Regional Perfusion Imaging in patients with arterial occlusions

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INTRODUCTION: The collateral circulation plays an important role in patients with cerebral artery occlusion. Successful recruitment of these subsidiary blood vessels may result in good clinical outcome in the face of proximal large vessel occlusion (1). Diagnostic strategies to evaluate the collateral circulation can be broadly divided into those that directly visualize the collateral blood vessels (conventionally using x-ray angiography) and indirect methods that assess tissue perfusion, including acetazolamide challenge tests of cerebro-vascular reserve. Until recently however, no imaging technique could combine both methods and quantitatively assess the flow territories supplied by each major brain vessel and its collaterals in such patients. Recently, a new class of arterial spin labeling (ASL) methods has been developed, allowing for independent regional perfusion imaging (RPI) (2-5). However, obtaining absolute values from such methods in patients suffering from cerebral artery occlusion may be questionable, as duration and arrival time of the labeled bolus is highly uncertain. An elegant solution to this problem has been suggested recently, which consists in combining conventional ASL techniques with a rapid Look-Locker-like sampling strategy to simultaneously measure both arrival time and perfusion (6,7). Thus, in this work, our aim was the assessment of collateral perfusion in a patient population with neurovascular diseases using ASL.

METHODS: Twelfth consecutively recruited patients presenting with either extra- or intracranial artery occlusions were included in this study. The experiments were approved by the local ethics committee and the MRI investigations were performed using a 3T Philips Intera whole body system. All patients underwent a measurement of global perfusion (n=12) using ASL acquisition at multiple time-points (8). In addition, RPI at a single or at multiple time-points were added (n=9) to address changes in perfusion territories. Also, perfusion reserve of global perfusion during resting state and under acetazolamide-induced stress were measured in n=5 patients. Typical scan protocols for global perfusion were: 6-9 slices; thickness = 8 mm; gap = 2 mm; matrix = 64 × 64; FOV = 240 mm; $\alpha = 35°$; T_R / T_E = 4000 / 23 ms; $TI_I/\Delta TI$ = 100 / 200 ms; time points = 18; SENSE = 3; labeling slab = 150 mm; inversion gap = 30 mm; 60 averages; scan time 4 min. RPI images acquired at a single time point had a T_R/ T_I = 3000 / 1500 ms. The planning of the labeling volume for the left- and right-internal carotid artery (ICA) as well as the posterior circulation was performed on the basis of the MIPs from TOF- and PC- MR angiograms in a way similar to Hendrikse et al (1). Cerebral blood flow (CBF) was obtained from the dynamically acquired data using a 3-parameter fit to the modified standard perfusion model (6). In addition to CBF, this gives information on the time of arrival as well as the duration of the bolus and therefore provides a quantitative measure of the delay time to a certain region caused by e.g. collateral perfusion.

