Measurement of the Cerebrovascular Reserve Capacity using Doppler Sonography and Phase Contrast MRA during Hypercapnia in Patients with Neurovascular Disease

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INTRODUCTION

In patients with neuro-vascular disease, the perfusion reserve capacity is an important predictor for the risk for ischemic events. Transcranial Doppler sonography (TCD) during inhalation of a CO_2-gas-air mixture to determine flow changes in the MCAs is the method most commonly employed clinically. The goal of the study was to perform TCD as well as phase contrast MRA measurements (1) of the flow increase during hypercapnia in patients with stenotic disease and compare the results.

MATERIALS AND METHODS

15 Patients with different degrees of unilateral stenosis or occlusion of the common or internal carotid artery and 6 normal controls were included. For TCD measurements, both middle cerebral arteries (MCA) were insonated through the temporal bone window. Flow was measured before and during the inhalation of 7% CO_2-air mixture. The MR-protocol started with T1, T2 imaging and TOF-MRA. ECG gated quantitative PC measurements before and during CO_2-inhalation in 2 slices perpendicular to the MCAs were performed on a 1.5T Siemens Sonata (see Fig. 1). The flow increase for both methods was determined according to the established evaluation of the TCD test: The flow changes were normalized to the end-tidal pCO_2-increase. A flow change of less than 1.5% per mmHg was considered to be pathologic.

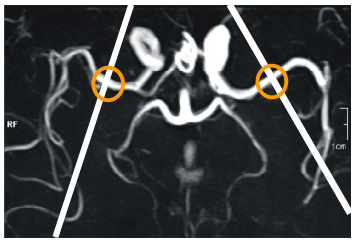

Fig. 1: Positioning of PC-MRA

RESULTS

An example of CO_2 induced flow increase in the MCAs of a patient is shown in figure 2. In this patient the normalized flow change was measured with PC-MRA to be 5.4 and -0.6 for the right and left MCA, thus indicating even a small steal effect in the stenotic left MCA. The TCD results showed normal reactivity on the right and almost no reactivity on the left side. Quantitative PC-MRA was successfully applied to and well tolerated by all patients and controls. All controls showed symmetrically increased flow (MCA mean 41%) during CO_2. 29/30 MCAs in patients were measurable. One patient did not show significant flow increase due to insufficient ET pCO_2. In one vessel the results from PC-MRA and TCD measurements differed. In this high-grade ICA stenosis the baseline flow was extremely low and thus the minor flow increase during CO_2 resulted in a false normal cerebro-vascular reserve capacity.

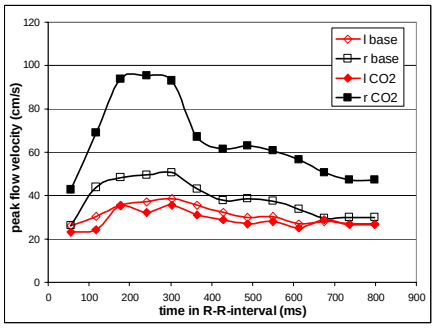

Fig. 2: Flow velocities measured in the MCA by PC-MRA. The diminished flow reserve in the stenotic left MCA is clearly visible

DISCUSSION

To our knowledge this is the first study that applies PC-MRA during CO_2-inhalation to measure the cerebro-vascular reserve capacity in patients. Quantitative mapping of the perfusion reserve with phase contrast MRA during CO_2-inhalation in patients is possible. In combination with methods that measure tissue perfusion reserve, e.g. with CO_2-BOLD techniques (2) the discrepancy between vascular territories perfused by an impaired MCA and less extensive areas of reduced tissue reserve may indicate collateral blood supply. The excellent correlation between the TCD and PC-MRA findings suggests that PC-MRA may be a widely available and easily applicable alternative for the 10-20% of patients without sufficient cranial bone window. Such patients are now being examined with nuclear medicine techniques, which measure tissue perfusion rather than vessel flow increase and are thus not directly comparable to TCD results. It remains to be examined in larger patient studies, which parameter has the highest prognostic significance for the risk of an ischemic event.

REFERENCES

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[2] O. Speck et al., Proc. 11th ISMRM: 2244 (2003)