# Reduced Field of View Imaging for Fetal fMRI (f-fMRI)

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**Introduction:** Fetal functional MRI (f-fMRI) may be a useful component in differentiating between normal and compromised fetal well-being for pregnancies at risk of intrauterine growth restriction (IUGR). Despite the relatively small fetal head, conventional pulse sequences require long readouts for a field of view (FOV) that encompasses the maternal abdomen in order to avoid aliasing [1]. We compare the performances of conventional spiral and reduced FOV (rFOV) pulse sequences for fMRI of the fetal brain.

**Methods:** The rFOV gradient echo (GRE) pulse sequence (Fig. 1) commences with two frequency-selective fat-saturation RF pulses (260Hz offset, bandwidth = 220Hz) and crusher gradient sets. Next, the spins are prepared by a two-dimensional spatially-selective pulse [2] and an adiabatic half-sech fast passage pulse to achieve outer volume saturation (OVS) before slice selective excitation. For the adiabatic pulse, the effective $B_1$ initially points along the transverse net magnetization vector of the previously selected spins. As $B_1$ amplitude decreases, and off-resonance increases, the effective $B_1$ sweeps up toward its final longitudinal orientation. A slice selective $90_x°$ generates signal, and the readout follows a spiral-out trajectory in k-space.

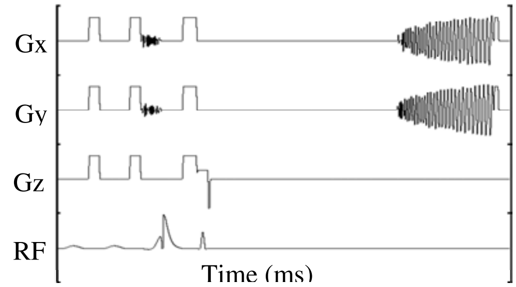



**Figure 1.** Reduced FOV pulse sequnce diagram.

Four women with late-term pregnancies at risk for IUGR were scanned, after giving informed consent, according to a protocol approved by the Stanford University IRB. Results from the fourth subject are presented here. The 2 fMRI stimuli consist of 1) 15s blocks of Mozart's "Wind Serenade" alternating with 15s blocks of silence, and 2) maternal breathing of 1min. blocks of oxygen separated by varying intervals of medical air. 128 and 210 time frames were acquired with TE/TR=70ms/2s, resulting in a 4:15min. and 7min. protocols, respectively, on a 1.5T scanner (GE) with the manufacturer's 8-channel cardiac array receiver coil. fMRI series for each stimulus were acquired with a conventional spiral GRE acquisition and with OVS for a rFOV (24cm) readout (Fig. 2). The respective conventional/rFOV imaging parameters were: FOV=44/24cm, number of pixels = 128/40. The slice thickness and spacing were 5mm and 1mm for both sequences. The shorter readout of the rFOV sequence (11.9ms) allowed the gradient slew rate to be lowered from 150T/m/s to 30T/m/s, resulting in a 21.4ms readout duration with scanner noise reduction (97dB to 90dB) and signal to noise ratio (SNR) gain of 15%. Data post-processing consisted of selective receiver coil exclusion, time frame alignment by rigid body transformation (SPM2), interpolation of time frame slices the global intensity of which varied by more than 3 standard deviations from the series mean, and visual inspection of time series in order to delete grossly misaligned frames. Activation is estimated as the cross-correlation coefficients (cc) between the time series and stimulus covariate functions.

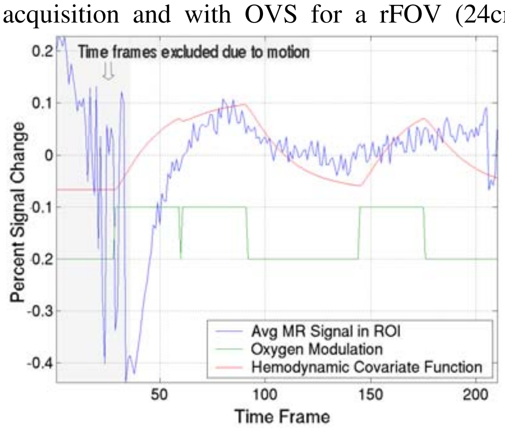
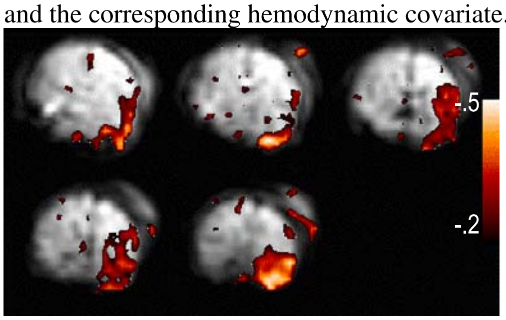



**Figure 2.** Activation maps with the rFOV sequence (below). Average signal within activated regions of interest (ROI) are plotted (above) with the oxygen modulation schedule, and the corresponding hemodynamic covariate.



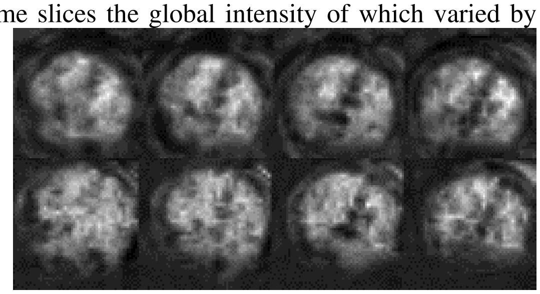



**Figure 3.** Maps of temporal SNR for 4 slices of a conventional (top) and rFOV (bottom) fMRI auditory time series.

**Results:** Comparison of the fMRI time series in a fetus demonstrates that OVS with a rFOV readout results in more homogeneous SNR levels than conventional GRE acquisition (Fig. 3), and less signal dropout around the hemispheric fissure. Activation maps acquired with the rFOV sequence (Fig. 2) show significant negative correlation with the oxygen stimulus (cc < -.2). Significant activation levels for the auditory stimulus were not found using either sequence.

**Conclusions:** Preliminary f-fMRI activation measurements with a rFOV sequence are encouraging. The OVS with rFOV readout allow good fMRI resolution and reasonable readout duration, independent of the size of the maternal abdomen. Lowering gradient slew rate is then possible, in order to reduce scanner noise and increase SNR. **Acknowledgements:** This work was supported in part by the NCI Training Grant T32 CA09695 and NIH R33 CA88205NIH, and the Center of Advanced MR Technology at Stanford (P41RR09784), and IR01EB0 02771.

**References:** **1.)** Fulford, J., S. H. Vadeyar, et al. (2004). "Fetal brain activity and hemodynamic response to a vibroacoustic stimulus." Human brain mapping. 22(2): 116-21. **2.)** Pauly J, Nishimura D, Macovski A. A k-space analysis of small-tip-angle excitation. J Magn Reson 1989;81:43-56.