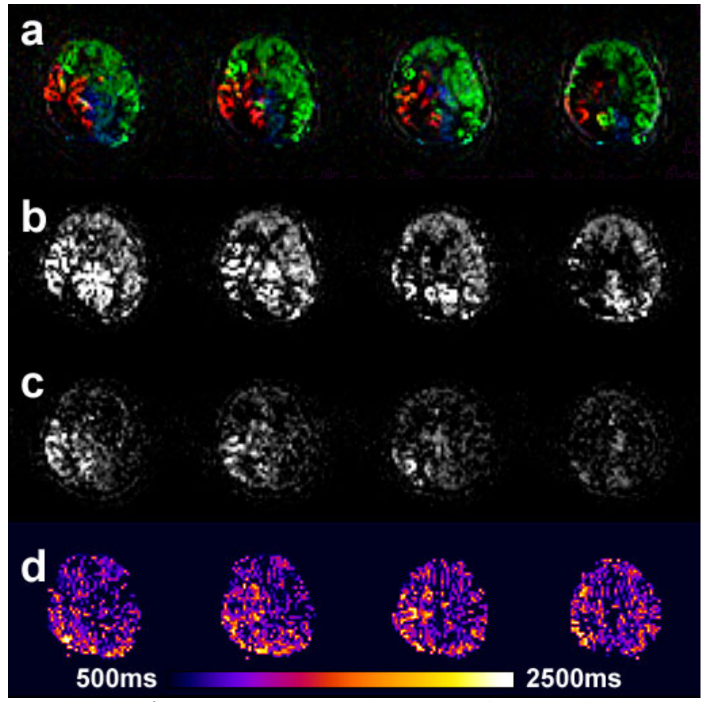

Fig. 1: a) RPI of a patient presenting with transient ischemic attacks (TIA) and right common carotid artery thrombus, with posterior circulation coded in blue, left ICA in green and right ICA in red, showing the large perfusion territory supplied by the LICA. No infarct is present on diffusion-weighted images. b) and c), non-selective perfusion-weighted images at 1400ms and 3000ms respectively. d) Time-of-arrival map, demonstrating slow flow from the RICA.

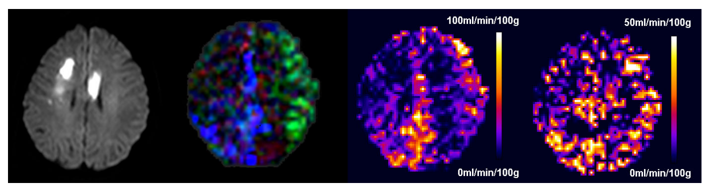

Fig. 2: a) Isotropic diffusion-weighted image of a patient with multiple athero-sclerotic disease, including complete occlusion of the RICA, showing recent infarcts in both right and left frontal lobes. b) RPI of the same patient, demonstrating large collateral perfusion from the posterior circulation at TI=1300ms. Note the drop in signal in the infarcted areas. c) Absolute global perfusion image showing reduced CBF in similar areas. d) Absolute cerebral reactivity map after acetazolamide challenge, demonstrating identical under-perfused areas (mainly right frontal lobe)

RESULTS and DISCUSSION: Estimation of the regional and possible collateral perfusion was fulfilled in 9 out of 12 cases and was in agreement with other imaging data while 3 cases were discarded due to heavy motion artifacts. This is an intrinsic problem of ASL that suffers from low signal-to-noise ratio necessitating averaging and long scans times, which proved to be especially problematic in patient studies. However, the remaining results seemed promising as depicted in the first case in Fig. 1, which presents a patient with transient ischemic attacks and right common carotid artery thrombus. In this patient, right internal carotid artery (RICA) perfusion territory has been reduced (red in Fig. 1a) and replaced by collateral supply from LICA which in turn resulted in delay of the flow by as much as 2.5s (Fig. 1b-d). This emphasizes the importance of acquiring ASL data at multiple time-points especially in a patient population like the one targeted in this study. For instance, acquiring at a standard inversion time of 1400 ms (Fig. 1b) could led to a conclusion of no perfusion in the posterior part of the right hemisphere while its in fact delayed (Fig. 1c). The second case (Fig. 2) presented here, highlights another promising use of ASL for imaging of the perfusion reserve acetazolamide challenge, which has been shown to be an important marker for the outcome (1). There is good correlation between the infracted region seen in the diffusion-weighted image (Fig. 2a) and the region showing low perfusion in the RPI image as well as pre-stress CBF (Fig. 2b-c). Post-stress, the same area shows no reactivity indicating that this region is incapable of compensating any further, thereby signaling increased risk for further ischemia.

CONCLUSION: Non-invasive regional perfusion imaging is capable of addressing collateral perfusion by labeling one flow territory at a time and could thereby become an alternative to the conventional X-ray based subtraction angiography which so far is the only modality giving temporal as well as spatial regional blood information. The method seems furthermore usable for perfusion stress tests, promising higher spatial resolution than possible using e.g. SPECT. However, more patient material needs to be acquired to prove its statistical strength towards these methods, as well as to address the reproducibility of these measurements.

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