Investigating Spiral Arterial Spin Labeling with Pulseq and Field Monitoring at 7T

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Introduction: *Pulseq[1] is an open-source MR pulse sequence development package with direct access to all elements in MR sequences without going through the time-consuming vendor-specific sequence programming. Field monitoring with additional NMR probes[2] enables high-fidelity measurement of the gradient performance. In this study, combining the two techniques, we aimed at developing and implementing Arterial Spin Labeling (ASL) acquisitions to investigate the possibility of improving the quality of the measured perfusion signal by comparing perfusion maps from various spiral readout strategies.*

Methods: *FAIR-QUPISS II labeling module using a tr-FOCI inversion pulse[3] was implemented for the spiral ASL sequence using Pulseq. Two resolution levels, denoted as low-res (8.82mm^3) and high-res (2.43mm^3), were chosen following an earlier study[4]. 2D single-band and multi-band CAIPI-sampled spiral[5], and 3D stack-of-spirals (SOSP) acquisitions were investigated. For 2D acquisitions, slices were acquired in the ascending order without gap between the neighboring slices. Same number of repetitions was measured for all acquisition strategies to facilitate the comparison afterwards. Other parameters included : TR/TI1/TI2/TE = 3000/700/1800/4.1 ms Echo Train Length = 25.60ms (10240 points), spiral-out, 50 control-label pairs, Flip Angle = 60^o (2D) and, 10^o (3D), BWTP of excitation pulse = 4.2 (2D), 25 (3D), Acquisition time: 5:00 min. The sequences designed using Pulseq were compiled using a vendor-specific interpreter and executed on a 7T whole body Siemens scanner (Siemens Healthineers, Erlangen, Germany) with a 1x32 channel head coil (Nova Medical, Wilmington , MA, USA). One participant was tested with all acquisition strategies.*
Field monitoring was performed after image acquisition with 16 F^{19} NMR probes (Skope, Zurich, Switzerland) placed at the iso-center of the scanner. GPU-accelerated algebraic reconstruction with field correction of up to 2nd order based on SENSE model[6] was programmed in Matlab. Relative Perfusion-weighted (PW) images, calculated as the difference between label and control images normalized to control images, were generated to evaluate the performance of perfusion signal detection for every encoding scheme. The source code of sequence and reconstruction will be made available under https://github.com/gogospin/Public shortly after the final validation.

Results: *Fig. 1 shows the relative PW images from various acquisitions. With our parameter settings, the 3D high-res acquisition showed very noisy perfusion signal without distinguishable difference between gray and white matter and was therefore not included in the figure. Low-res single-band and multi-band acquisitions both showed perfusion signal nicely following the gray matter. Higher contrast level was seen in the multi-band images. 3D low-res acquisitions yielded similar spatial distribution of perfusion signal but with slightly lower contrast level and less blurring. The advantage of high-res acquisition can be observed in the PW images from the 2D single-band acquisitions with spatially more clearly resolved perfusion signal, albeit with a higher noise level. In addition, the 2D high-res acquisition showed the highest contrast level among all examined cases.*

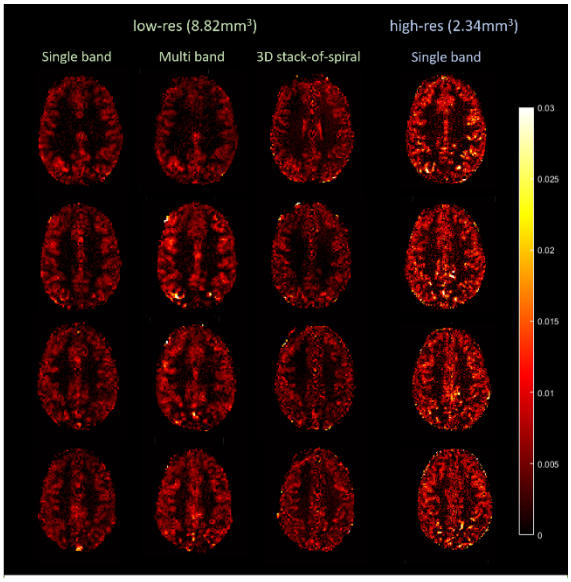

Figure 1. *Relative perfusion-weighted images from various acquisition strategies. The results from high-res 3D stack-of-spiral acquisition are not shown due to the very low contrast-to-noise ratio.*

Discussion: *In this study, using Pulseq and field monitoring, we successfully implemented FAIR-QUIPSS II ASL acquisitions and reconstructions with spiral readouts. Different levels of resolution with 2D and 3D spiral sampling were investigated. High resolution perfusion-weighted signals were obtained with the 2D acquisition. The measured perfusion signal, showed an unintuitive pattern following the change in acquisition scheme. The high perfusion signal in the 2D high-res acquisition could be linked to reduced partial volume effects. The very low contrast level in the high-res 3D acquisition compared to its 2D counterpart has not been clarified yet and requires further investigation. The long readout time in the 3D approach, i.e., 24 times as long as the 2D acquisition for each slice with our parameters, could result in larger physiological noise and larger dynamic change of the local magnetic field during the imaging period. Future investigation on optimizing the 3D acquisitions shall include approaches such as reducing the imaging time per volume, flip angle optimization schemes and different sampling orders in the slice direction.*

Conclusion: *Pulseq combined with field monitoring provides a practical, convenient, and reliable approach for sequence prototyping to investigate sequence behaviour for spiral ASL acquisitions.*

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