Dynamic Simultaneous T1 and T2* weighted 3D Dual-Echo Imaging with Compressed Sensing: Potential Advancement to Simultaneous DCE and DSC Imaging

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Introduction

Dynamic contrast enhanced (DCE) and dynamic susceptibility contrast (DSC) MRI techniques are routinely used in clinical studies [1,2]. DCE and DSC studies share some common aspects, e.g., injection of contrast agent and dynamic acquisition of MR images (weighted with T_1 and T_2* contrasts, respectively). DCE provides permeability maps (K_{tran}, v_e, v_p) and DSC provides perfusion maps (CBF, CBV, MTT, TTP). Since both permeability and perfusion maps are important for diagnosis of various diseases, they are often performed for one patient sequentially, which requires injection of contrast agent twice and a delay time for the contrast agent of the first injection to be washed out before the second injection. Moreover, the contrast agent is potentially harmful for patients with kidney dysfunction. If DCE and DSC can be performed simultaneously (rather than sequentially), it would greatly save the time and cost of the MR exams, increase the patient comfort and safety, and potentially provide additional clinical information for studies where only one of DCE and DSC is performed. In this study, we propose a new approach that enables us to acquire 3-dimensional T_1 and T_2* weighted images simultaneously and dynamically using a dual-echo sequence combined with compressed sensing reconstruction. The conflicting aspect of T_1 and T_2* weighting could be satisfied by using a special K-space sub-sampled reordering scheme [3] combined with k-t FOCUSS reconstruction [4].

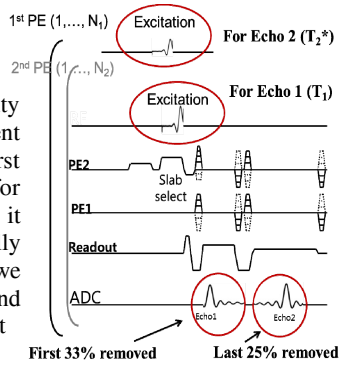

FIG. 1. Pulse sequence diagram of the dual-echo sequence used for dynamic simultaneous T_1 and T_2*weighted imaging.

Material and Methods

The experiment was carried out on Siemens 3T MRI system with the standard body coil for transmission and channel head matrix coil for reception. The MR scan was performed for one normal subject. A modified dual-echo sequence was used for dynamic simultaneous acquisition of T_1 and T_2* weighted images, as shown in Fig. 1. The first and second echoes were partially filled to minimize echo time (TE) and time to repeat (TR), respectively (Fig. 1). Imaging parameters were: TR = 21 ms, TE = 2.6/15 ms, acquisition bandwidth 150/80 Hz/pixel, matrix size = 128 × 128 × 6, corresponding field of view (FOV) = 220 × 220 × 30 mm^3, slice oversampling = 33.3%, and partial Fourier along slice encoding = 6/8, scan time per measurement = 16 sec, # of repeated measurements = 60, and total scan time = 16 min. The K-space center regions of the first (T_1) and second (T_2*) echoes were acquired at different RF excitations and with flip angles of 20° and 12°, respectively.

To apply for compressed sensing along the PE1 direction that was also used for the echo specific K-space reordering, we used down-sampling masks created with Gaussian probability distributions applied both at the center and edge regions along the PE1 direction, as shown in Fig. 2. The scheme reduced the # of PE1 lines to 32 (i.e., acceleration factor of 4). One dual-echo dataset was acquired with the same scan parameters except the reduced number of the PE1 lines, which reduced scan time per measurement and the total scan time by a factor of 4 (i.e., 4 sec and 4 min, respectively). For comparison, we also acquired fully sampled data with the scan time per measurement of 16 sec and the total scan time of 16 mins. To investigate the importance of in vivo accelerated acquisition compared to the retrospective down sampling study of CS, we also generated k-t FOCUSS reconstruction images from the fully sampled data using retrospective downsampling. A region of interest (ROI) was selected in a whole brain region from the middle slice. The mean square difference (MSD) was calculated from the ROI to measure the quality of reconstructions.

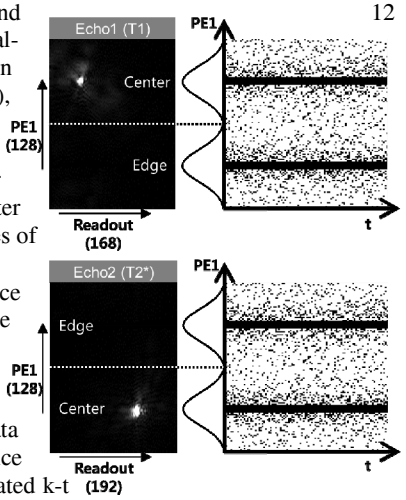

FIG. 2. K-spaces and sparsity schemes used for acceleration

Results and Discussion

For both echoes, the detailed structures and contrast in the images from the retrospective down sampling and the implemented down-sampling acquisitions were visually well preserved in both T_1 and T_2* weighted images compared to those in the original full sampled images (Fig. 3). The MSD of two images (*full* and *proposed*) was 0.018 and 0.101 for echo 1 and echo 2 respectively, which was negligible. As shown in Fig. 4, however, the proposed method clearly showed the signals in regions of cerebrospinal fluid (CSF), while the temporal difference images of fully sampled T_1 images only exhibited noises. This is presumably due to the fact that T_1 recovery was fully achieved in all parts of the brains in the fully sampled data with 16 sec scan time per measurement, whereas the CSF recovery was not as complete as other parts of brain in the accelerated acquisition with 4 sec scan time per measurement; so we could see the difference in CSF area. In order to confirm that this signal is not an artifact from k-t FOCUSS reconstruction, Fig. 4 also showed the time difference image from retrospective downsampled data with the same k-t FOCUSS reconstruction parameter. The signals in CSF area were not visible in this retrospective down sampled experiment.

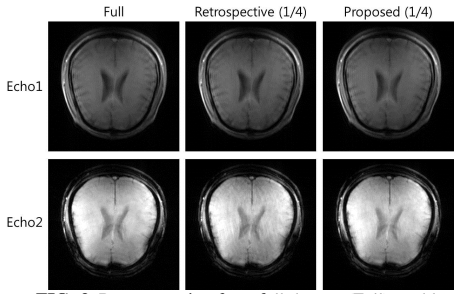

FIG. 3. Reconstruction from full dataset (Full), and k-t FOCUSS reconstruction from retrospectively down-sampled dataset (Retrospective), and in vivo acquisition at acceleration factor of 4 (Proposed).

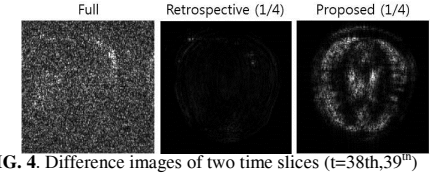

FIG. 4. Difference images of two time slices (t=38th,39th)

Conclusion

We demonstrated an accelerated 3D dynamic dual echo acquisition of T_1 and T_2* weighted images with compressed sensing scheme, for its potential application to simultaneous DCE and DSC study with one injection of contrast agent. Further studies are necessary to improve the spatial coverage and/or temporal resolution and to apply for the technique in combination with injection of contrast agent, i.e., simultaneous DCE and DSC studies.

References : 1. Li et al., JMRI 12:347-357 (2000). 2. Harrer et al., JMRI 20:748-757 (2004). 3. Park et al, MRM 61:767-774. 4. Jung et al, MRM 2009;61(1):103-116.