Mapping of arterial transit time using dual-coil CASL with sinusoidally modulated labeling function

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Introduction

The knowledge of arterial transit times from the labeling plane into the brain is essential for cerebral blood flow (CBF) quantification and could also be of importance for the characterization of vascular diseases, e. g. stroke (1). Several continuous arterial spin labeling (CASL) techniques were applied in the past (1-3). Especially, dynamic arterial spin labeling provides a tool to increase the sensitivity of the CBF measurement, because it is suitable for effective frequency filtering (2). Recently, this approach was extended to a sinusoidally modulated labeling function (LF) (4). The goal of the current work was to obtain robust maps of arterial transit time (ATT) by measuring the phase shift of the time series of each voxel with respect to a reference (5). In contrast to previous methods, results do not depend on a specific kinetic model of perfusion.

Method

All experiments were performed using a 3-T whole-body scanner (*Bruker Medical, Ettlingen, Germany*) with a helmet resonator for image acquisition. For perfusion imaging, a spin-echo EPI sequence with a 64×64 acquisition matrix was used (acquisition bandwidth 100 kHz, TE = 52 ms, echo position = 50%). For CASL, a perpendicular combination of two circular coil loops (6-cm diameter each) was used. This label coil was placed over the neck of the subject for simultaneous labeling of the left and right common carotid artery. A continuous RF pulse with a power of approximately 1.2 W was applied during the labeling periods of TR – 100 ms within each repetition (TR = 500 or 750 ms). The labeling gradient strength was 2 mT m^{-1}. The frequency offset of the labeling RF was swept during the entire experiment of 330 repetitions over a range of 9 kHz within a cycle of 11 steps (4). A single axial slice was acquired after a short post-labeling delay of 8 ms. Evaluation of the phase shift of the voxel time series was performed based on multivariate spectral analysis (5) with respect to a reference voxel that contained most frequency contributions at the LF frequency in the power spectrum.

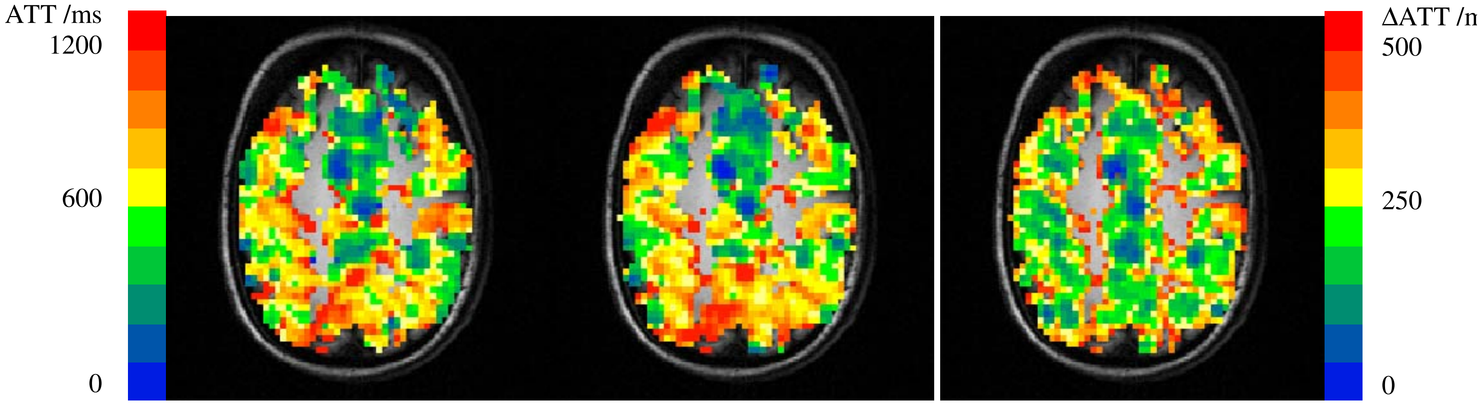

Fig. 1. Distribution of ATT within an axial slice obtained from a CASL experiment with sinusoidally modulated LF at TR's of 500 ms (left) and 750 ms (middle). Only voxels with a coherence measure above 70 % with respect to the reference voxel (ATT = 0) are color-coded. Right: map of the error (confidence interval) for the ATT at TR 750 ms.

Results

Figure 1 shows two maps of the ATT distribution obtained for the same values of the CASL frequency sweep and for two values of TR. Spectral analysis of the CASL time series (5) yielded measures of coherence (degree of linear association with respect to a reference) and phase shift (temporal delay or ATT difference) at the frequency of the LF. Figure 1 shows that the maps of ATT distribution are very similar, if the TR of the sinusoidally-modulated CASL experiment is changed. Because the perfusion signal is destroyed by the excitation pulse of each repetition, only blood that enters the slice during the short TR interval contributes to the signal, which is thus expected to be mainly of intravascular origin. This was supported by a strong signal drop in experiments (not shown) using stronger flow-weighting gradients. Due to frequency offsets (shim) at the neck and the varying depth of the carotid artery (B1 field), the shape of the LF varies among subjects. Hence, the absolute determination of the ATT without measuring the LF at the neck as a reference cannot easily be performed. In these preliminary experiments, only ATT differences were determined with respect to the time series of a reference voxel in the slice. The error of the ATT can also be estimated by spectral theory (5). For example, when using a TR of 750 ms and a time series of 330 repetitions, a mean error of 290 ms over the slice was obtained, cf. Fig. 1. Because the error decreases with the length of the time series, the detection of small ATT differences accordingly requires more repetitions.

Conclusion

A new method for arterial transit time mapping within a 4-min scan using dual-coil CASL with a sinusoidally-modulated LF and short TR's was introduced. Evaluation of the coherence and phase measures from spectral analysis of the time series was shown to yield robust maps of the ATT distribution in the slice of interest.

References

1. J. Wang et al., Magn Reson Med 2003;50:599-607.
2. E.L. Barbier et al., Magn Reson Med 1999;41:299-308.
3. T. Mildner et al., NMR Biomed 2005;18:19-23.
4. T. Mildner et al., Proc 13th ISMRM 2005:1157.
5. K. Müller et al., Neuroimage 2001;14:347-356.