Parallel MRI performance evaluation of a novel 32 channel fetal array at 1.5T

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Introduction Parallel acquisition and excitation are feasible for fetal MRI with less focal SAR (or hot spots), higher SNR and reduced scan time [1, 2]. However, since there is no dedicated fetal phased array commercially available, conventional torso or cardiac phased arrays are routinely used for fetal scans, which are unable to provide optimized SNR and parallel imaging performance for fetal MRI. A previous study demonstrated that the flexible 32-channel fetal array is capable to improve SNR and B_1 homogeneity in the region of interest [3]. In this work, numerical evaluation of the parallel imaging performance of the 32-channel fetal phased array has been performed. GRAPPA reconstructed images with different acceleration factors were calculated based on electromagnetic simulation results. Artifact power was employed to quantitatively evaluate parallel imaging performance. The results were then compared with a commercial 8-channel torso array at 1.5T.

Methods As shown in reference 3, the 32-channel fetal array consisted of 4×2 square surface coils on the bottom and 8×3 coils at the top while the commercial 8-channel torso array consisted of 2×2 square surface coils on the bottom and the other 2×2 at the top. To evaluate the parallel imaging performance of the fetal array, GRAPPA algorithm was utilized for image reconstruction. The electromagnetic field distribution of each element coil was numerically simulated separately by finite-difference time-domain method. The images of each element were then calculated pixel by pixel based on simulation results. Ignoring relaxation and susceptibility effects, the gradient echo image intensity *SI* is given by [4]

$$SI = C\sin(|B_1^+|\gamma\tau)(|B_1^{-*}|) \tag{1}$$

where C is a constant proportional to resonance frequency and initial magnetization, γ is the magnetogyric ratio, τ is the RF pulse duration, B_1^+ and B_1^- denote the positive and negative circularly polarized component respectively and the asterisk denotes a complex conjugate operation. Assuming the phantom is uniformly excited, SI is proportional to $|B_1^-{}^*|$ according to equation (1). A second order polynomial fit was performed to smooth the images.

The GRAPPA reconstruction was carried out by using PULSAR toolbox [5]. 32 Auto-Calibration Signal (ACS) lines in the center of the k-space were used to estimate the missing lines. The block size was 2. All the coils were used for GRAPPA reconstruction. The coil distribution was set to linear. 90% of k-space along frequency-encoding direction was employed for fitting. The GRAPPA reconstructions with subsampling factors of 2, 4, 6 and 8, corresponding to acceleration factors of 1.7, 2.6, 3.2 and 3.5 respectively, were performed to A/P direction in axial plane. Sum-of-square (SoS) images were calculated as reference.

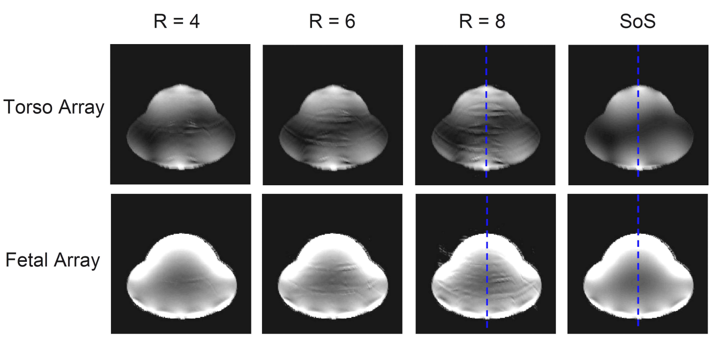

Fig. 1 GRAPPA reconstructed images. The image intensity at the center lines (blue dash lines) were measured and shown in Fig. 3

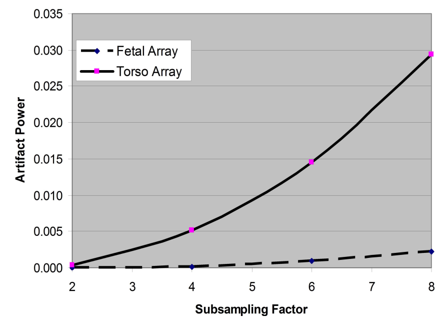

Fig. 2 Artifact power comparison between fetal array and torso array with subsampling factors of 2, 4, 6, and 8.

Results The GRAPPA and sum-of-square reconstructed images were shown in Fig. 1. The first row was the images of eight-channel torso array and the second row was of 32-channel fetal array. Artifact power was calculated to quantitatively evaluate the parallel imaging performance of two arrays. The artifact power (AP) was defined as [5]

$$AP = \sum_{x,y} \frac{\left\| I^{SoS}(x,y) \right| - c\left| I^{GRAPPA}(x,y) \right\|^2}{\left| I^{SoS}(x,y) \right|^2} \tag{2}$$

where I_{SoS} and I_{GRAAPA} were the image intensity of sum-of-square images and GRAPPA reconstructed images. As shown in Fig. 2, the fetal array dramatically reduced the artifact power compared with the torso array. The artifact power of fetal array with subsampling factor 8 was diminished to 7.8% of that of torso array. Fig. 3 showed the image intensity of SoS and GRAPPA reconstructed images with subsampling factor 8 at the center line, which demonstrated the image intensity of the fetal array increased 5-fold in surface region. The zoomed-in range in Fig 3 showed 50% improvement in the deeper region compared with that of torso array, although the sizes of each element of the fetal array were smaller than torso array.

Discussion The simulation results indicate that the proposed 32-channel fetal array improves parallel imaging performance for fetal MRI at 1.5T, compared with the routinely-used torso array. The artifacts of parallel reconstructed images are reduced dramatically by using the fetal array. These results demonstrate the feasibility and advantages of using the 32 channel flexible array for fetal MRI at 1.5T.

References

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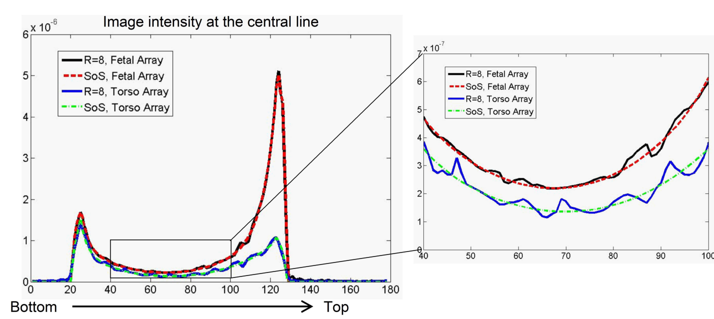

Fig. 3 The image intensity of SoS and GRAPPA reconstructed images with subsampling factor 8 at the center lines (blue dash lines in Fig. 1). The right figure is the zoom-in image, showing image intensity in deeper region in uterus.

Acknowledgments

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