SNAPSHOT INVERSION RECOVERY (SNAPIR): A ROBUST, OPTIMISED T1-WEIGHTED FETAL BRAIN MRI PROTOCOL FOR IMPROVED ANATOMY DELINEATION

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Background: T2-weighted single-shot fast spin-echo (SS FSE) sequences are the mainstay tool for fetal brain MRI, generating high contrast images even in the presence of fetal and maternal motion (1). Fetal T1-weighted gradient (field) echo breath-hold acquisitions, useful to confirm normal anatomy and pathology, lack the quality of their T2-weighted counterparts, mainly due to artefacts from maternal and fetal motion and inadequate grey-white matter contrast (2). An optimized T1 weighted fetal protocol (**Snap**shot **I**nversion **R**ecovery or **SNAPIR**), employing Inversion Recovery and single shot techniques, offers a potential robust alternative to standard T1 weighted sequences (3). The aim of this study was to prospectively compare and evaluate normal anatomy delineation as depicted by the SNAPIR approach and standard T1 weighted breath-hold acquisitions.

Methods: Research ethics committee approval and informed consent was obtained from all pregnant women prior to the scans. Imaging was performed at a 1.5 Tesla scanner (Achieva; Philips Medical Systems, Best, the Netherlands) and with a five element cardiac phased-array surface coil. Initial sample size comprised 42 fetuses. Standard fetal T1-weighted imaging presented no artefacts in only 10 patients and mild artefacts in 14; SNAPIR presented no artefacts in 27 of those patients and mild artefacts in 8. Only patients with artefact-free images of the standard T1-weighted protocol were included, resulting in a final sample size of ten. Their median gestational age (GA) was 29 weeks (range 23.86-35.71weeks). Indications for scan included ventriculomegaly (n=1), fetal brain pathology in previous pregnancy (n=2), query intrauterine growth retardation (IUGR) (n=1), healthy volunteers (n=2), posterior fossa pathology (n=1), twin pregnancy complication (n=1) and other abnormalities (n=2). The following protocols were compared in each patient: 1) The standard fetal T1-weighted Fast Field Echo (FFE) breath-hold acquisition, slightly modified from the literature (4, 5) for optimal contrast and resolution (table 1) and 2) the SNAPIR acquisition, both acquired in the axial plane. SNAPIR comprised an Inversion time TI of 400 msecs, parallel imaging acquisition at a speed factor of 2.00, centric K space sampling and a resolution of 1x1x4mm^3 (table 1). Images were evaluated both qualitatively and quantitatively. Qualitative assessment involved a comprehensive evaluation of both protocols for delineation of thirty-two anatomical structures of the fetal brain using a three point rating system (1=un-interpretable, 2=sub-optimal and 3=good quality) by a blinded observer. Quantitative assessment consisted of calculation of contrast ratios using regions of interest (ROIs) of an area of at least 25 pixels in cortical grey matter, subplate, intermediate white matter and cerebrospinal fluid in upper and lower cerebrum. The contrast ratios (CRs) were calculated using the following equation: $CR= (S_1-S_2)/\sqrt{(SD_1^2+SD_2^2)}$, where S_1 and SD_1 = the mean and standard deviation of signal intensity of the first tissue, S_2 and SD_2= the mean and standard deviation of signal intensity of the second tissue, respectively, as sampled in the ROIs. The denominator is used as a surrogate co-localised noise measure under the assumption that the tissue signal is homogenous in the ROI. Qualitative data for the two protocols were compared using Friedman's two-way ANOVA test with multiple comparisons and quantitative data were compared using two sided paired t test. A p value of less than 0.05 was considered statistically significant.

Results: The SNAPIR protocol proved superior to the standard T1 FFE acquisition in terms of normal anatomy delineation in 24 out of the 32 anatomical areas examined, with an overall statistical significance of $p<0.0001$ (figure 1). There was no significant improvement in the visualization of the following structures: pituitary gland ($p= 0.90$), differentiation of central grey matter and white matter ($p=0.96$) and the depiction of the dentate nucleus ($p=0.67$). The quantitative analysis showed that contrast ratios were significantly increased in both the upper and lower cerebrum measurements. More specifically the contrast ratios were higher in SNAPIR images and the upper cerebrum between grey and white matter ($p=0.01$), grey matter and subplate ($p=0.008$), white matter and subplate ($p=0.035$), and grey matter and CSF ($p=0.005$), as well as in the lower cerebrum ROIS between grey and white matter ($p=0.0001$) and grey matter and subplate ($p=0.0001$) but not for white matter and subplate ($p=0.945$).

