Spatially Selective Perfusion Imaging Applying Continuous Arterial Spin Labelling

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Introduction

Visualisation of the perfusion territories of the major brain-feeding arteries may be a useful diagnostic tool for patients with cerebrovascular diseases. Especially for patients with embolic stroke, therapeutic decisions depend on the origin of the embolus, e.g. from a cardiac thrombus or carotid or vertebral stenosis. Perfusion maps of the brain with a clear demarcation of the individual vascular territories may help to localise the origin of an embolus, particularly if the infarct lies in a border zone. Individual maps may also be used to show perfusion changes caused by major extracranial stenosis and to monitor related therapeutic interventions. Continuous Arterial Spin Labelling (CASL) is a promising, non-invasive method for imaging of brain perfusion in various applications. A separate labelling coil has originally been introduced to avoid MT problems in multi-slice imaging[1]. In addition, the second coil has been used for the selective labelling of one of the common carotid arteries[2]. We present a method for selectively labelling of the left- or right-sided carotid and vertebral artery by employing a send/receive headcoil only.

Materials and Methods

A *computer model* written in IDL (RSI, Inc.) simulates the spin inversion process on the basis of a stepwise integration of the Bloch equations for a single spin under the influence of T1, T2-relaxation, system gradient settings, and B1 irradiation. Gradient settings and B1-frequency offset determine the actual labelling plane. The effective B1-amplitude follows the measured intensity profile of the used headcoil, which shows a relatively steep decrease at its lower end. The spin's trajectory can be chosen to follow the realistic geometry of one of the four major feeding arteries as measured in a volunteer. As a predictor of the achievable image contrast, the resulting magnetisation in the artery at the imaging plane (z = 0) is calculated as the weighted average over all relevant blood velocities. Laminar flow is assumed. *MR Imaging* was performed on a Philips Intera 1.5 T. A standard angiography sequence provided a fast vessel overview for planning of the CASL sequence. The latter is based on a twofold inversion of flowing spins for the control experiment as described elsewhere[3]. The sequence was modified to allow for arbitrary placement of the labelling plane (labelling gradient direction and RF frequency offset) and for optimal control of inversion efficiency (labelling gradient strength and B1 amplitude). Parameters were: spin-echo EPI, scan res. 80x71, 7 slices, thickness 8 mm, TE 41.5 ms, labelling duration 2.2 s, post labelling delay 0.8 s, 50 pairs of labelled/control images, scan duration 6:15. The labelling plane was positioned to cross the selected carotid artery in a relatively straight section as cranially as possible, while not running through the brain. B1 amplitude and gradient settings for the actual plane positioning were adjusted for optimal labelling efficiency guided by the simulation results. Due to the plane's angulation, the contralateral artery is crossed far from the coil centre, where labelling is no longer effective (Fig. 1). Finally, anatomic images were obtained with a T1-weighted inversion recovery scan. The imaging procedure was tested in 13 healthy volunteers.

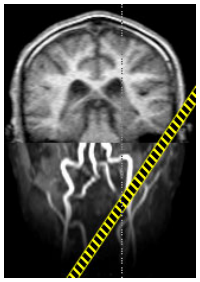

Fig. 1) Positioning of the labelling plane (illustrative)

Results

The computer model was used to determine the magnetisation at the z = 0 plane: If the labelling plane is crossing an artery at a distance of 18 cm or more from the coil centre, magnetisation at the imaging plane remains almost unaltered – labelling is not effective, no matter which potential settings of RF amplitude and gradient strength have been chosen. Closer to the coil centre, labelling becomes more effective and depends on the choice of B1 amplitude and gradient strength. With an angulation of the labelling plane of approx. 58 degree around the AP-axis, the discrimination between left- and right-sided arteries becomes most prominent. For this angulation, simulation results are summarised in Figure 2. The obtained perfusion-weighted images show a clear delineation of the perfusion territory of the selected arteries. Image contrast within the perfused area reflects the anatomical structures and is sufficient to distinguish between grey and white matter even in the basal ganglia (Fig. 3).

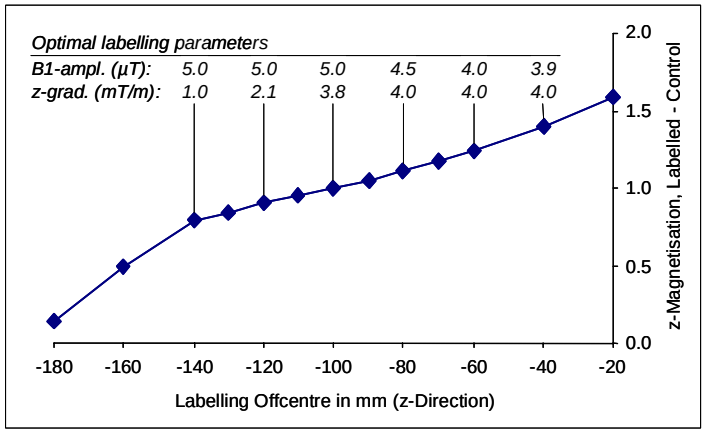

Fig. 2) Achievable magnetisation difference between labelled and control experiment in the artery at the z = 0 plane and optimal nominal (that is: amplitude at the coil centre) B1 amplitudes and z-gradient strengths for different labelling offcentres.

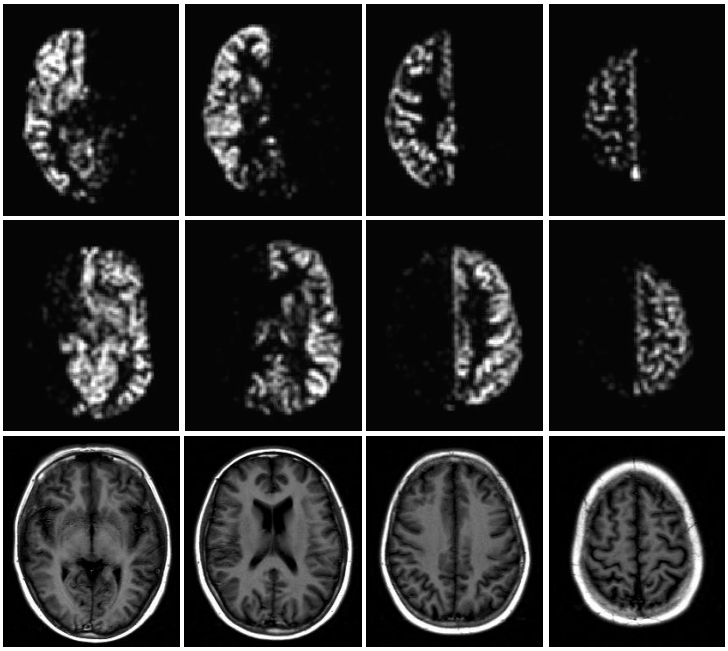

Fig. 3) First and second row: perfusion images with left/right-sided arteries labelled; bottom row: anatomical images. Only every other slice is shown.

Conclusion

The presented method is capable of selectively imaging perfusion territories of left- or right-sided feeding arteries of the brain non-invasively and with a standard MRI setup. Clinical trials are currently being pursued to evaluate its usefulness for therapeutic decision making and therapy control.

Acknowledgements

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References

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