SNR Recovery for Parallel EPI using Simultaneous Acquisition of Gradient Echo and Asymmetric Spin Echo(SAGA)

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Introduction: Recent developments in parallel imaging reconstruction techniques [1-2] and phased array coil design have generated a number of methods for MR imaging with a reduced data set. This data reduction can be used to decrease scan time, increase image resolution, or reduce image distortion [3]. The last application pertains to fast imaging methods where the image is encoded in a single shot, such as echo planar imaging and spiral imaging. In these fast scan techniques, because a long (~50 ms) readout period is required, field inhomogeneity can lead to image distortion or image blurring. Reducing the readout period using higher gradient strengths and faster slew rates is possible, yet the reduction is limited by gradient hardware specifications and potential harm to the subject via peripheral nerve stimulation. Parallel imaging can be used with ultrafast imaging to reduce readout time to minimize distortion comes, but at the cost of signal to noise ratio due to the shorter readout window. This paper describes a method to recover the lost SNR by a multi-echo averaging technique. For example, a second echo can be acquired using the same parallel imaging approach within the same TR. The combination of the first and second images should yield reduced distortion with comparable SNR. If a factor of 2 is used (R=2), the total imaging time will be similar to that of the non-accelerated acquisition, yet the resulting images will contain less geometric distortion. If a double gradient echo EPI sequence is used to acquire the data, then the images will have different T2* contrast. This confound can be detrimental to fMRI studies which rely on T2* dependent BOLD contrast. Therefore a more useful technique is to use a dual echo pulse sequence that acquires a gradient echo and an asymmetric spin echo in a single shot (SAGA). The SAGA pulse sequence has been shown to generate comparable BOLD contrast at 3 Tesla in both the gradient echo and asymmetric spin echo [4]. The paper demonstrates SNR recovery and distortion reduction in parallel EPI using the SAGA pulse sequence in human brain.

Methods: The pulse sequence used in this study acquires a gradient echo and an asymmetric spin echo in a single shot using EPI readout trains. The SAGA sequence timing is controlled such that both acquisitions are acquired with identical T2' weighting. Both images are magnitude reconstructed normally, and then combined in by the square root of sum of squares. Three experiments are performed on a normal human subject with informed consent. The first is a standard EPI acquisition, the second is a rate 2 GRAPPA-EPI acquisition, and the third is SAGA with the addition of GRAPPA for parallel imaging reconstruction. The readout window of the EPI scan is 60 ms, while the reduced readout window for each echo of the GRAPPA scan is 30 ms. Six calibration lines for GRAPPA are acquired for each echo with a pre-scan, and a reconstruction block size of 4 is used for GRAPPA fitting. Sequence parameters for both experiments include five axial 5 mm thick slices, a TR/TE of 1000/35, a 220mm FOV, and a 64x64 matrix (64×32 for GRAPPA). Reconstructed images are evaluated by ROI analysis to determine relative SNR for each case.

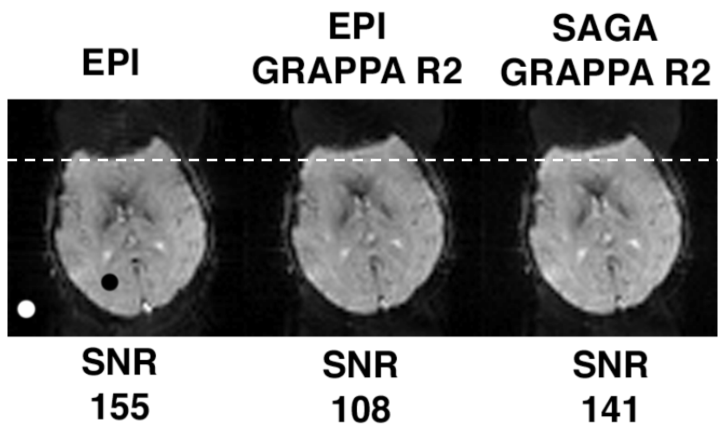

Figure 1. This panel displays the same slice from each of the three scans in an area with strong image distortion in the frontal region (indicated above dashed line). SNR is calculated by the ratio of the mean in the brain to the standard deviation in the background. (ROI's for SNR measurement are indicated on the left image, shown in black and white)

Results and Discussion: Fig. 1 displays results for one of the slices from the study. This inferior slice contains a strong geometric distortion in the frontal lobe indicated by the dashed line. In the GRAPPA images on the right, the distortion is significantly reduced. SNR measurements indicate a 30% reduction in SNR for the EPI-GRAPPA case due to the reduced readout. The SAGA-GRAPPA combined image (far right) shows a significant recovery in SNR, with only 9% of the signal lost. While total readout duration in the SAGA image is identical to the EPI in the far left, there is a small delay between the EPI trains for the refocusing pulse and the refocusing pulse may be imperfect. These factors are likely the source of the residual SNR loss. The combination of multiple echoes for SNR recovery can be considered as generating an effectively narrow-band image, yet having reduced distortion, which has been previously described [5].

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