Selective ASL with 2D RF pulses

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Target audience: RF engineers and MR physicists **Purpose:** In the last decades, different methods of selective labeling of single arteries emerged in Arterial Spin Labeling (SASL), where blood in selected arteries in the neck or brain is inverted (1). While techniques with non-subject specific spatially selective two-dimensional radio frequency (2D RF) label pulses have been applied in the past (2,3). In this work an approach for SASL with subject-specific 2D RF pulses is evaluated. Using parallel transmission (pTX), the 2D RF pulses are designed using subject-specific B1 maps and using a variable-density k-space trajectory. *The aim of this work is to compare the quality of ASL images using 2D RF labeling pulses with standard ASL methods and to measure perfusion territories of the ICAs and basilar artery using a subject-specific pulse design with a variable-density spiral.*

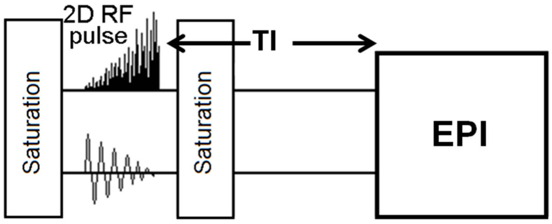

Fig. 1: 2D RF ASL sequence with 2D RF pulse labeling.

Methods: For the 2D RF pulse design, subject-specific B1 data (resolution 4.4x4.4x5mm^3) from sagittal and coronal slices in c-spine and head were acquired on a 3T MAGNETOM Skyra prototype 2-channel pTX system (Siemens Erlangen, Germany). A spiral with 16 no. of rounds and variable density was used for the pulse design, which was adapted to each subject resulting in a pulse duration of 7 to 9 ms. Magnetization target was an ellipse positioned utilizing angiography data to label both ICAs and the vertebral artery (VA) at once (sagittal orientation) or to selectively label left ICA, right ICA and basilar artery (coronal orientation). The RF pulse was designed including constraints from hardware and SAR. The quality of the 2D RF pulses was estimated using Bloch simulation of the designed pulses on patient-specific B1 data. The ASL sequence is shown in Fig. 1. The control image is obtained, switching off the RF power without changing the gradients of the 2D RF pulse. The time TI was set to 1800 ms. For imaging, a multislice EPI read-out with 6/8 partial Fourier was used (TE 13 ms, FoV 240x240 mm^2, matrix 64x64, resolution 3.8x3.8x5mm^3). 47 control-label pairs were averaged; the measurement time was 3:52 min. The results of the 2D RF ASL method were compared to a standard PICORE method with the same timing using a FOCI pulse.

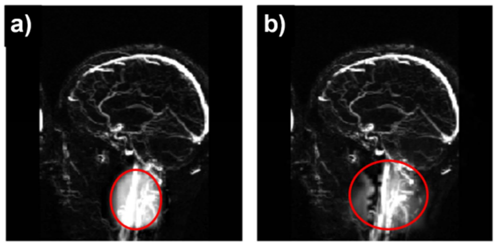

Fig. 2: Designed RF pulse (a) and blurring due to off resonance effects (b).

Results: Inversion flip angles of up to 155° were reached for the 2D RF labeling pulses due to the constraints and selected TX trajectory in the design. Off-resonance effects still caused some blurring in the label region (Fig. 2 target (a) and real magnetization (b) overlaid on sagittal phase contrast angiography). ASL label efficiency was dependent on the inversion flip angle as well as on the target size. Comparing a 1-channel with the 2-channel RF pulses design, 10% higher flip angles could be achieved with 2-channels even in non-transverse orientations. Without the saturation pulses after the labeling pulse, the “ASL” signal was increased, the signal ratio of white and gray matter being three times higher compared to PICORE. Using four saturation pulses, a comparable signal ratio of PICORE and the 2D RF ASL method was achieved. Selective labeling of the left ICA, right ICA and VA (Fig. 3, average inversion flip angle was 153°) was successful with small labeling regions (17 - 22 cm^2) showing perfusion territories. Masks of the perfusion territories from the superposed ICAs and basilar artery are shown in Fig. 4 (target sizes 3-5 cm^2, flip angle 143 – 156°).

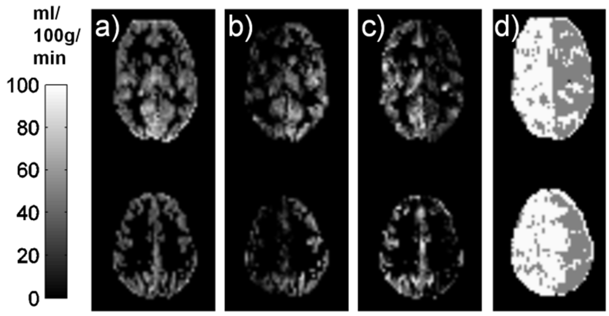

Fig. 3: a) PICORE measurement, b) labeling of right ICA and VA, c) labeling of left ICA and VA, d) mask of perfusion territories, white: left labeling, gray: right labeling.

Discussion/Conclusion: The 2-channel pTX design using subject-specific B1 maps and a variable-density spiral TX trajectory creates label pulses with comparable efficiency to standard PICORE-FOCI pulse. With the demonstrated 2D RF method, free positioning of the label pulse is possible. It was shown that selective labeling of the ICAs and VAs is feasible with small target sizes. This method revealed higher signal-to-noise ratio and is more flexible in the positioning than previous methods.

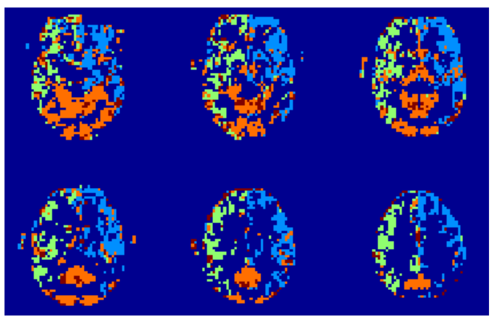
Fig. 4: Masks of perfusion territories of basilar artery (orange), left ICA (green) and right ICA (light blue).

References: 1. Paiva F, et al. (2007), NMR Biomed. 20, 633–42; 2. Davies N, et al. (2003), MRM 49, 1133–42; 3. Konstandin S, et al. (2010), Z. Med. Phys 21, 26–32