FLOW TERRITORY MAPPING OF THE CEREBRAL ARTERIES WITH REGIONAL PERFUSION MRI (RPI)

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Introduction

Conventional contrast enhanced (CE) angiography is the gold standard for the visualization of the vascular tree supplied by the individual major cerebral arteries. Recently, 2D pencil beam pulses and local surface coils have been developed for selective labeling of the arteries in the neck.[1,2,3] We here introduce a spatially selective arterial spin labeling approach, regional perfusion imaging (RPI), which is based on selective slab inversion of the arterial water with a pulsed ASL sequence. We show the ability of RPI for selective labeling of the left internal carotid artery (ICA), right ICA and the posterior circulation (basilar artery and vertebral arteries). Furthermore, CBF values are measured in regions-of-interest (ROIs) within the individual perfusion territories of the selectively labeled cerebral arteries.

Methods

The RPI sequence is shown in Figure 1. The inversion of inflowing spins is achieved by applying two consecutive slice-selective 90° RF pulses in a slab. This labeling slab can be in any angulation with respect to the imaging slices, according to the specific arteries one wants to label, e.g. Fig. 2. In the control scan the phase of the second 90° pulse is shifted by 180°, yielding no labeling effects but correcting for the magnetization transfer effects, as shown previously for the transfer insensitive labeling technique (TILT).[5,6] Subsequently, three saturation pulses are applied to remove the effects of the labeling pulses on the imaging slices. Each saturation pulse is followed by strong dephasing gradients in all three directions to spoil the remaining transverse magnetization (Figure 1). The range of the saturation slab was set from 10 mm below the lowest imaging slice to 45 mm above the highest imaging slice, rendering the sequence not sensitive to venous flow from the top of the brain. The labeling delay time TI (inversion time) was set to 1200ms. Other MR parameters were: TR = 3000 ms; TE =5.6 ms; 62% half Fourier acquisition; number of slices = 5; slice thickness = 8mm; slice gap = 1mm; slice order = descending; time between slices = 25 ms, FOV = 240 × 240 mm; matrix = 64 × 64; zero filling to 128 × 128 matrix; averages = 50; RPI scan time = 5 minutes. Planning of the labeling volume was performed on the basis of phase contrast (PC) surveys and TOF MR angiograms (Figure 2). To quantify CBF, perfusion weighted ASL signal was fitted to the perfusion model described by Calamante et al.[4]

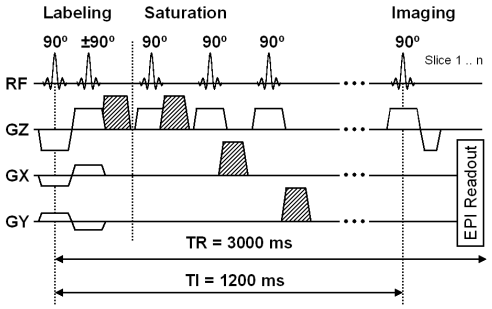

FIGURE 1. *Sequence for Regional Perfusion Imaging (RPI). The inversion of inflowing spins is achieved by applying two consecutive slice-selective 90° RF pulses in a slab, which can be angulated freely with respect to the imaging slice.*

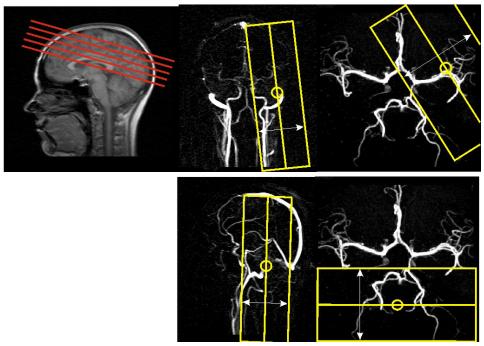

FIGURE 2. *Scan plan for selective labeling of the left ICA, right ICA and posterior circulation. The five imaging slices were planned parallel to the orbito-meatal line.*

Results

The CBFs for ICA territories were 65.8 ± 3.0 (n=8, mean±SEM) ml/min/100gr tissue, 22.1 ± 1.0 ml/min/100gr tissue and 40.1 ± 1.9 ml/min/100gr tissue for gray matter, white matter and whole hemisphere, respectively, whereas the gray matter CBF in the posterior circulation was 71.8 ± 5.5 ml/min/100gr tissue. Figure 3 shows, in a control subject, representative perfusion weighted images according to RPI labeling of the left, right ICA and the posterior circulation (basilar artery and vertebral arteries). When using oblique sagittal RPI labeling of the ICA, the flow territory of the basilar artery is excluded and no perfusion-weighted signal is present in the posterior part of the imaging slices. When using coronal labeling of the basilar artery, perfusion weighted signal is symmetrically present in the posterior part of the imaging slices.

Currently, the RPI method has been performed in 70 healthy control subjects, 20 patients with ICA occlusion and 10 patients after extracranial to intracrial bypass surgery.

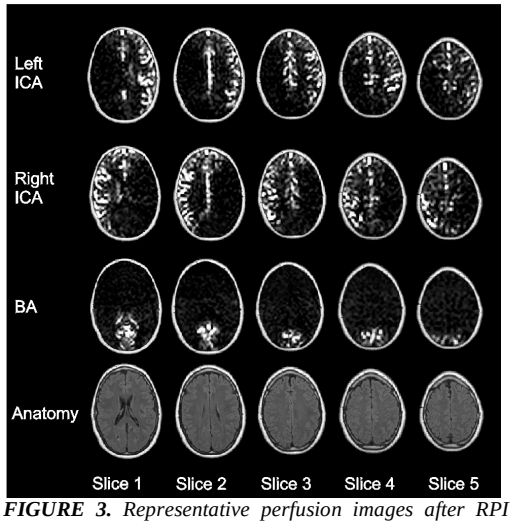

FIGURE 3. *Representative perfusion images after RPI labeling of the left ICA, right ICA, and the posterior circulation (basilar artery and vertebral arteries) in a healthy control subject.*

Discussion and conclusions

We developed a non-invasive method to determine the arterial flow territories with selective ASL labeling of the left ICA, right ICA, and the posterior circulation. CBF values measured with RPI in the hemisphere, white matter and gray matter are in agreement with literature data on regional cerebral perfusion. Selective labeling could be achieved because of the sharp labeling profiles of the TILT labeling pulses and the possibility to interactively plan of the spatially selective inversion slabs.[5,6] No extra coils are needed, magnetization transfer is compensated for, SAR is kept minimal, and CBF can be quantified using well established perfusion models. TILT labeling and control scheme (respectively +90/+90° RF pulses and +90/-90° RF pulses) provides global compensation for MT effects that are independent of the angulation of the labeling slab with respect to the imaging slice. A potential drawback of the use of RPI for flow territory mapping is the combined labeling of both the larger arteries, proximal and distal to the circle of Willis, and the small vasculature at the level of the brain tissue. However, the increased thickness of the presaturation slab will minimize the contribution of the small vasculature to the RPI perfusion signal.

[1]Zaharchuk G et al. MRM 1999, p. 1093-1098

[2]Davies NP et al, MRM 2003, p. 1133-1142

[3]Trampel R et al, MRM 2002, p. 543-546

[4]Calamante F et al. NMR Biomed 1996, p. 79-83

[5]Golay X et al. JMRI 1999, p. 454-461

[6]Pruessmann KP et al. JMR 2000, p. 58-65