b and 4b). Figure 3c and 4c show phase-sensitive T_1-weighted images with an increased dynamic range. If the chosen inversion time was too short and the blood signal had not nulled, a phase sensitive reconstruction can rectify this problem in a postprocessing step (Fig. 3c).

Conclusion: The interleaved T_1-T_2-weighted 3D gradient echo sequence allows the acquisition of T_1- and T_2-weighted images while suppressing specific signals such as CSF or blood. Furthermore, a phase-sensitive correction can improve imprecise nulling of certain tissues. This sequence is also more time efficient and acquires two datasets with different contrast enhancements but the same geometry, orientation, and motion state in one scan. This can be particularly advantageous in overcoming the differences in the T_1- and T_2- images that arises because of patient motion, as both images are acquired simultaneously in an interleaved fashion. A good application will be in patients following myocardial infarction where T_1-weighting (for late-enhancement) and T_2-weighting (for assessing zone at risk) images of the myocardium are needed [6].

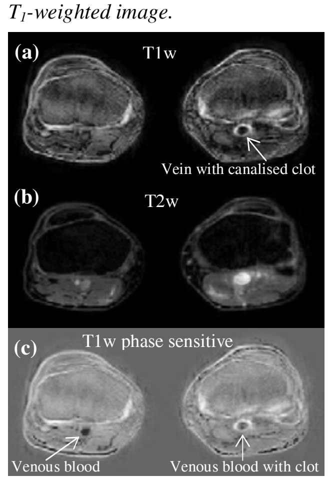

Figure 3: Selected transverse slice from a 3D dataset of both legs of a patient with DVT, (a) T_1- and (b) T_2-weighted image and (c) phase corrected T_1-weighted image.

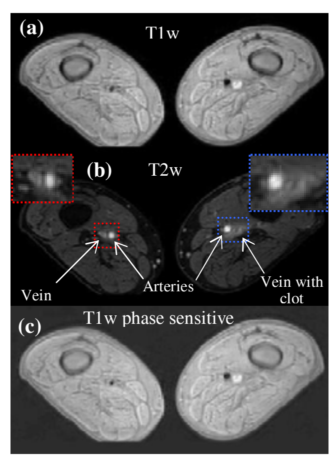

Figure 4: Selected transverse slice from a 3D dataset of both legs of a patient with DVT, (a) T_1- and (b) T_2-weighted image and (c) phase corrected T_1-weighted image.

References: [1] Tian G, et al, J Cardiovasc Magn Reson 1(2), 145-51 (1999); [2] Moody AR, et al, Lancet 350, 1073 (1997); [3] Kellmann, et al, MRM 47, 372-383 (2002); [4] Klein WM, et al, J Vascular Surgery 38, 1060-1066 (2003); [6] Abdel-Aty H, et al, Circulation 109, 2411-2416 (2004)