Improving Image Quality in Fetal MRI using Autocalibrating Reconstruction for Cartesian (ARC) Sampling

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Introduction. Fetal MRI has been shown to provide relevant complementary information to ultrasound for the assessment of fetal abnormalities. Fetal MRI is becoming increasingly popular due to the increased availability of rapid imaging methods and increased performance of MR hardware. An early diagnostic work-up *in-utero* is often paramount for the well being of both the fetus and the mother. While T2-weighted imaging is readily achieved with single-shot FSE, appropriate T1-weighted images are still difficult to obtain. In particular, the image quality is often frustrated by respiratory motion of the mother or fetal movements. Although motion artifacts can be reduced by breath-hold exams, they are often difficult to perform over longer breath-hold periods, especially for patients within the third trimester of pregnancy. Short acquisition times are therefore essential for the minimization of artifacts from bulk physiologic motion and for successful imaging. Recently, parallel imaging has been introduced to increase the speed of image formation by using radio-frequency coil encoding to complement regular gradient encoding. Methods like SENSE[1] or GRAPPA[2] can be applied to reduce overall acquisition time, improve coverage, or reduce overall image distortion from image blurring or susceptibility artifacts. Levine *et al.*[3] have successfully applied parallel imaging to improve the performance of single-shot FSE but otherwise very little has been reported on parallel imaging for fetal MRI. Recently, a robust new parallel imaging method, called ARC (Autocalibrating Reconstruction for Cartesian Sampling) has been developed, which does not need an external coil sensitivity calibration scan and is significantly faster than existing *k*-space based parallel imaging reconstruction methods. Since this method is autocalibrated, requiring no external reference scan, it is an ideal candidate for accelerated fetal MRI. The purpose of this study was therefore to investigate the potential strengths and weaknesses of ARC for T1w fetal MRI.

Materials and Methods. Both FGRE and LAVA (3D SPGR) sequences with ARC capabilities were implemented on our clinical pediatric 1.5T unit (GE Signa Twin, 11.0). Three pregnant women in the third trimester were enrolled in this study after written informed consent was obtained. The patients were referred to fetal MRI because of suspected diaphragmatic hernia, ventriculomegaly, and intra-uterine growth restriction. In all cases an 8 channel cardiac coil was used for signal reception. The scan parameters for the T1w FGRE were as follows: FOV= 31cm, matrix=224x256, slices= 16, slice thickness/gap= 4/1mm, phaseFOV=0.9, TR/TE=145/4.2ms, whereas the scan parameters for the LAVA sequence were: FOV= 36cm, matrix=224x288, slices= 40, slice thickness/gap= 4mm/1mm, phaseFOV= 1.0, TR/TE=6.5/2.6ms . Both sequences were performed with the new ARC acquisition pattern, in which the outer portions of k-space are subsampled by a factor 2, whereas a small region around the center of *k*-space is fully sampled and serves to derive the 2D kernel weights used for image reconstruction. The ARC image reconstruction was performed online using host-based prototype reconstruction software, and reconstructed images were transferred to the image database of the scanner.

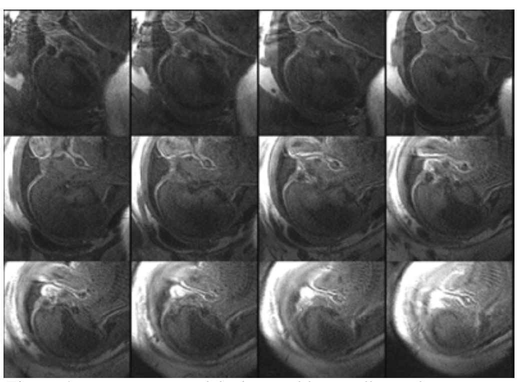

Figure 1 *– In utero MRI of the brain of fetus suffering from a pronounced cased of ventriculomegaly. Twelve out of sixteen FGRE slices are shown that were acquired within a breathhold of 15sec. Morphologic details of the fetal brain and the enlarged ventricles can be clearly delineated.*

Results. Rapid T1-weighted MRI was performed using both accelerated ARC FGRE and LAVA. The extremely short breath-hold times afforded by these techniques resulted in much better patient compliance. Due to its autocalibrating reconstruction ARC outperformed other externally calibrated parallel imaging techniques giving rise to much less residual aliasing artifact than comparable scans with conventional parallel imaging. With external calibration, both fetal movement and especially the respiratory excursions of the mother's abdomen can significantly impair the reconstruction due to a mismatch between the calibration scan and the subsequent accelerated scan.

