Improving Image Contrast in Conventional Dual Spin Echo at 3.0T with Short TE and Flip Angle Optimization

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Introduction

Even with the advent of fast imaging techniques, conventional spin-echo remains a useful tool in routine clinical diagnosis. Certain lesions, which may be difficult to detect on FSE and FLAIR images, can be more clearly delineated by conventional spin-echo [1]. Therefore, a conventional dual spin-echo (CDSE) sequence is frequently used to provide proton-density (PD) and T2 weighted images in our clinical practice. When combined with parallel imaging techniques, the longer acquisition time of CDSE is less problematic.

At higher field strength such as 3.0T, the CDSE imaging becomes more challenging. The artifacts produced by the pulsatile blood flow have higher intensity than at 1.5T, and persist even with first-order flow compensation. Although peripheral triggering effectively reduces the flow artifacts, the TR becomes dependent on the patient's heart rate. Sometimes TR is prolonged beyond the optimal value for CSF and brain tissue contrast in the PD-weighted image. The hyper-intense CSF tends to reduce the sensitivity of lesion detection [2]. Different approaches to improve the contrast between the brain parenchyma and CSF were investigated in this work.

Method

Assuming RF refocusing pulses have 180° flip angles, the relative signal intensity of given tissue type in the first echo of CDSE sequence is predicted by the formula:

$$S = \frac{M_0 \sin\theta_I \left(1 - 2e^{-(TR-(TE_1+TE_2)/2)/T1} + 2e^{-(TR-TE_1/2)/T1} - e^{-TR/T1}\right) e^{-TE_1/T2}}{1-\cos\theta_I \; e^{-TR/T1}}.$$

Based on this formula, there are two distinct approaches to increase the contrast between the brain tissue and the CSF. One is to shorten the TE of the PD weighted image (TE_1), because brain tissue has shorter T2 than CSF. Another approach is to increase the flip angle (FA) of the excitation pulse, as CSF has longer T1 [3].

To minimize TE_1, the width of flow compensation (FC) and frequency encoding gradients was reduced so that they were no longer limiting TE_1. Other parameters such as RF pulse width, crusher gradient area and echo fraction were kept the same to avoid any increase in SAR and artifacts. The reduction was made possible by relaxing the condition of first-order gradient moment nulling for the first echo in both slice and frequency encoding directions. Because flow artifacts are mostly in the T2 weighted images of the second echo, such partial FC is acceptable for the first echo. The FC gradients after the first echo were modified accordingly to maintain full FC for the second echo. Further reduction of TE_1 was achieved by increasing the receiver bandwidth for the data acquisition of the first echo (BW_1).

To predict the contrast between brain tissue such as gray matter (GM) and CSF, the values of PD/T1/T2 in the literatures (0.7/1400ms/110ms for GM and 1.0/4200ms/300ms for CSF) were used in the simulation [3, 4]. For verification, a healthy volunteer were scanned on a GE 3.0T Excite scanner using an 8-channel head coil with a modified CDSE pulse sequence using typical clinical protocols of 24cm FOV, 384x192 matrix, 5mm slice thickness and a SENSE acceleration factor of 2. In this experiment, a fixed TR of 3s was used to eliminate the variation of heart rate between scans. To evaluate the change of contrast with shorter TE and larger FA, axial PD weighted images were acquired with TE_1/BW_1 of 11.8ms/±31.25KHz, 10.3ms/±41.7KHz and 8.8ms/±62.5KHz using partial first echo FC, and a series of scans was made with FA varying from 90° to 150° using TE_1/BW_1 of 8.8ms/±62.5KHz and partial first echo FC. To quantify the contrast between brain tissues and CSF, the image intensity of CSF and the adjacent gray matter (caudate nucleus) was measured, as illustrated in figure 2, for each experimental condition.

Results and Discussion

Both simulation and measurement show greater contrast between GM and CSF in PD weighted images with shorter TEs. However, because higher BW is used, the CNR is slightly lower due to the increase in noise. The predicted and measured CNR normalized to the CNR of 90° FA is plotted figure 1. They both show that the CNR between GM and CSF with 120° FA is approximately 57% higher than 90° FA. Figure 2 demonstrates the improved contrast in 3.0T PD weighted CDSE images after optimization. No flow artifact is observed with partial FC even though peripheral triggering was not used in the experiment. The GM and WM contrast in PD weighted image does not change significantly with shorter TE and larger FA as shown in figure 2. No significant change is observed in T2-weighted images either.

Flip angle dependence of image contrast in single echo SE sequence has been explored [5]. Less than 90° FA flip angle has recently been shown to improve the T1 contrast in SE imaging at 3.0T [6]. In CDSE, signal from tissue with long T1 is suppressed with larger FA, similar to the case of GRE. The opposite occurs in the case of single-echo SE due to the odd number of refocusing pulses.

Because of the dielectric resonance effect at 3.0T [7], the actual FA may be different from the prescribed value, and can vary by location. Therefore, it could be difficult to optimize the FA for the entire imaging volume. A hypo-intense region in the center was observed with FA approaching 150°. Such B1 field inhomogeneity could be one of sources for the discrepancy between experimental results and simulation. Although the higher BW produces slightly lower CNR, it does provide better contrast, less chemical shift artifacts and more PD weighting. This technique is currently used in our routine clinical practice.

References

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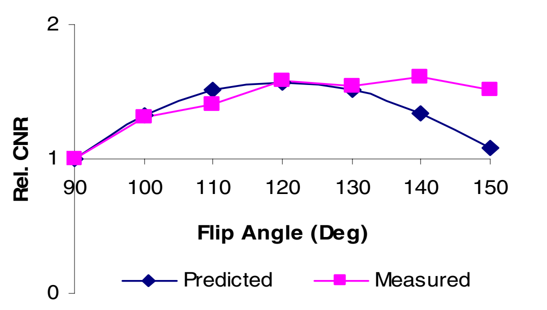

Figure 1. Flip angle dependence of relative CNR between GM and CSF in CDSE.

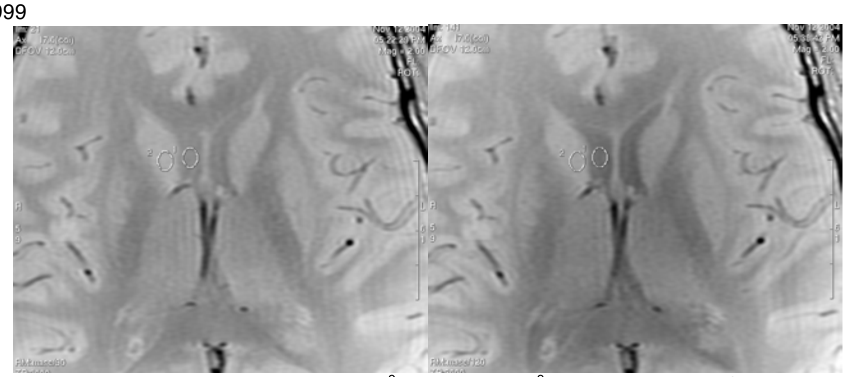

Figure 2. PD weighted images with 90° (left) and 120° FA (right). The W/L values are identical. The circles outline the ROIs for CNR measurement.