Discussion: These initial results show that SNAPIR is a robust, reliable technique for acquiring T1 weighted images of the fetal brain, offering improved visualization of the majority of fetal brain anatomy and increased contrast between grey and white matter. Overall the SNAPIR approach was much more reliable in giving artifact free diagnostic images than the standard T1-weighted FFE protocols. Further improvements should be focused on the visualization of the pituitary gland and the other short T1 structures in the central grey matter to establish SNAPIR as a robust alternative to the commonly used T1 weighted fetal brain MR acquisitions.

References: 1. Huisman T, et al.Fetal magnetic resonance imaging of the brain: technical considerations and normal brain development. European Radiology 2002; 12:1941-1951, 2. Sandrasegaran KMD, et al.Fetal Magnetic Resonance Imaging. Journal of Computer Assisted Tomography July/August 2005; 29(4):487-498, 3. Malamateniou C, et al. T1 Weighted MRI of the Fetal Brain with 3D reconstruction using Single Shot Techniques. Proceedings of the ESMRMB, October 2009, Antalya, Turkey, 4. Levine D. Obstetric MRI. Journal of Magnetic Resonance Imaging 2006; 24:1-5, 5. Prayer D, et al. Fetal MRI: techniques and protocols. Pediatric Radiology 2004; 34:685-693.

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Sequence	Prayer ([5]) 2004	Levine ([4]) 2006	T1-weighted reference	SNAPIR ([3]) 2009
Breath hold	Yes	Yes	Yes	No
TE (msec) (minimum)	4.6	2.2/4.5	6	8-9
TR (msec)	(135) shortest	180	142	20-22000(shortest)
FOV (mm)	375X375	360 x 360	320 x 300	320x340
In-plane resolution (mm) (pixel size mm^2)	1.67 x 1.46 (2.43mm^2)	2.25 x 1.40 (3.15mm^2)	1.2 x 1.6 (1.92mm^2)	1x1 (1mm^2)
Slice Thickness (mm)/gap	5 /(-0.5)	5	6	4
Number of slices	15	14	12	20
FA	80	80	45	N/A
Inversion Time (TI) (msecs)	N/A	N/A	N/A	400
Total Time	17 sec	17 sec	17 sec	40sec

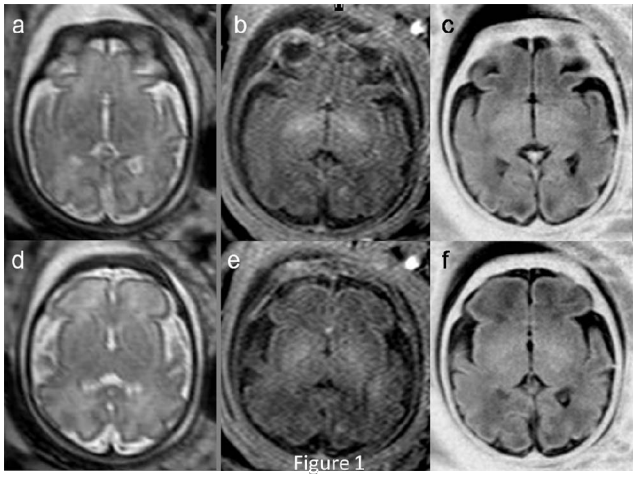

Figure 1

Table 1: Protocol parameters of the current literature FFE reference protocols (first two columns), the local reference T1-weighted protocol (third column), slightly modified from current literature practices for optimal contrast and resolution and the SNAPIR sequence (fourth column).

Figure 1: Axial T2 weighted (a, d), standard T1 FFE (b, e) and SNAPIR (c, f) images on a 34-week-old fetus. Image anatomy delineation was significantly increased with SNAPIR compared to the standard FFE protocol in 24 out of the 32 anatomical structures studied.