Reduced Field-of-View DWI of the fetal brain with adaptive averaging

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Introduction: Diffusion weighted brain imaging (DWI) *in utero* can be useful for assessing fetal brain development [1-2] and enhance understanding of the brain development process in general. Unfortunately, current state of the art technologies are unable to achieve consistent image quality or high spatial resolution due to the small size of the fetal brain, magnetic inhomogeneity of the surrounding tissue environment, fetal motion and maternal breathing. Conceptually, reduced field-of-view (rFOV) methods such as inner volume or 2D spatially selective RF excitations should lend well to this application by obviating the need to spatially encode a large FOV encompassing the entire maternal pelvis in the phase-encoding direction. For single-shot echo-planar imaging (ssEPI), this would reduce the echo-train length for a given resolution, in turn reducing image distortion and other off-resonance artifacts. Recently, rFOV techniques have been demonstrated for DWI of the spinal cord, breast and the brain stem [3-5]. The purpose of this work is to evaluate if the rFOV method can improve image quality of fetal brain DWI. Additionally, we will investigate the application of retrospective adaptive averaging to mitigate artifacts arising from fetal motion.

Methods: The FOCUS sequence, which employs a 2D spatially selective echo-planar RF excitation pulse in a standard spin-echo ssEPI sequence, was used for rFOV DWI. The 2D 90° RF and the 180° pulse pair also provides fat suppression by spectral selection of the on-resonance water profile [5]. Ten fetuses were scanned in accordance with the IRB guidelines after being referred for clinical fetal MRI on a 1.5 Tesla GE scanner (EXCITE, Waukesha, WI) with an eight-channel cardiac array (USA Instruments) without any sedation. The rFOV sequence parameters were: TR/TE=3200/58 ms, FOV=20x10 cm^2, slice thickness = 4 mm, acquisition matrix = 128x64, partial Fourier factor (PF) =0.62, 12 averages and scan time = 2 mins:35 secs during maternal free breathing. For a basis of comparison, images were also acquired with the existing conventional full-FOV DW ss-EPI protocol: TR/TE=4500/58 ms, FOV=32x32 cm^2, slice thickness = 4 mm, acquisition matrix = 128x128, with PF=0.62 and parallel imaging factor = 2, 18 seconds breath-hold scan. Both diffusion sequences used b-value= $600 s/mm^2$. Data from individual repetitions in rFOV DWI were combined by complex averaging after reconciling inter-average phase differences. Images were reviewed by a neonatologist for artifacts and ability to visualize the layers of the fetal brain. Two rFOV datasets with obvious incidence of fetal motion and motion-induced artifacts were identified. An adaptive averaging algorithm that selects data from repetitions that have highest inter-average correlations was incorporated into the reconstruction algorithm. This motion adaptive reconstruction was then retrospectively applied to the two above mentioned two rFOV datasets.

Figure 1: Fetal DWI in a fetus of 22 weeks gestational age. **The brain layers are more clearly delineated in images acquired with rFOV EPI than with standard EPI. There is also less distortion and aliasing artifacts with rFOV EPI.**

Note: Partial visualization of co-twin brain on the bottom of images **b)** and **c)**.

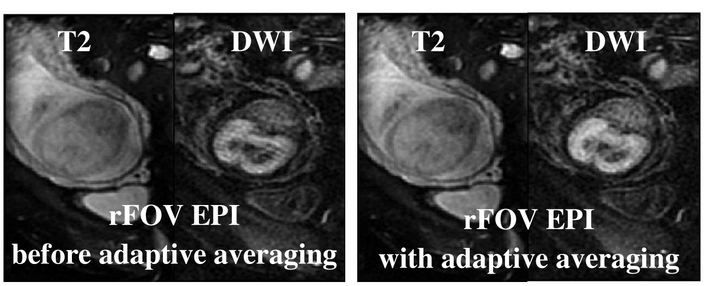

Figure 2: Motion artifacts in rFOV image-set (slight blurring in T2, strip artifact in combined DWI) have been mostly removed by retrospective application of the adaptive averaging technique**.**

Results: In radiological evaluation, image quality was observed to be better with the rFOV DWI sequence compared to standard DWI, with respect to visualization of the different layers of the brain and absence of image artifacts, in all subjects, as shown by a typical case in Figure 1. Figure 2 shows representative results from the adaptive averaging reconstruction – striping artifacts in the rFOV DWI image and slight blurring of the T2 image induced by fetal motion have been mostly removed by the algorithm.

Discussion: This work demonstrates the feasibility of using a 2D spatially selective RF pulse that also provides robust fat suppression to **enable high resolution DWI of fetal brain with minimal artifacts**. With this rFOV technique, not only were the off-resonance effects reduced due to shortening of the echo-train, regions of inhomogeneity such as the air-filled maternal rectum could be excluded from the FOV. Complex averaging and registration of single-shot DW images were able to alleviate maternal breathing and fetal motion artifacts to some degree. Adaptive averaging technique improves the robustness of this method to fetal motion, and will be explored further in future.

Reference: 1. Glenn OA et al, AJNR 2006 ;27:1807-14, 2. Levine D. JMRI 2006;24:1-15 3. WheelerKingshott C et al, Neuroimage 2002;16:93-102. 4. Wilm B et al, MRM 2007;57:625-30 5.Saritas E et al, MRM 2008; 60:468-73 6. Schneider MM et al, AJNR. 2009;30: 1799-1803.