Fetal imaging with EPI – FOV, SNR and distortion correction

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Introduction

Fetal brain imaging with echo planar imaging (EPI) has extensive applications [1] notably in Diffusion tensor imaging (DTI) [2]. In other applications of EPI for brain imaging it is desirable to use the smallest field of view (FoV) combined with a parallel imaging (PI) acceleration factor (typically 2-3) to reduce distortion and mitigate signal losses from T2 and T2* decay. Although many distortion correction algorithms have been developed [3], it is often not possible to fully correct extreme local distortions, particularly close to air-tissue interfaces. As a result it is common to analyse EPI data in its native coordinate system with only limited use of detailed fusion to other anatomical images. The balance of issues is quite different for fetal applications: 1) the T2 and T2* of the fetal brain are much longer (T2 ~ 150msec), 2) there is no air or mineralised bone to produce highly localised anomalies in the static field (B_0) within the womb and 3) fetal motion means it is highly desirable to use Slice-to-Volume Reconstructions (SVR) to achieve 3D brain images, but this requires slice data with internally consistent geometry so it can be realigned and jointly reconstructed. We have explored the implications of these factors to achieve improved SVR using EPI.

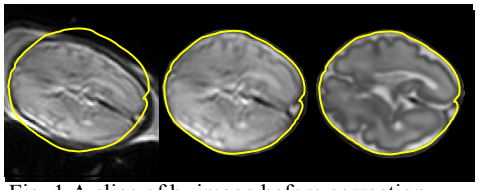

Fig. 1 A slice of b_0 image before correction (left) and after correction (middle), the same slice in a non-distorted ssTSE image

Methods

Simulation was used to explore the trade off of EPI factor (n) and SNR for fetal pulsed gradient spin echo sequences. EPI factor increases linearly with FoV at fixed resolution resulting in a potential root(n) gain in SNR, but a linear increase in spatial distortion and a loss of signal due to T2 and T2* decay. PI reduces distortion, but damages SNR. If the FoV is reduced below that required for the maternal anatomy, rest slabs can be used to mitigate aliasing. SNR and distortion were assessed on phantoms and pregnant subjects as a function of FoV. Distortion correction was implemented using FSL-FUGUE [4] with B_0 maps acquired at the start and end of each fetal examination using a pair of multislice field echo images. Following distortion correction in the scanner coordinate system, the individual slices were realigned into anatomical space and SVR-DTI was employed [2] to reconstruct 3D datasets. All subjects gave informed consent and were imaged on a 1.5T Achieva system (Philips Healthcare) with a 32-channel SENSE Torso/Cardiac coil. B_0 field map: TE1 = 4.6ms, TE2 = 9.2ms; TR = 10ms, Flip Angle = 10 degree, Voxel size = 2.27×2.27×10 mm^3. Spin Echo EPI images were acquired with fixed resolution of 2.3x2.3x3.5mm^3 varying the FoV. DTI was acquired with the same resolution in transverse sections: b = 500s/mm^2 using 15 non-colinear directions, TE = 121 ms; TR = 8500 ms, EPI factor = 125, no SENSE, Gap = -1.75 mm, FOV = 290×290×128 mm^3.

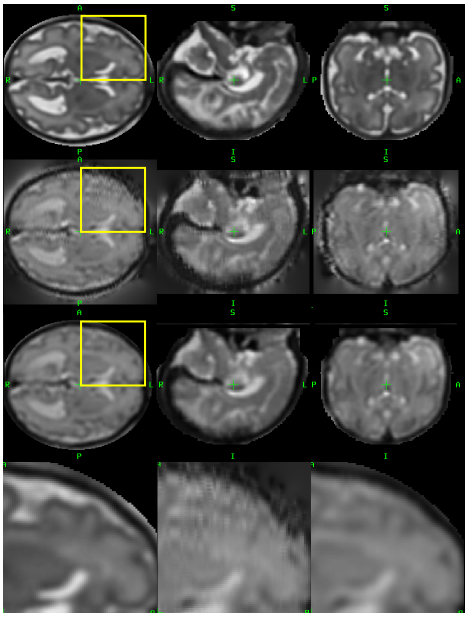

Fig. 2 non-distorted ssTSE image (first row), distorted b_0 image without correction (second row) and with correction (third row) in transverse, sagittal and coronal planes; the amplified image inside the yellow box for above cases at the same position (fourth row)

Results

The SNR advantage of large FoV without PI was confirmed. Even with a very restricted FoV with saturation bands to suppress surrounding maternal tissue, distortion remained significant, up to 2 pixels in many cases. However, B_0 mapping was effective and resulted in accurate distortion correction (Fig. 1) leading to greatly improved SVR reconstruction (Fig. 2) allowing improved FA mapping (Fig. 3). A 2D reconstruction of a cortico-spinal tract is generated in Fig. 4.

Conclusion

Fetal brain EPI requires quite different parameter choices. However optimisation and use of distortion correction results in a capability to create 3D reconstructions and perform DTI, creating a platform for fetal tractography and fMRI. An added advantage is that the distortion corrected images can be readily fused with anatomical images obtained by single shot FSE and reconstructed with SVR

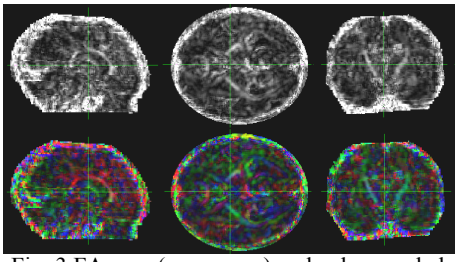

Fig. 3 FA map (upper row) and colour-coded diffusion tensor image (lower row) in sagittal transverse and coronal planes

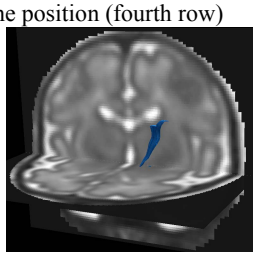

Fig. 4 reconstruction of a cortico-spinal tract in its ssTSE space

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Acknowledgements: This work was funded by Action medical research