APPLICATION OF SNAPSHOT INVERSION RECOVERY (SNAPIR) IN NEONATAL PATIENTS WITH SNAPHOT-TO-VOLUME-RECONSTRUCTION (SVR): A PILOT STUDY AT 3 TESLA

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Background: Patient motion creates artefacts which may decrease diagnostic confidence. Snapshot Inversion Recovery (SNAPIR), a single shot T1-weighted Inversion Recovery prepared acquisition offers a robust T1-weighted alternative for improved fetal brain anatomy delineation in the presence of fetal motion (1), compared to the standard T1-weighted breath-hold gradient echo protocol. Although multi-shot are the preferred acquisitions for imaging the neonatal brain, optimized single-shot acquisitions such as SNAPIR may be advantageous in the presence of neonatal motion. However single-shot techniques are often of lower resolution and signal-to-noise ratio (SNR) compared to their multi-shot counterparts. To compensate for that dynamic scanning and image registration in the form of Snapshot-to Volume Reconstruction (SVR) (2) may be used in combination. The aim of this study was to evaluate the role of SNAPIR in the examination of the neonatal brain in relation to the standard imaging protocols in the presence of motion and to assess the value of the SVR in improving image quality of single-shot techniques.

Methods: Research ethics committee approval and informed consent was obtained from the parents of all patients prior to the scans. Imaging was performed on a 3.0 Tesla scanner (Achieva; Philips Medical Systems, Best, the Netherlands) with an eight-channel SENSE head coil. The five term-born infants included in this study had motion artefacted datasets and were imaged for the following clinical indications: Hypoxic Ischemic Encephalopathy (HIE) (n=2), isolated seizures (n=3). Their median gestational age was 40.3 weeks (range 36.7-41.4 weeks) and their median postmenstrual age at scan (PMA) was 42.9 weeks (range 38.1-46 weeks). We used: 1) a T1-weighted volume magnetization prepared gradient echo (MP RAGE) multi-shot acquisition, 2) a T2-weighted multi-slice fast spin echo (FSE) multi-shot acquisition, 3) the SNAPIR protocol (using 2 dynamic loops with 2mm slice thickness and slice overlap of 1mm) and 4) a dynamic single-shot T2-weighted FSE scan with the imaging parameters appearing on the table on the right. Dynamic scans were reconstructed with the SVR algorithm and all scans were resampled to match the MP RAGE resolution. Images were analysed in the axial plane with the same magnification using both qualitative and quantitative methods. Qualitative analysis comprised i)overall image quality rating (assessing visualisation of all brain structures for full clinical interpretation) on a three point scale (1=poor, 2=sub-optimal, 3=good) ii)evaluation of motion artefacts on the same rating scale, iii)assessment of the appearance of myelin (signal intensity, width, length) in the posterior limb of the internal capsule (PLIC) and iv)assessment of the delineation of cerebral cortex for the T1 MPRAGE and SNAPIR acquisitions with and without SVR reconstruction. Whole brain volumes (excluding posterior fossa) and cerebellar volumes were calculated in a semi-automated fashion for the T1 MP RAGE, SNAPIR and the T2 dynamic acquisitions using the ITKSNAP (3) software (ITK-SNAP 2.1.4-rc1). All image quality rating scores were analysed using the Kruskal-Wallis test and volumes were analysed using a one-way ANOVA test. Intraclass coefficient correlation (ICC) was used for assessing intra-observer reliability in the volumetric analysis.

	T1 GRE (sag)	T2 FSE (axial)	SNAPIR (axial)	T2 dynamic
TR/TE (in msecs)	17/4.6	15715/160	22000/6.1	27744/160
FA (in degrees) or TI (in msecs)	13	90	400	90
Slice thickness/ slice gap (in mm)	0.5mm	2mm -1mm	2mm -1mm	2mm -1mm
In plane resolution (in mm)	0.82x 0.93	1.15x 1.15	0.98x 0.98	0.98x 0.98
FOV (in mm)	210x158	220x220	200x161	220x176
Number of slices	200	100	100	100
description	Multi-shot volume	Multi-shot multi-slice	Single-shot dynamic with 2 loops	Single-shot dynamic with 2 loops
Scan time (mins)	06:24	03:40	3:18 per loop	1:51 per loop

