Improving 4D pCASL angiography by combining Hadamard time-encoding with Look-Locker readout

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Purpose: Time-resolved 4D-MRA provides important information for diagnosis, treatment, and follow-up examinations of cerebrovascular disease and can be achieved by combining pulsed arterial spin labeling (PASL) with a multi-phase Look-Locker readout. This approach offers hemodynamic information at a high spatial and temporal resolution without contrast agent injection and has been successfully applied to several cerebrovascular diseases[1]. In those diseases, flow territorial information can provide important additional information, e.g. for identification of the feeding arteries in arterio-venous malformations and for estimation of collateral (or bypass) blood flow patterns in steno-occlusive diseases. However, vessel selectivity of PASL is limited to the main carotid arteries, whereas the recently introduced superselective pseudo-continuous ASL method (superselective pCASL) can target much smaller intracranial arteries, such as A2/A3 and M2/M3 segments distal to the circle of Willis[2]. The use of superselective pCASL for time-resolved 4D-MRA is, however, impeded because of the need for a long labeling duration. To observe the arterial inflow phase, labeling duration should be kept as short as possible, although such a short labeling duration would result in low SNR, especially within peripheral arteries at later time-points. Such a low SNR would be further reduced by the application of many RF-pulses during the Look-Locker readout of multi time-point data. Hadamard time-encoded pCASL (te-pCASL) was recently proposed as an approach to increase the SNR and time efficiency of multiple timing acquisitions[3]. The purpose of this study is to introduce a new superselective pCASL 4D-MRA sequence which combines the te-pCASL and Look-Locker readout to achieve an observation of arterial inflow phase and improvement of SNR by using Hadamard encoding blocks of different duration, resulting in a longer effective labelling especially for the peripheral arteries.

Methods: The sequences used in this study are: a) pCASL Look-Locker readout, b) te- pCASL with 8x7 encoding matrix, c) combination of te-pCASL with 4x3 encoding matrix and 3-phase Look-Locker readout, as illustrated in Fig.1. All sequences were adjusted to have a labeling delay of 300 ms for the 1st phase, a phase interval of 200ms and 7 or more phases. The labeling duration of sequence a) was set to 200 ms with 100ms delay time between end of labeling and image acquisition. In sequence b), 1400 ms total labeling duration consisting of 7 blocks of 200 ms (with different 8 encodings) was used. In sequence c) 1200 ms total labeling duration consisting of 3 blocks with different length and a 3 phase Look-Locker readout was used (see Figure 1c). Three healthy volunteers participated in this study. All experiments were performed on a 3.0T scanner (Achieva TX, Philips Healthcare). 3D segmented T1-TFE-EPI sequence was used with following parameters: FOV = 230 mm, Matrix = 168 x 168, 120 slices with thickness of 0.75mm, EPI factor = 5, TFE factor = 12 for a) and c), 25 for b), flip angle = 8º for a) and c), and 10º for b). Scan time of each sequence was; a) 5:38, b) 5:46, c) 5:49.

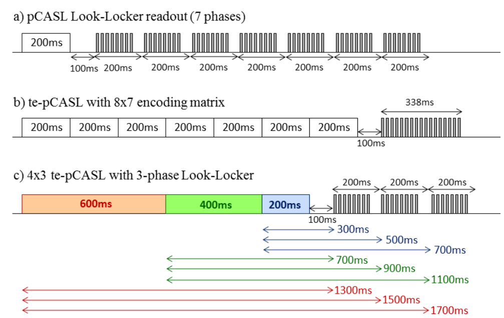

Fig.1. Timing scheme of the employed sequences showing duration of labeling (blocks), delay time and phase interval.

Results and Discussion: Fig.2 shows an example image of the arterial inflow phase acquired with sequence c), showing good image quality; similar quality was achieved by sequence a) as well as b) (data not shown). Fig.3 shows a comparison of the ability of the three sequences to depict the peripheral arteries at later time-points. In the images acquired with sequence b) and c), peripheral arteries were depicted more clearly than sequence a), which might be attributed to the use of successive RF pulses during the Look-Locker readout saturating the signal of labeled blood before arriving in peripheral arteries, and this side-effect was avoided by using te-pCASL. Although sequence c) also employs a Look-Locker readout, the number of acquired phases is limited to three, and this sequence uses longer labeling durations of 400 ms and 600 ms for the later phases resulting in a higher SNR and thereby the best depiction of peripheral arteries. Only healthy volunteers without cerebrovascular disease participated in this study. Therefore, it is difficult to predict image quality in clinical applications with e.g. slow flow. However, the results of this volunteer study do show improved image quality in the later phases by using te-pCASL in combination with a Look-Locker readout with reduced number of phase, as compared to the conventional pCASL Look-Locker readout. A combination with superselective labeling presents good image quality as well (Fig.4).

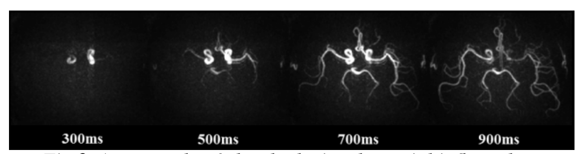

Fig.2. An example of clearly depicted arterial inflow phase acquired with sequence c).

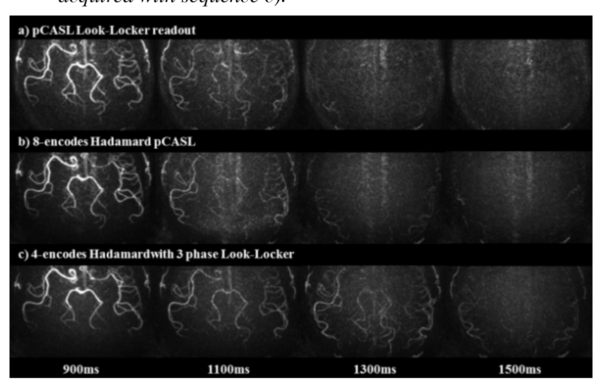

Fig.3. Comparison of peripheral arteries at late phases.

Conclusion: The combination of te-pCASL with different length of sub-boli and Look-Locker readout with reduced number of phases gives both observation of the arterial inflow phase and improved depiction of peripheral arteries at later phases to superselective pCASL 4D-MRA.

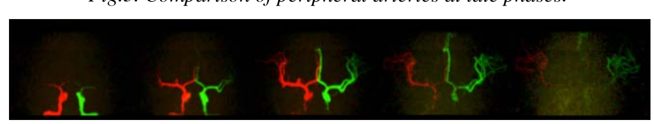

Fig.4. Selective 4D-MRA images acquired with 4 Hadamard encodings and 3 phase Look-Locker..

Reference: 1. Nakamura M. et al., Proc. Intl. Soc. Mag. Reson. Med (2010), 2. Helle M. et al., Magn. Reson. Med. 64, 777 (2010), 3. Günther M. Proc. Intl. Soc. Mag. Reson. Med (2007).