Simultaneous acquisition of perfusion maps and 4D MR angiography by means of arterial spin labeling MRI

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Purpose: 4D magnetic resonance angiography (4D-MRA) as well as perfusion imaging can be performed by arterial spin labeling (ASL) MRI. Both techniques have proved their value in the characterization of hemodynamic pathology in cerebrovascular disease; while 4D-MRA highlights large vessel pathology such as stenosis or collateral blood flow patterns, perfusion imaging provides information on the micro-vascular consequences, e.g. it can be considered a proxy for the delivery of oxygen and nutrients to the neuronal tissue. Their complementary information provides a complete picture of the hemodynamic status, which may prove especially important in conditions such as acute stroke. The main drawback of acquiring both scans is the total scan-time: each sequence can easily last 5 minutes. Since both sequences share a similar preparation (the labeling module), a combined acquisition seems achievable. The feasibility of this idea has already been demonstrated by Hadamard time-encoded ASL (te-ASL) that can provide images of the arterial- and perfusion phase in a single acquisition. However, the minimum voxel size of this approach, which is governed by SNR requirements in the perfusion image, renders too low a resolution for 4D-MRA. In this study, we propose the combination of a te-ASL preparation with two sequential readout modules: a segmented high-resolution TFE-EPI readout with small flip angles for 4D MRA, followed immediately by a low resolution single shot EPI sequence for perfusion imaging. By sharing the same labeling module for both the MRA and perfusion acquisition, the total acquisition time can be approximately halved.

Methods: Six healthy volunteers participated in this study. All experiments were performed on a 3.0T scanner (Achieva TX, Philips Healthcare). For te-ASL preparation, a Hadamard 8 encoding scheme[1] was modified by introducing a pause between block 1 and 2 to establish an adequate post labeling delay (PLD) for perfusion imaging, while the timing and duration of the remaining 6 Hadamard blocks were optimized for MRA (block durations: 1650 ms, 725 ms pause, 6 * 120 ms, see fig 1). For MRA acquisition, a 3D segmented TFE-EPI sequence was used with the following parameters: FOV = 230 mm, Matrix = 120 x 113, 70 slices with 0.95 mm thickness, EPI factor = 5, TFE factor = 33. For perfusion imaging, a multi-slice single shot EPI sequence was used, with FOV = 240mm, matrix = 80 and 17 slices with 7 mm thickness. The combined acquisition time for MRA and perfusion was 5:38 minutes. To investigate the saturation effect on the perfusion image caused by the RF pulses used in the MRA imaging, the acquisition was repeated with different flip angles for MRA (1, 2.5, 5, 7, 10, 12.5 and 16°) with perfusion imaging parameters unchanged. For each scan the temporal SNR (tSNR, mean perfusion signal divided by the standard deviation of perfusion signal over the signal averages) was calculated. Unsubtracted images were averaged to study the saturation effect in the baseline signal. SNR in the MRA images was measured by drawing ROIs in peripheral arteries.

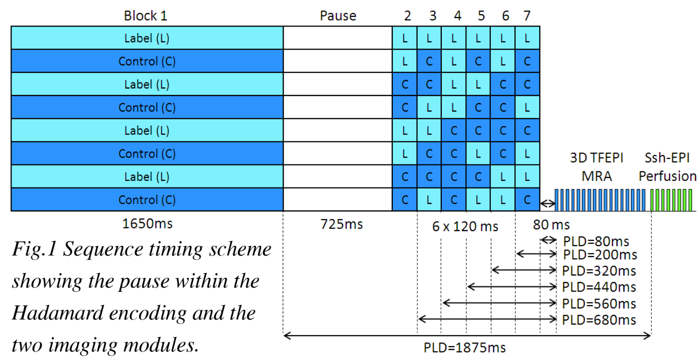

Fig.1 Sequence timing scheme showing the pause within the Hadamard encoding and the two imaging modules.

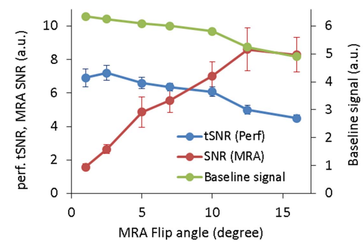

Fig.2 MRA SNR, gray matter perfusion tSNR and baseline signal (i.e before subtraction) acquired with different flip angles for MRA acquisition.

Results and discussion: Fig.2 shows the gray matter perfusion tSNR and baseline signal acquired after MRA acquisition with different flip angles. Both tSNR and baseline signal show a gradual decrease with increasing MRA flip angle between 1 and 10º, and a steep decrease for higher MRA flip angles. This suggests that too large flip angle in MRA acquisition may lead to an unacceptable loss in tSNR for perfusion images. The benefit of a higher MRA flip angle is demonstrated by the increase in SNR in the peripheral arteries (Fig.2). When the MRA flip angle drops below 7°, visualization of peripheral arteries becomes increasingly difficult (Fig.3). Fig.4 shows simultaneously acquired perfusion images and 4D-MRA (MRA flip angle of 10º). These results demonstrate the feasibility of simultaneous acquisition of perfusion images with clinical quality and 4D-MRA with good visualization of peripheral arteries. With only a small compromise of perfusion image quality due to simultaneous 4D-MRA acquisition, additional information on large vessel pathology is provided.

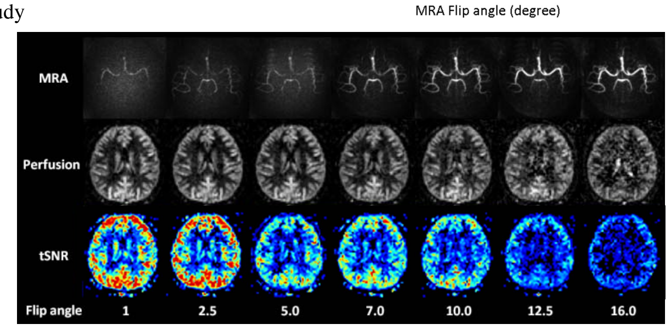

Fig.3 Transverse MIP of MRA, perfusion images and tSNR maps (top to bottom) acquired with different flip angles for MRA imaging (left to right)

Conclusion: This work demonstrates the feasibility of simultaneous acquisition of ASL-based perfusion images and 4D-MRA by sharing the same time-encoded labeling module for both acquisitions. This approach reduces the total examination time to ~5 minutes, making it suitable for clinical applications, including acute stroke patients.

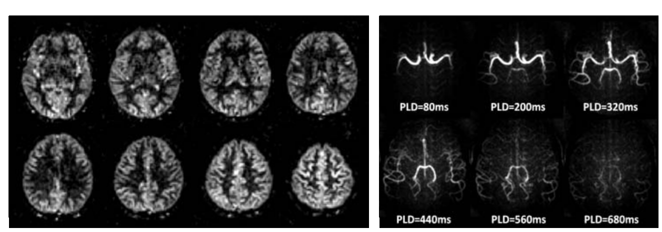

Fig. 4 Whole brain perfusion(left) and 6-time point MRA images (right, transverse MIP) acquired in 5:48 min scan time (MRA flip angle = 10°)

Reference: 1. Günther M. Proc. Intl. Soc. Mag. Reson. Med (2007).