Fig 1 shows a sagital view through the brain of a fetus that was acquired in a 15-sec snapshot scan. The images are of adequate diagnostic quality and are lacking significant motion artifacts. Recently, it has been suggested to use parallel imaging to reduce motion artifacts by investing the speed gain in extra averages[4]. Certainly, there is no net win in speed but the extra averages were reported to be beneficial to minimize motion. Fig. 2 shows a side-by-side comparison of our attempt to accomplish such motion compensation. Despite this notion it is however evident that the faster single breath-hold sequence clearly outperforms the multi-NEX approach.

Conclusion. Fetal MRI is generally challenged by the fast and unpredictable movement of the fetus. In this study a new variant of parallel imaging acquisition and reconstruction was tested for its utility in fetal T1-weighted MRI. Throughout this study the image quality of the ARC scans was consistently better than either conventional T1w scans or conventional parallel imaging scans. We have demonstrated that using ARC FGRE and LAVA can significantly improve the robustness and reliability of T1w imaging and allows images to be acquired within a single breath-hold of reasonable duration for pregnant women (~15sec).

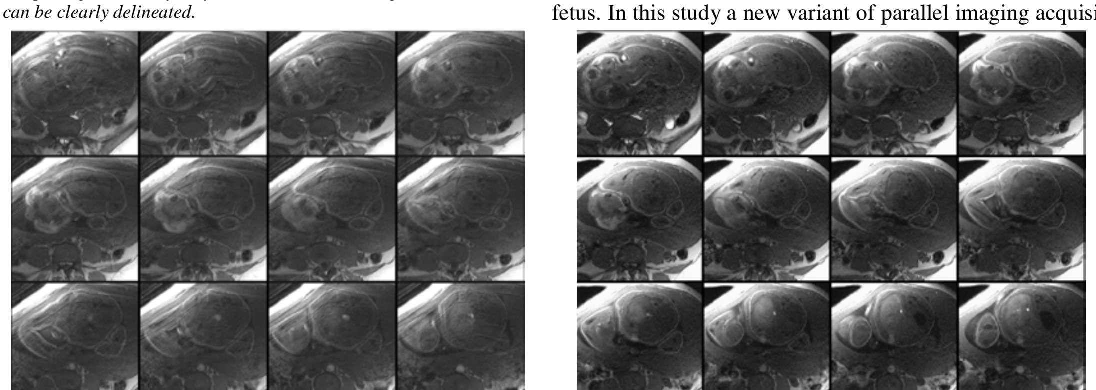

Figure 2 *– Fetal T1w FGRE scan with ARC (two-fold acceleration). (left) 12 out of 20 slices from a 45sec exam (NEX=3). (right) corresponding slices acquired in a single breath-hold scan. Hyperintense signal ghosts from the anterior fat of the mother is greatly reduced. The delineation of fetal organs was significantly better with the single breathhold scan.*

References. [1]Griswold, M. *et al*. MRM 47: 1202-10, 2002; [2]Pruessmann, K. *et al*. MRM 42: 952-62, 1999; [3]Levine, D. et al. 12th ISMRM, Kyoto, p.57; [4]Bammer, R. *et al*. Top Magn Reson Imag 15:207-19, 2004. **Acknowledgements.** This work was supported in part by the NIH (1R01EB002771), the Center of Advanced MR Technology at Stanford (P41RR09784), Lucas Foundation, and Oak Foundation.