Comparison of two ways of measuring cerebrovascular reactivity

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Introduction

Cerebrovascular reactivity (CVR) reflects the ability of cerebral arterioles to dilate in order to maintain cerebral blood flow under conditions such as hypertension and hypotension. CVR provides more sensitive hemodynamic information than resting flow. It has been shown that diminished CVR is related to the presence of cerebral white matter hyperintensities (1,2). Also, it has been demonstrated that among patients with symptomatic stenosis or occlusion of the internal carotid artery, patients with diminished CVR have an increased risk for developing stroke (3,4).

Several methods have been developed to measure CVR. In all available methods CVR is assessed by measuring cerebral blood flow (CBF) before and after a stimulus which causes vasodilation. CBF measurement can be performed non-invasively with several well-established methods. Methods using radioisotopes are SPET and Xe-CT. Limitations of these methods are high costs, and difficulties in quantitation. Another method is Doppler ultrasound. Using Doppler ultrasound only the highest flow velocity in the center of the vessel is measured, which causes the flow in the whole vessel to be overestimated (5).

Recently, two ways of measuring the CVR based on MRI were introduced (6,7). These methods are relatively unexplored. With MR perfusion imaging cerebral blood flow can be assessed by recording the arrival of a bolus gadolinium. Assessment of the CVR with this method requires the administration of two doses of gadolinium, one before and one after administration of acetazolamide. Quantitation of this method is difficult and controversial (8).

Another method to assess CVR is quantitated flow mapping (QF) using phase contrast MR (PC-MR). Using QF, the CBF can be estimated by measuring the flow in both internal carotid and basilar arteries, before and after the administration of a vasodilating agent such as acetazolamide. This method is robust, easy to perform, and permits straightforward quantification.

The aim of this study is to compare the assessment of the CVR using QF with the assessment of the CVR by MR perfusion imaging.

Materials and methods

We performed flow measurements and perfusion imaging in nine healthy male volunteers before and after the administration of acetazolamide. All imaging was performed on a 1.5T Powertrak 6000 system (Philips Medical Systems, Best, The Netherlands). For flow measurements we used a non-triggered gradient echo phase contrast technique (TR/TE: 16/80ms; flip angle 7.5°; 5mm slice thickness; FOV 250mm with eight NSA). The scans were performed in a plane perpendicular to the left and right internal carotid artery and the basilar artery. Images were analysed using the locally developed software package FLOW® (Department of Radiology; Division of Image Processing). Scan parameters for the FFE EPI perfusion imaging were: TR/TE: 412/20ms; 9 slices with 6mm slice thickness; FOV 250mm. For perfusion imaging we gave 25 ml gadolinium as a bolus injection with an injection rate of 5 ml/min. Perfusion images were analysed with the quantitative analysis module of the software package EasyVision release 4.2 (Philips Medical Systems, Best, The Netherlands). We used the mean relative cerebral blood volume (rCBV) given for each slice after manually drawing a contour around the parenchyma.

The total CBF, defined as the summation of flow in the basilar and both internal carotid arteries, was measured before and in five minute time intervals after the administration of 14 mg/kg acetazolamide for a period of 20 minutes. Perfusion imaging (performed 10 minutes before administration of acetazolamide and twenty minutes thereafter) was preceded and followed by QF. CVR was defined as a percentage of CBF (QF with PC-MRA) or rCBV (perfusion MR) before the administration of acetazolamide. Blood pressure, peripheral saturation and heart rate were continuously monitored. The two methods were compared in a Bland and Altman plot.

Results

One volunteer was excluded because movement made comparison of flow measurements impossible. In the remaining eight volunteers (age: 19-26 yrs) we found an average increase in CBF from 24 ml/min to 1038 ml/min (43%). The range of the CVR assessed by QF was 28-72%. The mean CVR measured with perfusion imaging was 45% with a range of 22-73%. When both measurements of the CVR were plotted in a Bland and Altman plot (see figure) the mean of the differences was found to be near to zero (-0.5). Furthermore, six of the eight flow measurements gave higher CVR values than the CBV. In three cases the difference between the two way of measuring CVR was ±30%. The coefficient of variation was 9%. We did not find evidence for an influence of gadolinium or acetazolamide on physiologic parameters.

Conclusions

Using MRI, CVR can be assessed by performing perfusion imaging and by QF mapping. In this study the range of the CVR in healthy volunteers was the same for both methods. Nevertheless there was a considerable difference in the CVR between the two measurements in three patients. Furthermore, CVR measures assessed by QF were systematically higher than those obtained by perfusion imaging. These differences might be due to methodological differences between these two methods.

As compared to perfusion techniques, QF has several advantages. It permits straightforward quantification, is robust, and does not require the use of a contrast agent. Due to these advantages QF might be the method to prefer in studies that address the CVR and that are not focused on regional distribution of the CVR in the brain.