Assessing CO2 Reactivity in Patients with Carotid Artery Disease using BOLD fMRI

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Introduction

The mechanism by which carotid artery disease produces stroke is traditionally considered to be embolic or haemodynamic. To accurately predict risk of stroke, both the risk of embolization and the haemodynamic vulnerability of the brain needs to be assessed. The current work uses new functional MRI (fMRI) based techniques to examine whether we can identify the 'vulnerable brain'. Cerebrovascular reserve (CVR) refers to the spare capacity of the cerebral circulation to increase blood flow if necessary. Impaired CVR has previously been shown to predict increased stroke risk in Transcranial Doppler studies[1]. MRI based assessment can be used to produce high spatial resolution CVR maps and provide information on whole MCA territory reactivity as well as to identify small areas of impaired reactivity which are not detectable using transcranial Doppler[2]. We have successfully established a technique of non-invasively mapping the CVR capacity using BOLD (Blood Oxygen Level Dependent) hypercapnia fMRI. Hypercapnia fMRI allows full assessment of the CVR of patients with carotid artery disease. The aim of this study was to assess the CVR capacity in patients with carotid artery disease, and also to assess the improvement provided by Carotid Endarterectomy (CEA).

Methods

12 patients with recently symptomatic internal carotid artery stenosis and occlusion were scanned using a clinical 1.5T Intera (Philips, Best, Netherlands) MR scanner. 5 of these patients underwent a CEA and therefore were additionally scanned 4-6 weeks postoperatively. Unfortunately 1 patient had to be excluded from the analysis due to high degrees of movement during scan acquisition. Using a standard non-rebreathing anaesthetic circuit, 8 % carbon dioxide was administered to achieve transient episodes of hypercapnia; the patients physiological parameters were continuously measured (blood pressure, pulse and arterial oxygen saturations, ET CO_2). All patients underwent a 9 minute long paradigm consisting of 2 periods of hypercapnia (lasting 2 minutes 20 seconds) and 3 periods of normocapnia (air). The data was analyzed using SPM software and the MarSBaR toolbox, to get percentage signal change (%SC) for the grey matter of the middle cerebral artery (MCA) territory bilaterally.

Results

11 patients (9 males and 2 females) with a mean age of 67.4 years (+/- 12.9) underwent successful fMRI scanning. In the ipsilateral carotid artery, there were 5 occlusions, 5 with 70-99% stenosis and 1 with 50-69% stenosis. In the contralateral (asymptomatic) carotid arteries, there was one artery with 70-99% stenosis, one with 50-69% and the rest did not have any significant disease. There were no significant changes in the blood pressure, pulse and oxygen saturations during the experiments. The mean %SC in the symptomatic MCA territory [0.486% (SD 0.558)] was significantly lower than the mean %SC [1.143% (SD 0.623)] in the asymptomatic MCA territory (Wilcoxon, p=0.003) (Figure 1). In the 5 patients scanned pre and post operatively, the mean %SC increased from 0.78% (SD 0.144) preoperatively to 1.39% (SD 0.896) postoperatively (Wilcoxon p=0.068) (Figure 2, 3).

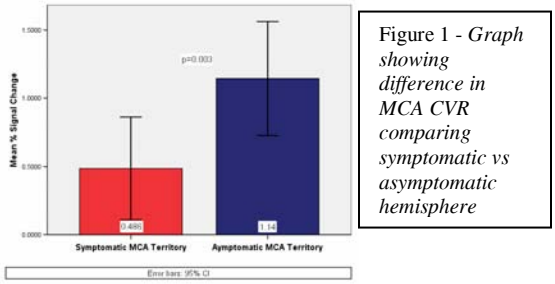

Figure 1 - *Graph showing difference in MCA CVR comparing symptomatic vs asymptomatic hemisphere*

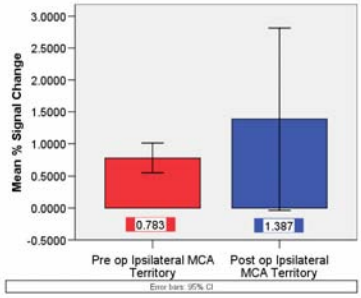

Figure 2 - *Graph showing improvement in CVR post CEA*

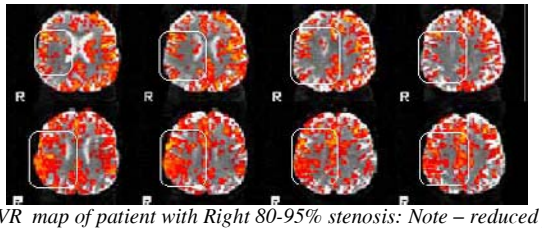

Figure 3 - *Pre and postop CVR map of patient with Right 80-95% stenosis: Note – reduced preop CVR ipsilateral to stenosis in the MCA territory and increased CVR postop in the MCA territory as compared to contralateral hemisphere*

Conclusions

In those patients with significant carotid stenosis or occlusion, the ipsilateral symptomatic hemisphere has an approximately 57% reduced CVR as compared to the asymptomatic hemisphere. These results confirm and extend previous findings in transcranial Doppler studies. Analysis of results from patients undergoing CEA suggests improved CVR following recanalising intervention. possibly overshooting in some.

References

1. Markus, H. et al. *Severely impaired cerebrovascular reactivity predicts stroke and TIA risk in patients with carotid artery stenosis and occlusion.* Brain, 2001. **124**(Pt 3): p. 457-67.
2. Ziyeh, S., et al., *Blood oxygen level-dependent MRI of cerebral CO2 reactivity in severe carotid stenosis and occlusion.* Stroke, 2005. **36**(4): p. 751-6.