Delayed arrival of arterial blood measured with arterial spin labeling in patients with a symptomatic carotid artery stenosis

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Introduction

Patients with a stenosis of the internal carotid artery (ICA) are at high risk of future ischemic stroke (1). Several studies have reported that this risk is higher in those with impaired perfusion in the hemisphere ipsilateral to the stenosis. At the level of the brain tissue, the presence of such reduced cerebral perfusion can be detected by a delayed arrival of blood from the arteries in the neck towards the brain (2).This delay arrival ahs been demonstrated in studies using time-to-arrival and time-to-peak measurements with both perfusion CT and perfusion-weighted dynamic susceptibility MRI (3-5). Recently, arterial spin labeling (ASL) MRI with image acquisition at multiple delay times after the labeling pulse has been introduced has a alternative non-invasive perfusion technique that is capable of measuring the temporal dynamics of arterial blood inflow in addition cerebral blood flow (CBF) (6;7). With this ASL imaging strategy it is possible to quantify both the arrival time and the duration needed for the end of the labeled bolus to reach the brain tissue (respectively, the transit and trailing edge times). The purpose of this study was to investigate the effect of a symptomatic stenosis of the ICA on ASL timing parameters, and to evaluate the effect of collateral flow via the circle of Willis on these timing parameters.

Methods and materials

Forty-four functionally independent patients (30 men; 14 women; age, 69±9 years) with a recently symptomatic ICA stenosis ≥50% and 29 healthy sex and age matched volunteers (23 men; 11 women; age, 68±6 years) were investigated on a 1.5 T MRI system (Gyroscan ACS-NT, Philips Medical Systems). A pulsed transfer insensitive labeling technique (TURBO-TILT) was used to regionally quantify CBF, transit time and trailing edge (TR/TE, 3000/5.6 ms; 62% partial Fourier acquisition; 50 averages; FOV, 240×240 mm; matrix, 64x64; scan time, 5 min) (8). The perfusion signal at varying delay times was fitted to the kinetic perfusion model of Buxton et al (9), with the adaptations proposed by Gunther et al (10), to quantify CBF and the transit and trailing edge times (R_1, 1000 ms; R_{1a}, 1400 ms; λ, 0.9 mL/g). Regions of interest were manually drawn on the ASL control images: two in the frontal lobe and one in the fronto-parietal, parieto-occipital, and occipital regions. CBF values for the left and right hemisphere of the control volunteers were averaged for analyses. One-way ANOVA with Bonferroni correction was used to evaluate differences between CBF, and transit and trailing edge times in ROIs of controls and those of hemispheres ipsi- and contralateral to the ICA stenosis in patients. The study was approved by the institutional review board, and informed consent was obtained.

Results

In the hemisphere ipsilateral to the ICA stenosis, the CBF was significantly lower (P<0.01) in the anterior frontal, posterior frontal, parieto-occipital, and occipital regions than in control subjects (Figure 2). The transit times were prolonged (P<0.01) in the ipsilateral anterior frontal, posterior frontal and fronto-parietal regions when compared with the control subjects (Figure 3). The trailing edge time was prolonged (P<0.01) in the ipsilateral fronto-parietal region when compared to the control subjects (Figure 4). In the 27 patients without a contralateral stenosis, the trailing edge was longer (P<0.01) in the ipsilateral posterior frontal, fronto-parietal and parieto-occipital regions than in the contralateral regions. In the 17 patients with a contralateral stenosis ≥ 50%, there were no differences. Collateral flow via the circle of Willis did not affect the CBF, transit or trailing edge times.

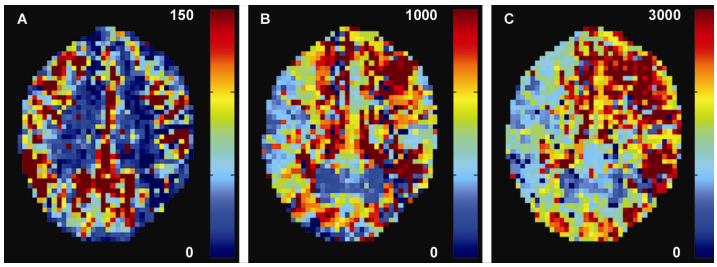

Figure 1. *Perfusion images of a patient with a unilateral left-sided ICA stenosis (90%).* ***A,*** *CBF (ml/min/100gr);* ***B,*** *transit time (ms);* ***C,*** *trailing edge time (ms). Decreased CBF and increasing ASL timing parameters can be appreciated in the hemisphere ipsilateral to the ICA stenosis.*

Conclusion

The most important finding of our study was that delays in the arrival of arterial blood to the brain can be assessed with ASL MRI at multiple delay times in patients with a symptomatic ICA stenosis. Furthermore, that in patients with a unilateral ICA stenosis, the trailing edge times in the ipsilateral hemisphere were longer than those in the contralateral hemisphere, whereas no differences were found in patients with a contralateral stenosis ≥50%. Using non-invasive ASL with image acquisition at multiple delay times it is possible to assess delays in the arrival of arterial blood in patients with a symptomatic carotid artery stenosis. Regional assessment of ASL timing parameters may provide valuable information on the hemodynamic changes in patients with an ICA stenosis

References

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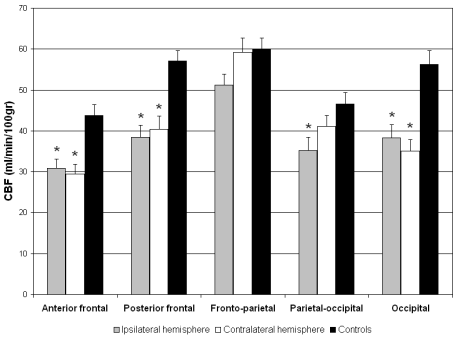

Figure 2. *Cerebral blood flow (mean ± SEM). A significant (p<0.01) difference with the control subjects is indicated by* *******.

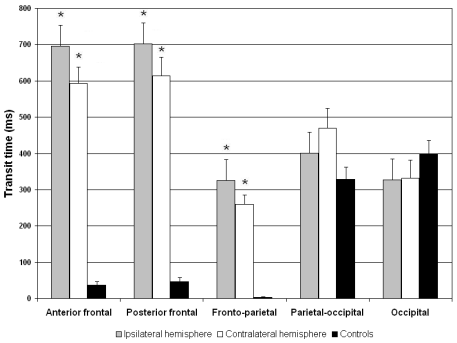

Figure 3. *Transit times (mean ± SEM). A significant (p<0.01) difference with the control subjects is indicated by* *******.

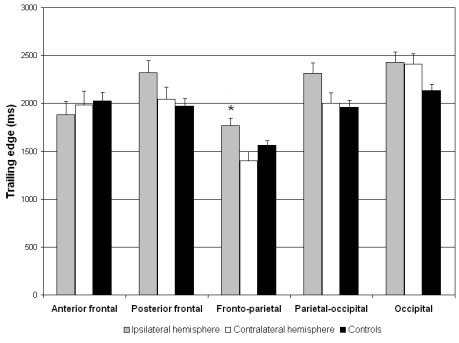

Figure 4*. Trailing edge times (mean ± SEM). A significant (p<0.01) difference with the control subjects is indicated by* *******.