Improved Contrast to Noise per Unit Time "CNR/t" at 3Tesla using Parallel Imaging (SENSE) with 3D Spoiled Gradient Recalled Echo for Dynamic Contrast Enhanced MR Imaging DCE-MRI

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Summary:
We present a method to increase the contrast to noise per unit time "CNR/t" at 3 Tesla using a 3D Spoiled Gradient Recalled Echo SP-GRE acquisition in conjunction with parallel acquisition processing "SENSE". 3D SP-GRE is a very time efficient way to cover volumetric k-space however the CNR/t suffers due to the combined imaging time constraint imposed by high temporal resolution dynamic contrast enhanced acquisitions coupled to the reduced contrast inherent at 3 Tesla with long tissue T_1 and short TR acquisition strategies. Here we take advantage of the additional flexibility afforded by parallel processing capabilities with array coils and reconstruction algorithms to optimize CNR/t at 3T by trading the time used for phase encoding steps for the increased signal to noise achieved by decreased sampling bandwidth and the increased contrast achieved by using an increased flip angle at the longer TR. Using this strategy we were able to increase the CNR/t at 3Tesla by 18.2% by taking advantage of the SENSE functionality.

Introduction:
Several applications have been presented to demonstrate how parallel Imaging "SENSE" can be used to either decrease imaging time; reduce susceptibility or motion artifacts; or reduce blurring in multi-echo acquisition strategy [1]. With regards to parameter optimization in MRI imaging protocols, it is well known that SNR can be increased by lowering acquisition bandwidth and it has also been shown that increasing acquisition TR and flip angle using multi-slab 3D one is able to increase CNR [2]. Here we use the flexibility of reduced k-space sampling (SENSE) to increase CNR in 3D SPGRE imaging techniques by appropriate parameter selection. At a given imaging time (without parallel processing) it is possible to 1) reduce the acquisition time by reducing the number of required phase encoding steps while maintaining resolution and then 2) go back to the original imaging time by decreasing sampling bandwidth which in turn increases the TR and therefore the optimal flip angle to move to a higher region of the CNR/t portion of the 3D SP-GRE parameter optimization space. Here we explore this process to improve DCE-MRI clinical imaging protocols.

Materials and Methods:
First we simulated the contrast to noise per unit time parameter space for 3T data sets to find an optimal region for choosing appropriate TR and flip angle for grey white matter contrast using measured T_1 data from our 3T system. Parameter space was mapped using IDL (Research Systems, Boulder) and standard equations for signal difference as a function of TR, and flip angle. In addition, the basic signal difference equations were then further normalized with the given TR and scan efficiency to produce CNR/t parameter space. With these values we acquired a data set based on standard clinical imaging time constraints (2 minutes) without parallel processing and then we used this same imaging time constraint with parallel processing to measure the respective CNR/t. For the imaging experiments we used a normal volunteer on a 3T Philips system (Best, Netherlands) with an 8 element head coil. The 3d SP-GRE acquisition without SENSE had TE/TR/flip/BW of 1.9/3.9/7/693 and with SENSE factor of 2 we achieved TE/TR/flip/BW of 3.3/8/12/290. The CNR/t was measured in homogeneous regions of grey matter and white matter with the noise taken as the standard deviation of the white matter region due to the complex noise character of the background in parallel image reconstructed data.

Results:
The CNR/T simulations are shown in Figure 1 for brain grey-white matter data at 3T. Using this as a basis for selection of optimized acquisition parameters Figure 2 shows two images of the central slice in the brain region. The improvement in CNRT calculated from these images was 18.2%.

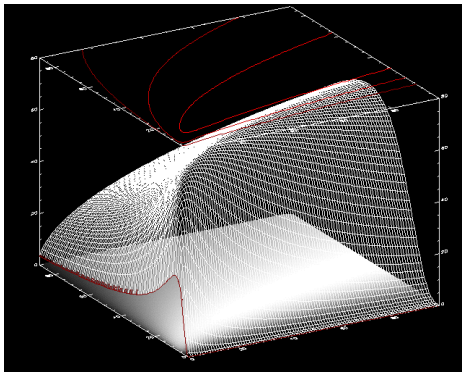
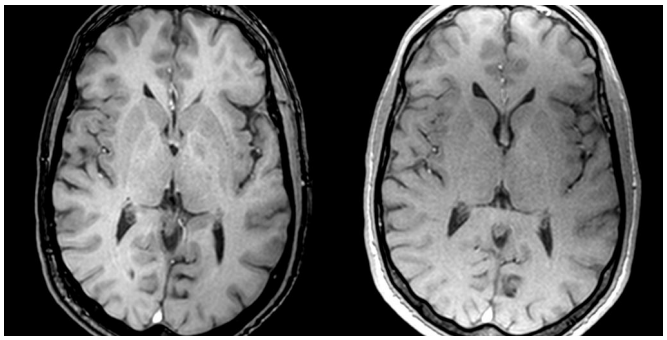


Figure 1. CNR/t parameter optimization surface for 3Tesla brain grey-white matter. Signal amplitude represents CNR/t as a function of TR and Flip Angle



a) Sense b) non-Sense

Figure 2. 3D SP-GRE acquisition at similar imaging times but a) using Sense factor 2 and TR=7.5 and b) non-sense at TR=4

Conclusion:
3D SPGRE imaging holds promise as a time efficient method of T_1 weighted imaging in the brain [3]. Due to the longer T_1 at 3T the CNR/T compared to 1.5 T can be compromised. The use of parallel processing is one way to compensate for these challenges. Although this technique requires an increase in TE, the fractional decrease at 3T for these small changes is acceptable. Another potential disadvantage of this strategy is the concomitant increase in susceptibility at 3T which is exacerbated by using longer TE/TR. However in 3D GRE imaging of the homogeneous regions of the brain these did not appear significant.

References:
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