Feasibility of dynamic susceptibility-weighted perfusion MRI at 3T using a standard head coil and 8-channel phased-array coil with and without SENSE reconstruction

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Introduction

The emergence of high field MR systems for routine clinical use necessitates the optimization of the echo planar imaging (EPI) acquisition method used for dynamic susceptibility-weighted perfusion MR. Although the benefits of imaging at higher field strengths include increased SNR which can translate to higher resolution images or faster acquisitions, the tradeoff in EPI is increased B_0 inhomogeneity and magnetic susceptibility differences at air-tissue interfaces, leading to signal drop out and geometric distortions, most notably in the phase encode direction. Multi-channel coil arrays along with a partially parallel imaging acquisition and sensitivity-encoding (SENSE) reconstruction algorithms have been shown to improve image quality by minimizing these artifacts at the cost of reducing SNR.[1] In this study we investigate changes in both the SNR of the ΔR2* curve and magnetic susceptibility induced artifacts between a standard quadrature head coil and 8-channel phased array coil with and without SENSE at 3T, compared to the current clinical standard head coil acquisition at 1.5T.

Methods

Image Acquisition: Eighty-two brain tumor patients were recruited for this study. Images were acquired on either a 1.5T GE Signa Echospeed (26 patients) or 3T GE Signa Echospeed system with EXCITE platform (56 patients), with either a standard quadrature head coil (12/56 patients) or 8-channel phased-array coil (44/56 patients). The dynamic susceptibility-weighted perfusion imaging consisted of the injection of a bolus of 0.1 mmol/kg body weight of gadopentetate dimeglumine (Gd-DTPA) contrast agent at a rate of 5 mL/s. A series of 60-80 $T2^*$-weighted gradient-echo, echo-planar images were acquired during the first pass of the contrast agent bolus injection, with a TR/TE of 1250-1500/54 ms, 35^o flip angle, FOV of 26×26 cm^2, 128×128 reconstructed image matrix, and 3-6 mm slice thickness. The echo planar images for eighteen of the forty-four patients scanned with the 8-channel coil at 3T were acquired using SENSE with a reduction factor of 2. T1-weighted SPGR images were also acquired as a distortion-free reference for image registration.

Dynamic SNR Estimation: The T2* signal time curve, S(t), was converted to the change in relaxation rate for all voxels using the relationship $\Delta R2^* \sim -\ln(S(t)/S_0)$, where S_0 is the average pre-contrast signal intensity baseline. An automated routine to select/segment normal appearing brain voxels based on histogram analysis of the image intensities from the pre-contrast echo planar images was utilized to exclude curves within the T2 and contrast enhancing lesions ventricles, large veins, and necrotic regions.[2] The dynamic SNR of each normal brain ΔR2* curve was calculated by dividing the peak height by the standard deviation of the noise from 16 time points of the pre-contrast baseline. A mean dynamic SNR value was determined for each patient and then averaged across all patients with a group. Statistical significance of group comparisons was determined through the use of a Wilcoxon ranked sum test.

Quantification of geometric distortion and signal dropout artifacts: An additional conventional GRE EPI sequence was acquired for ten of the twenty patients who had undergone the SENSE acquisition at 3T, utilizing the same imaging parameters and slice prescription. Both the conventional and SENSE EPI volumes were registered to a pre-contrast, T1-weighted SPGR image, first by rigid body transformations, followed by non-rigid B-spline warping through maximization of normalized mutual information.[3,4] Volumes of geometric distortion were defined as the magnitude of the difference between the masked volumes of the warped and acquired images for both the conventional and SENSE EPI acquisitions. The amount of signal dropout was quantified by subtracting the masks of the warped EPI volume from the T1-weighted reference volume.

Results and Discussion

Dynamic SNR Estimation: Figure 1(a-d) shows a slice from the first time point image volume of the dynamic echo planar image series and corresponding ΔR2* curves for normal-appearing white matter using a 1.5T head coil, 3T head coil, 3T 8-channel coil, and 3T 8-channel coil with SENSE acquisitions. As expected, visual inspection of these curves shows a clear elevation in dynamic SNR with both increasing field strength and number of reception coils. This observation is quantified in Table 1, which shows a significant rise in mean dynamic SNR with field strength ($p<.001$) and coil type ($p<.01$). Although the addition of SENSE at 3T significantly reduces dynamic SNR ($p<.02$), the values are still higher than those obtained from the 3T head coil acquisition, but the difference is not significant ($p=.2$).

Quantification of geometric distortion and signal dropout: An increase of magnetic susceptibility induced EPI artifacts was observed with higher field strength. Figure 2 depicts noticeable distortion (magenta) and signal drop out (cyan) surrounding air/tissue interfaces of the EPI images compared to the T1-weighted reference contour (yellow). The SENSE acquisition improves image quality through artifact reduction. For 8/10 patients, the difference in distorted volume ranged from 4 to 70%, favoring SENSE. The decrease in volume of signal dropout obtained from the SENSE acquisition ranged from 1.1 – 8.5% for 9/10 patients.

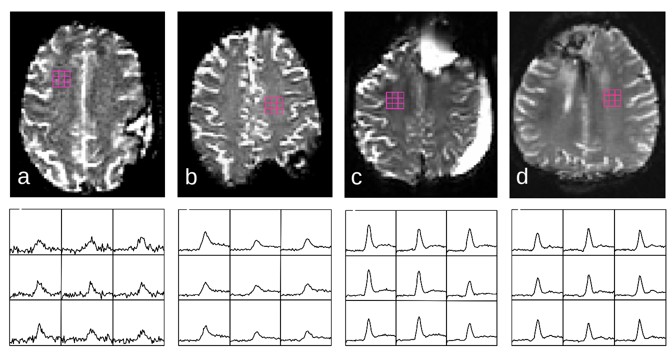

Figure 1. First time point image volume and corresponding white matter ΔR2* curves for (a) head coil at 1.5T, (b) head coil at 3T, (c) 8 channel coil at 3T, and (d) 8 channel coil with SENSE at 3T.

Conclusions

Dynamic susceptibility-weighted perfusion MRI is feasible at 3T, especially with the implementation of a multi-channel coil array and partially parallel acquisition. In addition to improved dynamic SNR, 3T SENSE EPI allows a nearly 2-fold increase in slice coverage. Although alignment of the dynamic data to anatomical images remains a challenge due to magnetic susceptibility artifacts, application of non-rigid registration techniques in conjunction with SENSE EPI is a viable option.

field strength	1.5 T	3 T	3 T	3 T
coil	*head*	*head*	*8 channel*	*8 channel*
SENSE recon	no	no	no	yes
no. exams	26	12	26	18
mean	10.87	34.47	57.00	41.11
median	11.03	33.03	56.31	37.85
std. dev	4.75	14.67	24.66	15.63

Table 1. Dynamic SNR values for a quadrature head coil and an 8 channel phased array coil with and without SENSE at 1.5T and 3T.

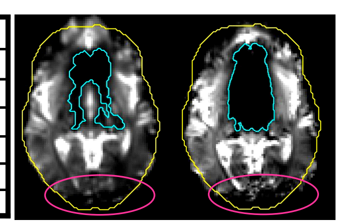

Figure 2. Depiction of signal dropout and geometric distortion in EPI (a) with and (b) without SENSE.

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