# Cerebrovascular reactivity within perfusion-territories in patients with an ICA occlusion

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## Introduction

Patients with a symptomatic internal carotid artery (ICA) occlusion have an annual risk of 2-5% for potential recurring stroke. This risk is raised to 9 -18% per year in patients with compromised cerebral hemodynamics and poor collateral blood flow (1). A large, international randomized trial in 1985, showed that extracranial to intracranial bypass surgery does not prevent stroke in patients with symptomatic ICA occlusion (2). More recent studies have however suggested that patients with hemodynamic compromise of the brain perfusion, may benefit from bypass surgery (3;4). Arterial spin labeling MRI has been introduced as an alternative non-invasive technique for measuring cerebrovascular reactivity and the perfusion-territories of the brain feeding arteries throughout the brain. The aim of our study was to investigate cerebrovascular reactivity in the perfusion-territories of the cerebral arteries at brain tissue level in patients with an internal carotid artery (ICA) occlusion using ASL-MRI, and determine whether cerebrovascular reactivity varies within the perfusion-territory of the remaining ICA.

## Methods and materials

Sixteen patients (mean age ± standard deviation, 56±4) with a recently symptomatic unilateral ICA occlusion and 16 age-matched healthy control volunteers were investigated on a 3 Tesla MRI scanner (Philips Medical Systems). All patients had suffered a transient ischemic attack (TIA) or non-disabling ischemic stroke ipsilateral to the ICA occlusion. The MR protocol consisted of pseudo-continuous and regional perfusion imaging (RPI) ASL imaging (5-7) before and 15 minutes after administration of an intravenous bolus of 14 mg/kg acetazolamide. RPI perfusion images were acquired to determine the flow territories of the basilar and ICAs. The pseudo-continuous ASL parameters were: FOV 240x240 $mm^2$; 17 slices; SENSE 2.5; background suppression; label duration 1650 ms, TR 825ms; TE 14ms. An inversion recovery sequence was acquired for $M_0$ and segmentation purposes. For the placement of the regions of interest, three preprocessing steps were performed (Fig. 1): first, the flow-territories of the basilar and remaining ICA were manually segmented on the RPI images. Two additional ROIs were drawn within the perfusion-territory of the unaffected ICA contralateral to the occlusion; one containing all the brain tissue on the unaffected side and one of the brain tissue fed through collateral pathways of the side of the occlusion. Second, a $T_1$ image was calculated from the IR sequence and segmented into gray and white matter probabilistic maps. Thresholding of the GM maps was applied to avoid partial voluming of WM. The final step was to combine the flow territory masks with the GM mask.

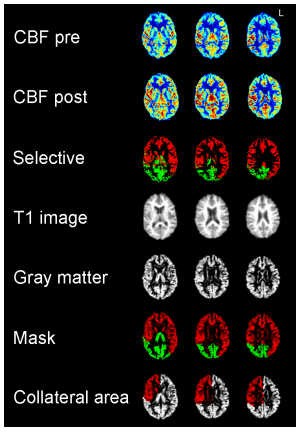


**Figure 1:** Post-processing steps in a 62-year old patient with an occluded right ICA.

## Results

Table 2 summarizes the CBF measurements before and after acetazolamide, and the cerebrovascular reactivity measurements. CBF increased ($p<0.01$) in all perfusion-territories after administration of acetazolamide in both patients and the healthy control. The cerebrovascular reactivity was decreased in the tissue fed by the unaffected ICA when compared to the healthy control subjects (mean difference, -32%; 95% CI, -42–-21). Within the perfusion-territory of the unaffected ICA contralateral to the occlusion in the patients, the cerebrovascular reactivity was lower in the brain tissue on the symptomatic side when compared to the unaffected side (paired mean difference, -13%, 95% CI, -20–-5). When compared to the healthy control subjects, the cerebrovascular reactivity was decreased on both side; for the symptomatic side, paired mean difference, -41%, 95% CI, -53–-28 and for the unaffected side, paired mean difference, -28%, 95% CI, -39–-18.

## Conclusion

By combining quantitative perfusion with perfusion-territory selective ASL we measured the cerebrovascular reactivity of the individual cerebral arteries in patients with a symptomatic ICA occlusion. The cerebrovascular reactivity was decreased throughout the brain in comparison with healthy control subjects and varied throughout the perfusion-territory of the ICA contralateral to the occlusion. The brain tissue on the side of the occlusion, fed through collaterals originating from the unaffected ICA, was the most impaired.

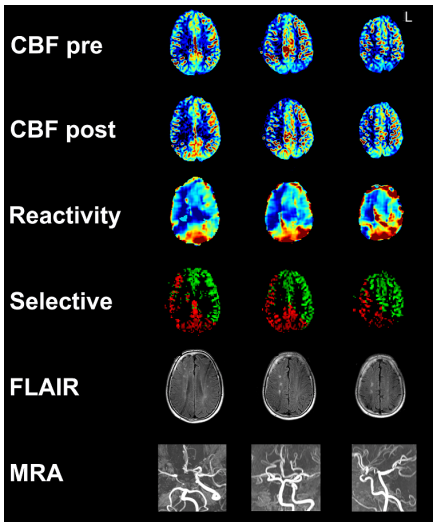


**Figure 2.** Images of a 47-year old man with a symptomatic occlusion of the left ICA. Decreased CBF and a decreased cerebrovascular reactivity can be appreciated in the left hemisphere. hemisphere.

| | **Pre-ACZ** *(mL·100mL$^{-1}$·min$^{-1}$)* | **Post-ACZ** *(mL·100mL$^{-1}$·min$^{-1}$)* | **Reactivity** *(%)* |
|---|---|---|---|
| **Control group** | | | |
| ICA | 51.8 ± 8.1 * | 78.6 ± 12.4 | 54.2 ± 13.1 |
| Basilar artery | 48.8 ± 12.1 * | 83.4 ± 20.3 | 73.7 ± 23.7 |
| **Patient group** | | | |
| ICA | 44.7 ± 6.0 * | 54.7 ± 9.3 | 22.8 ± 16.1 † |
| *Symptomatic side* | 41.6 ± 13.0 * | 47.2 ± 17.5 | 13.5 ± 20.4 † |
| *Unaffected side* | 47.4 ± 4.3 * | 59.6 ± 7.7 | 26.0 ± 16.5 † |
| Basilar artery | 45.4 ± 11.1 * | 59.5 ± 16.0 | 32.3 ± 16.6 |

**Table 1:** *CBF measurements pre and post acetazolamide. * indicates a significant difference (paired t test, p<0.01) between the pre and post-acetazolamide perfusion. † indicates a significant difference (t test, p<0.01) between patients and controls.*

## References

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