Results: Overall image quality was comparable for SNAPIR (with & without SVR) and MP RAGE (p=0.36). Motion artefacts were less prominent in the SNAPIR acquisition (mean 2.6±0.8) compared to MP RAGE (mean 2±0.7). Visualisation of cortex was significantly improved with SNAPIR (mean 2.8±0.4, p=0.03) compared to MPRAGE (mean 1.4±0.5); however the SVR introduced some blurring in cortex visualisation (mean 2.2±0.4) (figure 1F). Myelin within the PLIC was better detected with the MP RAGE protocol but signal intensity and length of myelination detected within the PLIC improved when the SVR reconstruction was applied to SNAPIR, (figure 1). Volumetric analysis using the SNAPIR SVR produced robust results, comparable to both multi-shot T1 MPRAGE (coefficient of variation, CoV=0.6% - 6.8%) and T2 SVR (CoV, 2.8% - 5.6%) for both the whole brain (p=0.83) and the cerebellum (p=0.97). The ICC of twice repeated volumetric measurements for the same patient for all acquisitions was excellent (0.994, CI 0.977-0.999, with CoV for SNAPIR 0.7%-3%, MPRAGE 1.4%-4.1% and T2 SVR 1.7%-7.1%, respectively).

Discussion: These findings are comparable with the results of the application of SNAPIR in fetal patients (1), suggesting SNAPIR is a potentially robust T1-weighted alternative in cases of neonatal motion. Myelin visualisation was sub-optimal with SNAPIR compared to the MP RAGE but improved with introduction of the SVR; however more patients will have to be studied to verify our results. The SVR blurred the cortex, suggesting further optimisation is required before using SVR data for automated segmentation; however our study showed that the SVR reconstruction of SNAPIR can provide robust volumetric datasets for viewing in orthogonal planes and for quantification, unlike multi-shot motion-resistant sequences such as PROPELLER (4).

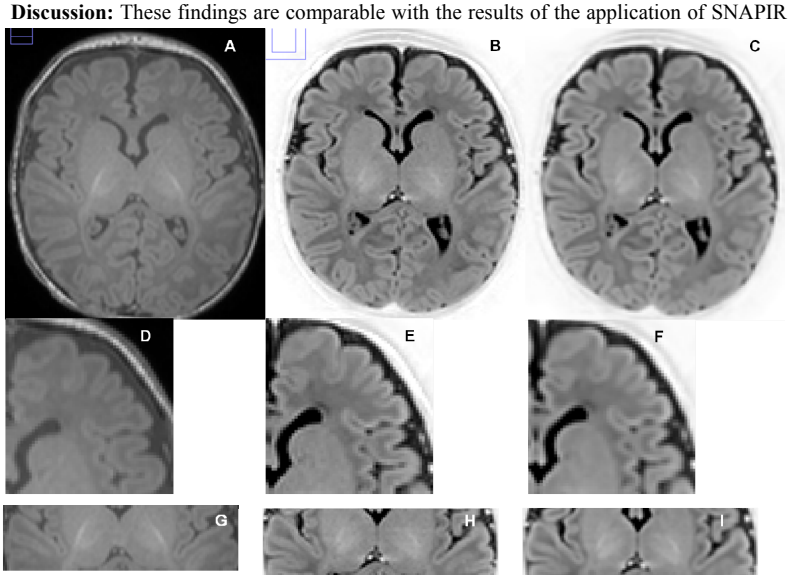

Figure 1: Axial scans of an MP RAGE (A), SNAPIR without (B) and with SVR application (C) of the same neonatal patient imaged at 42 weeks PMA. Magnified images (inset) of the cortex (D-F) and posterior limb of internal capsule bilaterally (G-I) highlight improved visualization of cortex with SNAPIR (E) and improved visualization of myelin with SVR (I).

References: 1. Malamateniou C, et al, Radiology, 2010, 2. Jiang, S., et al, IEEE TMI 2007, 3. Paul A. Yushkevich, et al, *Neuroimage,* 2006, 4. Pipe JG. MRM, 1999. **Acknowledgements:** Medical Research Council, Imperial College Healthcare NHS Trust, The Comprehensive Biomedical Research Centre, Academic Health Sciences Centre and Philips Medical Systems for research grant support and all infants and their parents that took part in this study.