Hemispheric brain perfusion and atherosclerotic lesion burden in patients undergoing carotid endarterectomy

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Introduction

Progressive accumulation of atherosclerotic plaque in carotid arteries may ultimately result in reduced cerebral blood flow (CBF). Since CBF is redistributed intracranially through the circle of Willis, it is not straightforward to detect the hemodynamic effects of unilateral lesions in the internal carotid arteries (ICA) using conventional perfusion measurement techniques. This problem can be overcome with a hemispheric pulsed arterial spin labeling (HPASL) perfusion imaging technique developed previously[1] to individually image the perfusion distribution of carotid arteries in the left and right hemispheres through selective labeling. The purpose of this investigation was to investigate the HPASL technique for determining the dependence of hemispheric brain perfusion on the degree of obstruction of the ipsilateral ICA. Toward this goal the degree of stenosis of the left and right ICA was measured from transverse, black-blood images through the neck[2], and correlated with measurements of hemispheric perfusion in a set of patients undergoing carotid endarterectomy (CEA).

Methods

Subjects were patients diagnosed with carotid artery disease who underwent successful CEA (n=6, 4 male, 2 female, mean age 71.8 years). Magnetic resonance imaging was performed on a Siemens Sonata 1.5 T scanner. Hemispheric perfusion data were acquired using a modified QUIPPS II sequence and the subsequent construction of perfusion maps from subtraction of hemispherically-labelled and control images, as described previously[1]. The perfusion imaging was performed pre- and post-operatively, the main parameters being: 24 cm FOV, 8 (7 mm) slices with spacing 9.45 mm between centers, 128 kHz receiver bandwidth, 50 averages, TI_1 (pre-saturation delay) = 700 ms, TI_2 (total delay time) = 1700 ms, TR = 2.3s. The resulting high SNR M_0-maps, which are a product of data reconstruction (together with T1 and perfusion maps), were used as anatomical images for normalization of the perfusion maps to Talairach space. This was performed using the statistical parametric mapping (SPM) toolbox (Wellcome Department of Imaging Neuroscience, University College London) for MATLAB (The MathWorks, Inc.). The relative volume and mean perfusion of the vascular territories in the 3D FOV were then calculated using an algorithm implemented in IDL (Research Systems, Inc.). Perfusion measurements were calculated as the mean perfusion for the anterior and middle cerebral artery (ACA and MCA) territories. A multi-slice, double inversion black blood, fast spin echo technique was used for imaging transverse slices through the carotids[2] prior to surgery. The main imaging parameters were 256×256 matrix, 12 cm FOV, 12 × 2 mm slices , ETL = 17, echo spacing = 7.4 ms, 64 kHz receiver bandwidth, TR = 800 ms. Images of the common and internal carotid artery were segmented into the lumen and vessel wall using an objected class-uncertainty enhanced hybrid snake method[3] developed at our laboratory with a user-friendly GUI. This technique was further augmented by “forbidden zone” and “smooth wire deformation” features to handle the challenges of the specific application and yielded visually stable results for all image slices to which it was applied. The ratio of ICA vessel wall area to total vessel area (lumen + wall) was used as a measure of lesion burden. This ratio was averaged for three slices (6 mm) at the center of the lesion, and was calculated for both the left and right ICAs of the 6 patients pre-CEA. Means are quoted with uncertainties of one standard error of the mean, and P-values were obtained from paired-t tests. Perfusion was computed in units of ml/100g/min.

Results and Discussion

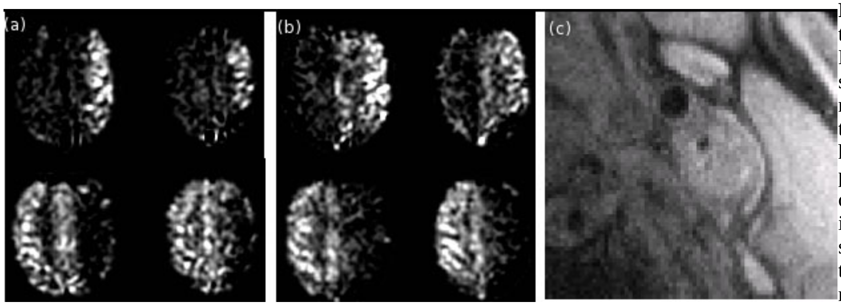

Fig. 1 Pre-surgery perfusion images at 2 levels with labeling of the left, stenosed ICA (a, upper) show perfusion limited to left MCA territory. Labeling of the contralateral ICA with no significant stenosis shows perfusion distributed in ipsilateral right MCA and bilateral ACA territories (a, lower), illustrating the effectiveness of collateral flow through circle of Willis to the hemisphere ipsilateral to the ICA stenosis. Post-surgery perfusion maps (b), display a visible improvement in perfusion on left, ipsilateral to operated side (b,upper), most evident in increased supply to left ACA territory. Labeling contralateral to stenosis shows a corresponding decrease in supply to left ACA territory (b, lower). A representative black blood image of the markedly stenotic left ICA is shown in (c).

Perfusion (averaged over anterior circulation territories) from unilateral labeling ipsilateral to stenosis (21.8±3.0) increased (to 31.2±3.2) post-CEA, the mean of the difference in the pre- and post- surgery groups being significant (P=0.03). There was no significant difference in pre- and post- surgery values of perfusion (averaged over circulation territories bilaterally) with unilateral labeling contralateral to stenosis (P=0.75). When perfusion measurements from conventional global labeling were compared to the sum of the unilaterally labeled perfusion measurements, there was no significant difference between the two labeling methods either pre- (P=0.79) or post- (P=0.35) surgery. Fig. 2 displays mean CBF in anterior circulation territories (bilateral) measured on perfusion images with unilateral labeling of the ipsilateral (stenotic) ICA as a function of lesion burden of the ipsilateral ICA. The negative correlation (R = -0.49) is expected to become more significant as the sample size increases.

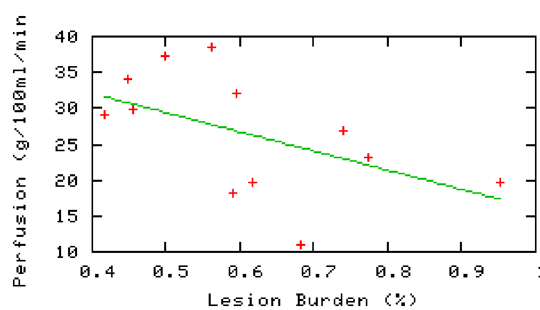

Fig. 2 Mean perfusion with unilateral labeling vs lesion burden.

Conclusion

Perfusion measurements from unilateral labeling in carotid artery disease provide insight into the hemodynamic effect of carotid artery stenosis and may provide additional information regarding potential benefit of surgery or stenting to the patient. The method provides an estimate of the fractional perfusion provided to cerebral vascular territories from each carotid artery.

References: (1) Song, HK et al., Proc. Intl. Soc. Mag. Reson. Med. 11 (2004). (2) Song, HK, et al., Mag Reson. Med. 47:616-20(2002). (3) Das, B., et al., Proc. SPIE Conf. On Medical Imaging, 5370: 369-380(2004). **Acknowledgement:** NIH RO1 HL68908