Magnetic resonance imaging of cerebral borderzones

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Introduction

The locations of the vascular territories irrigated by the anterior cerebral artery, the middle cerebral artery and the posterior artery have been investigated in cadaver studies with selective injection of dyes and subsequent investigation of the extend of the vascular territories in cross sectional analysis. In these post-mortem studies a large variability of the borders between different vascular territories was reported. Thusfar, no imaging modality could depict the exact location of the cerebral borderzone regions *in-vivo*. By definition, the arterial borderzone areas are located at the distal end branches of the cerebral arteries, therefore one would expect that even with an adequate cerebral perfusion pressure, these areas can be detected on the basis of longer arterial travel times. Here we show that it is possible to visualize the borderzone regions between the distal branches of the cerebral arteries with arterial spin labeling MRI based on an increase in arterial blood transit time.

Methods

All experiments were performed on a 3.0 T Philips Intera Imager (Philips Medical Systems, Best, The Netherlands). All images were acquired using the quadrature body coil as sending coil and a 8-element phased-array head coil as receiving coil. For arterial spin labeling we used the recently developed QUASAR pulse sequence (**qua**ntitative **S**TAR labeling of **a**rterial **r**egions). This sequence is capable of acquiring images at multiple inversion times (TIs) after labeling with a high temporal resolution and has a bolus saturation scheme for clear definition of the arterial blood bolus (Proceeding #34; Petersen E.T., Lim T.C.C, Golay X. ISMRM'05). From the filtered data, the latter were defined as regions with a transit time of more than 0.5s.

Results

A significant increase in arterial transit time was detected for the anterior borderzone 0.93 ± 0.02 s (mean ± s.e.m.) and posterior circulation 1.01 ± 0.02 s compared with a non-borderzone gray matter transit time of 0.54 ± 0.02 s; $P<0.001$. Furthermore, the CBF values of the anterior borderzone 61.7 ± 3.3 ml/100g/min and posterior circulation 62.4 ± 3.2 ml/100g/min were significantly lower than CBF from the non-borderzone gray matter 78.3 ± 3.2 ml/100g/min; $P<0.001$. The arterial blood volume was reduced at both the anterior 0.88 ± 0.07 ml/100g and posterior borderzone 1.19 ± 0.11 ml/100g with respect to the non-borderzone gray matter 1.64 ± 0.08 ml/100g; $P<0.001$

Discussion and conclusions

This is the first time that longer travel distance and consequently longer travel times to the distal branches of the intracranial arteries are exploited to visualize the location of the borderzones in healthy subjects. We demonstrate the ability of arterial spin labeling MRI to image the cerebral borderzones based on an increase in arterial transit time of, on average, 0.43 seconds to these regions. The observed increase in arterial transit time and the reduction of CBF and CBV in the borderzone regions may indicate vulnerability of the cerebral borderzone regions to ischemia after a decrease in arterial perfusion pressure.

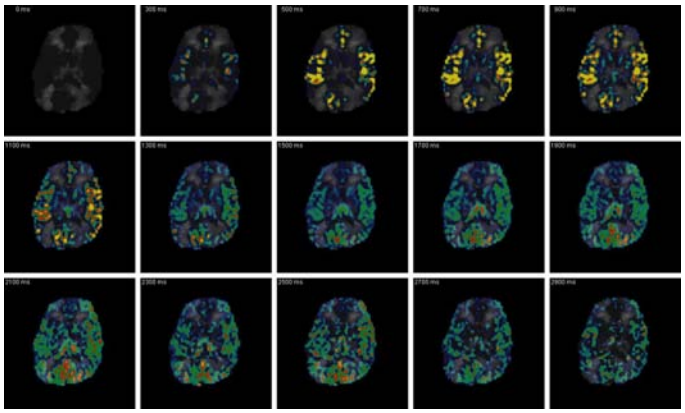

Figure 1. *The 15 images show the temporal evolution of the arrival of the labeled arterial water at the brain tissue at a series of time points, from 0 to 2900ms. Longer arterial transit times can be appreciated in anterior and posterior aspect of the middle cerebral artery flow territory (light grey areas in the background).*

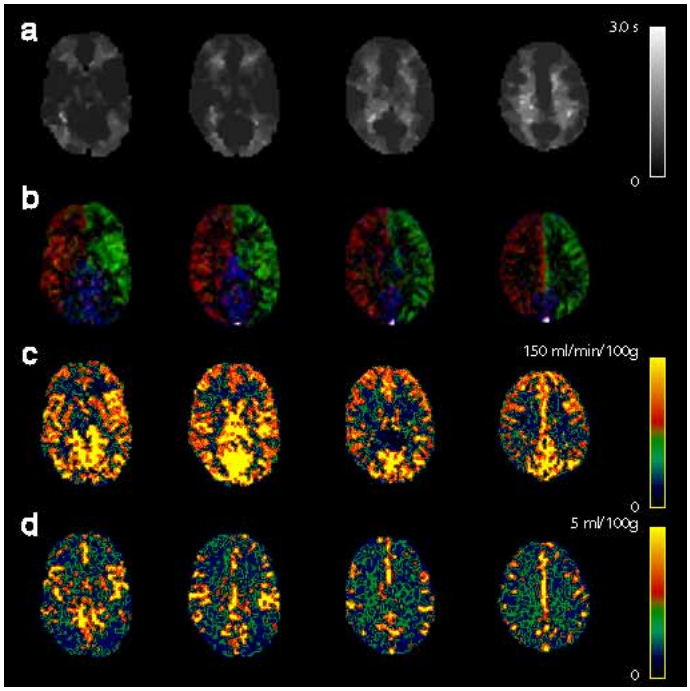

Figure 2. *Four typical slices from one volunteer: borderzone images demonstrating regional differences in the absolute arterial transit time in seconds (**a**), MR flow territory images of the right ICA labeled in red, left ICA labeled in green and the posterior circulation labeled in blue (**b**), cerebral blood flow images in ml/min/100g tissue (**c**), and arterial blood volume in ml/100g (**d**).*

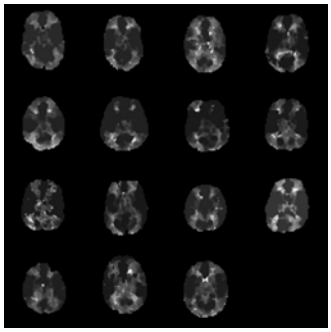

Figure 3. *Borderzone images for the 15 control subjects based on measured arterial transit time for one of the middle slices. A similar pattern can be appreciated for all subjects with an increase in arterial transit time at the anterior and posterior aspect of the expected middle cerebral artery flow territory.*

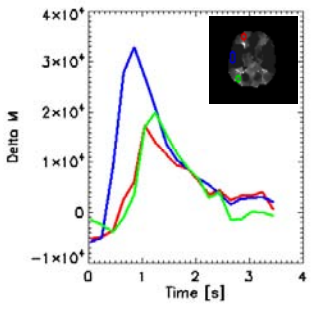

Figure 4. *ROIs placed in the anterior borderzone (red), other gray matter area (blue) and posterior borderzone (green). Arrival of the label in the borderzones can be seen at 0.7-0.8 s for the anterior and posterior borderzones compared with arrival of the labeled spins at 0.4 ms for the non-borderzone area.*