Improved temporal SNR of accelerated EPI using a FLASH based GRAPPA reference scan

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Target audience

MRI researchers using EPI with GRAPPA parallel acquisition.

Purpose

Current EPI based fMRI protocols frequently incorporate accelerated parallel acquisition techniques (PAT) such as GRAPPA (1) and SENSE (2). These techniques help to reduce EPI distortions and to increase the number of slices per TR. However, use of PAT also reduces the image SNR by sqrt(R) * g-factor, where R is the acceleration factor and g-factor is a spatially dependent noise enhancement factor determined by the receiver array. Similar to data shown in a recent paper (3), we have observed that the temporal SNR (tSNR) of GRAPPA EPI data can be highly inhomogeneous and significantly compromised with certain EPI protocols. Purpose of this work is to show that the tSNR of GRAPPA accelerated EPI can be made more spatially uniform and enhanced by using a PAT reference scan based on a FLASH acquisition scheme rather than an EPI acquisition scheme.

Method

All studies were conducted under an approved IRB protocol using a 3T MRI scanner (Siemens, Skyra). Images of a quality control phantom and human brains (n = 9) were acquired using the 20 channel brain receiver array in axial and sagittal planes with 2D gradient echo EPI, TR = 2 s, TE = 30 ms, flip angle = 70 degrees, field-of-view = 22 cm, matrix = 64 X 64, slice thickness = 3 mm and 100 measurements. Different image series were acquired without (NoPAT) and with GRAPPA acceleration factor R = 2 (PATX2). For GRAPPA scans, two sets of 24-line PAT reference data were collected using EPI and FLASH acquisition schemes. All images were reconstructed on the scanner using software provided by the manufacturer. The same GRAPPA accelerated raw data were reconstructed using either EPI (PATx2epi) or FLASH (PATx2flash) reference data to generate separate image series.

Reconstructed images were transferred offline for further analysis using AFNI and IDL software. Image series were motion corrected and low order signal drifts removed from each pixel time series prior to calculating the tSNR. The increase in temporal signal fluctuation due to PAT reconstruction was quantified by calculating the scaled tSNR ratio, g_t = tSNR_NoPAT /(sqrt(R) * tSNR_PATx2), with R= 2. For pixels without physiological noise (e.g. phantom data), g_t will be close to 1. When physiological sources contribute to the temporal signal fluctuations (e. g. brain data), g_t is expected to be less than 1.

Results

The tSNR and g_t maps calculated from the phantom data are shown in Fig 1. As expected, tSNR_NoPAT (Fig. 1a) is higher than tSNR_PATX2epi (Fig 1b) and tSNR_PATX2flash (Fig. 1c). However, PATX2epi data (Fig. 1b) show significantly lower tSNR in large areas of the images compared to PATX2flash (Fig 1c). The areas of low tSNR in PATX2epi (Fig 1b) exhibit high g_t values (Fig 1d). In comparison, the g_t maps of PATX2flash (Fig 1e) are relatively flat. The median g_t value for PATX2epi is 1.25, while that for PATX2flash is 0.97. The g_t value is greater than 1.1 in 75% of the pixels in PATX2epi data compared to only 15% in PATX2flash (Fig. 1f).

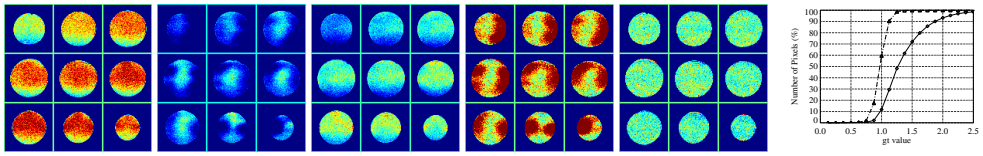

Fig. 1: tSNR maps of NoPAT (a), PATX2epi (b) and PATX2flash (c) phantom images. tSNR scale: 200(blue) to 600(red). (d) and (e), g_t maps for PATX2epi and PATX2flash, respectively. g_t scale: 0.5(blue) to 1.5(red). (f), Cumulative histograms of (d) (diamond) and (e) (triangle).

The tSNR and g_t maps calculated from human data are shown in Fig 2. Similar to phantom data, the human PATX2epi tSNR maps (Fig. 2b) show large areas with abnormally low tSNR (arrow) and correspondingly high $g_t > 1.25$ (Fig. 2d). Such regions were identified in similar slice locations in all subjects. In contrast, PATX2flash data show that the tSNR and g_t values of these areas are restored to values similar to other brain areas (Figs. 2c and 2e). Further, PATX2flash produced ~12 % higher tSNR averaged over the whole brain.

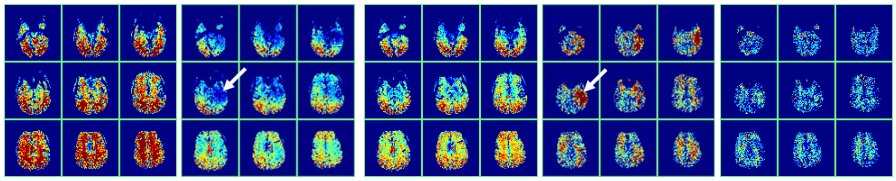

Fig. 2: Human brain tSNR maps of NoPAT (a), PATX2epi (b) and PATX2flash (c) data. tSNR color scale: 45(blue) to 135 (red). (d) and (e), g_t maps for PATX2epi and PATX2flash, respectively. g_t map color scale: 0.75 (blue) to 1.25 (red). Arrows indicate abnormally low tSNR and high g_t regions.

Discussion

In this study, we have demonstrated that the tSNR of GRAPPA accelerated EPI can be improved by using FLASH PAT reference data during image reconstruction. Therefore, this approach should directly benefit fMRI studies using similar protocols. Reduction of tSNR when using EPI PAT reference data may be due to uncorrected phase errors in the reference data that propagate into GRAPPA kernel calculation. Since contribution from physiological sources can dominate the temporal fluctuations of signal in human data, it is necessary to correct for such effects to better quantify the improvement due to the FLASH PAT reference scan. Further studies are underway to determine the effectiveness of using FLASH PAT reference scans at higher image resolutions and acceleration factors.

References: 1) Griswold et al., MRM 47:1202 (2002). 2) Pruessemann et al., MRM 42:952 (1999). 3) Cheng H. JMRI 35:462 (2012).