Visualization of Collateral Supply by Two-Coil Continuous Arterial Spin Labeling

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Motivation

Besides the degree of stenosis, knowledge of the amount of compromise of cerebral blood flow (CBF), of the affected perfusion territories, and whether collateral flow is available are important parameters for assessing stroke risk and the need for surgery in patients with carotid artery occlusive disease. Continuous arterial spin labeling (CASL) is a noninvasive method for perfusion imaging exploiting magnetically labeled water as an endogeneous tracer. Approaches that have been suggested for mapping the perfusion territories of major brain-supplying arteries include:

- CASL with a separate labeling coil (right- or left-sided carotid) [1-4].
- Use of spatially selective two-dimensional (2D) radiofrequency (RF) pulses [5],
- Single-coil experiments with an oblique labeling plane or precessional motion of the labeling gradient to achieve selective labeling [6, 7].

GOAL

Investigating the potential of non-invasive perfusion territory imaging by CASL for an assessment of the hemodynamic status of the brain in two patients with known carotid artery disease.

Patients

Patient 1 (male, 68 years): Asymptomatic stenosis of the left internal carotid artery (ICA).

Patient 2 (male, 28 years): Aneurysm of the left ICA had developed after an accident during childhood and caused a minor stroke. Treatment by embolization coil occlusion. Preceding carotid balloon occlusion test had revealed tolerance of permanent ICA occlusion due to sufficient collateral supply to the left hemisphere. Perfusion imaging was performed prior to and three months after the intervention.

MRI Methods

- 3-T whole-body scanner (Bruker Medical, Ettlingen, Germany).
- Custom-built helmet resonator for brain imaging (Fig. 1).
- 2D MDEFT images as anatomical reference.
- Spin-echo EPI (TE 50 ms; bandwidth 100 kHz; echo position at 50%).
- 10 slices acquired from superior to inferior (matrix 64×64).
- Circular coil of 6-cm diameter for labeling (Fig. 1).
- RF label pulse (1.2 W) applied for 3.5 s with a gradient of 2.5 mT/m.
- Post-labeling delay of 1.5 s to reduce transit-time effects.
- 100 interleaved repetitions (TR 7 s), CASL only during odd repetitions.
- Subsequent investigations with label coil over the right and left common carotid artery (CCA).

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Figure 1. RF coil setup used for the perfusion experiment, here demonstrated with one of the authors as a volunteer.It consist of a 6-cm diameter circular surface coil for labeling the blood in either the left or right CCA and a 24-cm diameter circularly polarized helmet coil for brain imaging.

Results & Discussion

No significant differences in the perfusion of the left and right hemisphere were observed in patient 1. This was consistent with the result of a single-photon emission computed tomography (SPECT) scan using ^{99m}Tc ethyl cysteinate dimer (ECD) and with the clinical status of an asymptomatic ICA stenosis at rest.

Perfusion-weighted images (arbitrary units) recorded in patient 2 before and after embolization coil occlusion of the left ICA are shown in Figs. 2 and 3. The perfusion data were registered to a T_1-weighted 3D data set (MDEFT) to allow for a direct comparison of individual slices acquired in a separate session. As expected, the area of significant signal change obtained when labeling the blood in the left CCA was limited to the left side (top row) whereas the right CCA supplied blood predominantly to the right hemisphere with an indication of some overflow to the left side in the frontal region (middle row). Following left ICA occlusion, perfusion contrast was created almost symmetrically in both hemispheres when labeling only the blood of the right CCA (bottom row). This is corroborated by the quantitative analysis indicating an average CBF as commonly found in human cortical gray matter (Table 1) and a normal histogram of CBF values (Fig. 4) in both hemispheres. In summary, these observations verify the existence of sufficient collateral supply in agreement with the information from the carotid balloon occlusion test.

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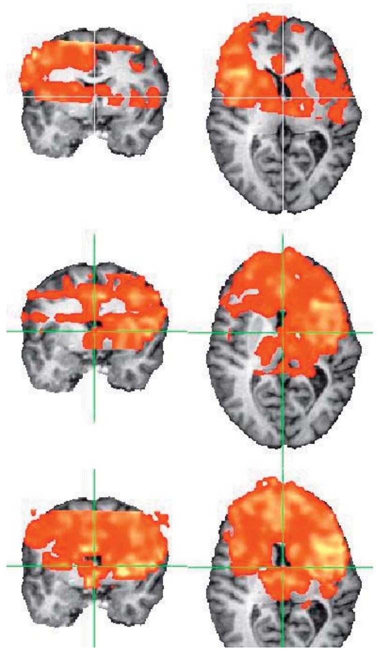

Figure 2. Perfusion territories of the left (top row) and right ICA (middle row) recorded in patient 2 at the first examination and of the right ICA three months after permanent occlusion of the left ICA (bottom row) indicating collateral supply.

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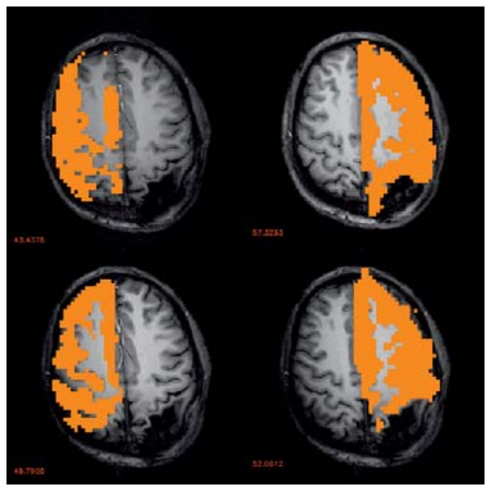

Figure 3. Regions of interest (*i.e.*, voxels with significant signal change upon CASL; $p < 0.05$) used for computing cortical perfusion mean values in the left and right hemisphere in patient 2. The top row shows results obtained before left ICA occlusion with CASL of either the left or right CCA. Results obtained with CASL of the right CCA after the intervention are shown in the bottom row. These were manually segmented for separate analysis of both hemispheres.

Table 1. Mean CBF values in ml/min/100g of the perfusion territories of the CCA in cortical gray matter in patient 2.

	Left hemisphere	Right hemisphere
Before left ICA occlusion	43	57
After left ICA occlusion	50	52

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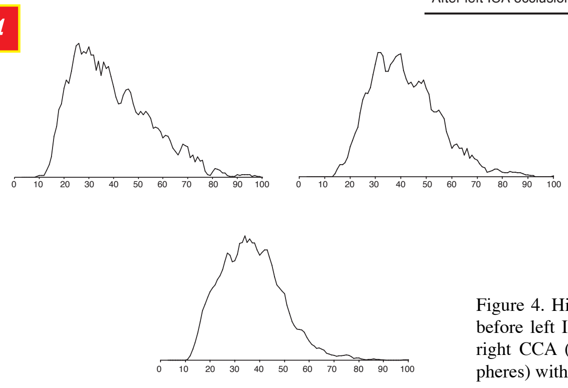

Figure 4. Histograms of CBF values in ml/min/100 g obtained before left ICA occlusion with CASL of the left (top left) and right CCA (top right) and after the intervention (both hemispheres) with CASL of the right CCA (bottom).

Conclusion

Our preliminary results indicate a potential of CASL-based perfusion imaging to assess the significance of carotid artery stenosis and potentially compensating collateral flow. Due to the possibility to perform repeated scanning, it might be used for screening purposes or for monitoring perfusion changes during therapeutic interventions, which is not achieved by more invasive methods, such as PET or dynamic susceptibility contrast MRI.

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