Hemodynamic steal in patients with symptomatic internal carotid artery stenosis and occlusion

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Introduction

Cerebrovascular reactivity (CVR) is the compensatory ability of the brain to sustain blood flow when there are fluctuations in cerebral perfusion pressure through vasodilatation of the cerebral vasculature. Decreased CVR is an early predictor of hemodynamic impairment and is associated with increased risk for developing ischemic stroke (1). CVR can be assessed by measuring the increase in cerebral blood flow (CBF) in response to a vasodilatory stimulus such as carbon dioxide or acetazolamide. Negative CVR, also known as hemodynamic steal, occurs when arterial blood is redistributed from regions of exhausted cerebrovascular capacity to areas with preserved vasodilatory capacity (2). This may occur within the same hemisphere, interhemispherical through cross-flow via the circle of Willis, or even earlier, at the level of the aortic arch. Patients with a stenosis or occlusion of the internal carotid artery are already at increased risk for future stroke and the presence of steal may indicate that more aggressive treatment options need to be considered. The aim of our study was to investigate the occurrence and extent of hemodynamic steal in patients with a carotid artery stenosis by combining ASL perfusion imaging with a vascular challenge.

Methods and materials

Thirty-two patients with a recently unilateral symptomatic steno-occlusive ICA lesion were investigated on a 3 Tesla MRI scanner (Philips); 17 with a stenosis ≥ 50% (mean age ± standard deviation (SD), 68±6 years) and 15 with an occlusion (58±14 years). All patients had suffered a transient ischemic attack (TIA) or non-disabling ischemic stroke on the side of the affected ICA within the past 3 months. The MR protocol consisted of FLAIR, MR angiography and a pseudo-continuous ASL perfusion imaging sequence before and 15 minutes after administration of an intravenous bolus of 14 mg/kg acetazolamide (3). The ASL parameters were: FOV 240x240 mm^2; 17 slices; background suppression; SENSE 2.5; label duration 1650 ms, TR 825ms; TE 14ms. For M_0 and segmentation purposes an inversion recovery sequence was acquired. Presence of hemodynamic steal was evaluated by two expert readers. CBF pre and post acetazolamide was measured in the brain tissue area with hemodynamic steal and the flow territory of the middle cerebral artery territory as defined by a standardized atlas by manually outlining the boundaries. Thresholding of the gray matter maps was applied to avoid partial voluming of white matter. This was done by calculating a T_1 image from the inversion recovery sequence and segmented with SPM8 into gray and white matter probabilistic maps. All images were co registered to correct for motion. Differences between CVR were tested using paired *t* test.

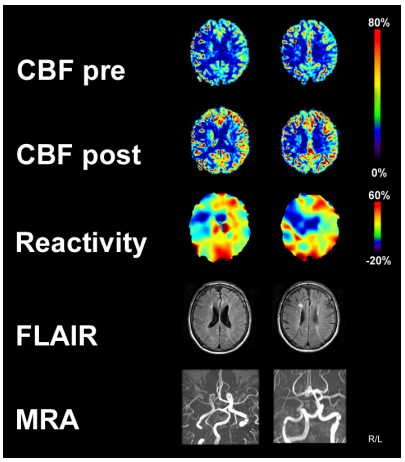

Figure 1. *Images of a 67-year old man with a symptomatic stenosis of the left right. Decreased CBF and steal can be appreciated in the right hemisphere. hemisphere.*

Results

Table 1 summarizes the CBF values before and after administration of acetazolamide, and the cerebrovascular reactivity, in the affected and unaffected MCA flow territory. Hemodynamic steal occurred in 5 of the 15 patients (33%) with an ICA occlusion and in two of the 17 patients (11%) with a stenosis. CVR was significantly lower in the brain tissue area with steal in patients with an ICA occlusion compared to the ipsilateral MCA flow territory (-34±7% vs. 9±8%, p=.01). In patients with a stenosis, there was a trend towards lower CVR in the area with steal when compared to the MCA flow territory (-41±0 vs. 22±10%, p=0.1). There were no differences in volume of brain tissue with steal (1.2±0.5 vs. 3.2±1.4 mL, p=0.2) or severity of steal (-41±0 vs. -34±7%, p=0.2) between patients with an ICA stenosis or occlusion.

	Pre-ACZ mL·100mL^{-1}·min^{-1}	**Post-ACZ** mL·100mL^{-1}·min^{-1}	**Reactivity** (% increase)
Stenosis patients			
Affected hemisphere	43.9 ± 3.9	57.6 ± 4.6	34.5 ± 5.4
Unaffected hemisphere	42.6 ± 3.9	60.4 ± 5.2	39.2 ± 4.8
Occlusion patients			
Affected hemisphere	44.3 ± 4.9	47.6 ± 5.7	17.0 ± 5.5
Unaffected hemisphere	44.4 ± 3.5	60.6 ± 4.3	27.4 ± 3.8 *

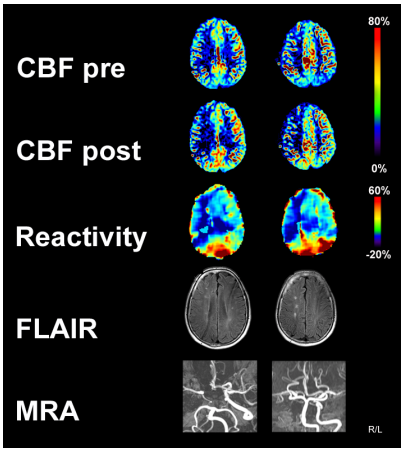

Figure 2. *Images of a 47-year old man with a symptomatic occlusion of the left ICA. Decreased CBF and steal can be appreciated in the left hemisphere. hemisphere.*

Conclusion

The results of this study show that hemodynamic steal occurs in both patients an internal carotid artery stenosis and occlusion. Our findings support furthermore earlier studies with transcranial Doppler and positron emission tomography that patients with more severe obstruction of arterial blood inflow have more severe cerebral hemodynamic impairment. ASL in combination with a vascular challenge can assess cerebrovascular reactivity and detect hemodynamic steal at brain tissue level. In clinical practice this may potentially be used to assess a patient's individual risk for future stroke.

References: [1] Markus et al, Brain 2001;124:457-67. [2] Alexandrov et al, Stroke 2007;38:3045-48. [3] Dai et al, jMRI 2008;60:1488-97.